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VOLUME 3

Resource Management Strategies

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Resource Management Strategies

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Contents

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Acronyms and Abbreviations

°C	degrees Celsius
µg/L	micrograms per liter
20x2020 Plan	20x2020 Water Conservation Plan
AB 32	Assembly Bill 32, California Global Warming Solutions Act
ACWA	Association of California Water Agencies
ACWD	Alameda County Water District
af	acre-feet
af/yr.	acre-feet per year
AFRP	Anadromous Fish Restoration Program
AGR	agricultural production
AMI	advanced metering infrastructure
APG	Climate Change Adaptation Policy Guide
APS	Alternative Planning Strategy
ARB	California Air Resources Board
ARRA	American Recovery and Reinvestment Act of 2009
ASC	agricultural stakeholders committee
AWMC	Agricultural Water Management Council
AWMP	agricultural water management plan
AP	Assessment Program
AWS	automatic water softeners
AWUF	agronomic water use fraction
AWWA	American Water Works Association
BAER	Burned Area Emergency Response
BARDP	Bay Area Regional Desalination Project
BCDC	San Francisco Bay Conservation and Development Commission
BDCP	Bay Delta Conservation Plan
BLM	U.S. Bureau of Land Management
BMOs	basin management objectives
BMPs	best management practices
BOF	California State Board of Forestry
C2VSIM	California Central Valley Groundwater-Surface Water Model
CA LCC	California Landscape Conservation Cooperative

Acronyms and Abbreviations continued

Cal BOATING	California Department of Boating and Waterways
Cal EMA	California Emergency Management Agency
Cal/EPA	California Environmental Protection Agency
CAL FIRE	California Department of Forestry and Fire Protection
CAL LCC	Landscape Conservation Cooperative
CAL POLY	California Polytechnic State University, San Luis Obispo
CALAFCO	California Association of Local Agency Formation
Commissions CALFED	CALFED Bay-Delta Program
Cal/EPA	California Environmental Protection Agency
CALGreen	California Green Building Code
California State Parks	California Department of Parks and Recreation
CalWARN	California Water/Wastewater Agency Response
Network CAMAL	NetCalifornia Mutual Aid Laboratory Network
California's Flood Future	California's Flood Future Report: Recommendations in Managing the State's Flood Risk (2013)
CalWARN	California Water/Wastewater Agency Response Network
CalWEC	California Water and Energy Coalition
CalWEP	California Water and Energy Program
CAMAL Net	California Mutual Aid Laboratory Network
CASGEM	California Statewide Groundwater Elevation Monitoring
CASQA	California Association of Storm Water Quality Agencies
CAWSI	California Agricultural Water Stewardship Initiative
CBSC	California Building Standards Commission
CCC	California Coastal Commission
CCLU-IN	Climate Change, Land Use, and Infrastructure Working Group
CCR	California Code of Regulations
CCUF	crop consumptive use fraction
CCWD	Contra Costa Water District
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CEAP	Natural Resources Conservation Service Conservation Effectiveness
CEC	California Energy Commission
CEQA	California Environmental Quality Act

Acronyms and Abbreviations continued

CERC	Crisis and Emergency Risk Communication
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CFS	cubic feet per second
CII Task Force	Commercial, Industrial, and Institutional Task Force
CIMIS	California Irrigation Management Information System
CLCA	California Landscape Contractors Association
CII	Commercial, Institutional, and Industrial
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
COG	Regional Councils of Government
CPUC	California Public Utilities Commission
CRAE	California Roundtable on Agriculture and the Environment
CRWQMP	California Rangeland Water Quality Management Plan
CSBC	California Building Standards Commission
CSMW	California Coastal Sediment Management Workgroup
CUWCC	California Urban Water Conservation Council
CVC	Cross Valley Canal
CVFPP	Central Valley Flood Protection Plan
CVHM	Central Valley Hydrologic Model
CVJV	Central Valley Joint Venture
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CVWD	Coachella Valley Water District
CWA	Clean Water Act
CWC	California Water Code
CWP	California Water Plan
CWS	community water systems
CWSRF	Clean Water State Revolving Fund
DAC	disadvantaged community
DBP	disinfection by-products
Delta Reform Act	Sacramento-San Joaquin Delta Reform Act of 2009

Acronyms and Abbreviations continued

Delta	Sacramento-San Joaquin Delta
Desal RMS	Desalination Resource Management Strategy
DF	delivery fraction
DFW	California Department of Fish and Wildlife
DHCCP	Delta Habitat Conservation and Conveyance Program
DLRP	Division of Land Resource Protection
DMM	demand management measure
DNAPL	dense non-aqueous phase liquid
DOC	California Department of Conservation
DU	distribution uniformity
DWR	California Department of Water Resources
DWSAP	Drinking Water Source Assessment and Protection
DWSRF	Drinking Water State Revolving Fund
EAD	expected annual damage
EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
ED	electrodialysis
EDR	electrodialysis reversal
EGPR	Environmental Goals and Policy Report
EIR	environmental impact report
EIR/EIS	environmental impact report/environmental impact statement
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
EQUIP	Natural Resources Conservation Service Environmental Quality
ERG	Expense Reimbursement Grant Program
ESA	Endangered Species Act
ET	evapotranspiration
ETAF	evapotranspiration adjustment factor
ETo	reference evapotranspiration
EWA	environmental water account
EWMPs	efficient water management practices
EWQSK	Emergency Water Quality Sample Kit
FEMA	Federal Emergency Management Agency

Acronyms and Abbreviations continued

EWQSK	Emergency Water Quality Sample Kit
FESSRO	FloodSAFE Environmental Stewardship and Statewide Resources Office
FO	forward osmosis
FPR	forest practice rules
FRPA	Fish Restoration Program Agreement
FRWP	Freeport Regional Water Project
GAF	Grassland Area Farmers
GAMA	Groundwater Ambient Monitoring and Assessment Program
GDA	grassland drainage area
GHG	greenhouse gas
GIS	geographic information system
GPCD	gallons per capita per day
GPF	gallons per flush
GPM	gallons per minute
GPS	global positioning system
HAA5	haloacetic acids
HCD	Department of Housing and Community Development
HCP	habitat conservation plan
HET	high-efficiency toilet
HFI	Healthy Forest Initiative
HMP	Cal EMA Hazard Mitigation Program
HSEEP	Homeland Security Exercise and Evaluation Program
IACC	Interagency Coordinating Committee
IAP2	International Association of Public Participation
IDSP	In-Delta Storage Project
IE	impingement and entrainment
IFDM	integrated on-farm drainage management
IID	Imperial Irrigation District
IPCC	Intergovernmental Panel on Climate Change
IRWM	integrated regional water management
IRWMP	integrated regional water management plan
IWA	International Water Association
IRWM	integrated regional water management

Acronyms and Abbreviations continued

IWM	integrated water management
IWRIS	Integrated Water Resources Information System
kW	kilowatt
kWh	kilowatt hour
kWh/af	kilowatt hour per acre-foot
LACFCD	Los Angeles County Flood Control District
LADWP	Los Angeles Department of Water and Power
LAFCD	Los Angeles County Flood Control District
LAFCO	Local Agency Formation Commission
LEED	Leadership in Energy & Environmental Design
LEED-ND	LEED for Neighborhood Development
LGA	local groundwater assistance
LHMP	local hazard mitigation plan
LID	low-impact development
LNAPL	light, non-aqueous phase liquids
LRMP	land and resource management plan
LRN	Laboratory Response Network
LTMS	Long-Term Management Strategy for the Placement of Dredged Strategy
LVE	Los Vaqueros Reservoir Expansion
maf	million acre-feet
maf/yr.	million acre-feet per year
MAGPI	Merced Area Groundwater Planning Initiative
MCL	maximum contaminant level
MCY	million cubic yards
MED	Multi Effect Distillation
mg/L	milligrams per liter
mgd	million gallons per day
MHI	median household income
MM	management measures
MMWD	Marin Municipal Water District
MOU	memorandum of understanding
MP	management practice
MPO	Metropolitan Planning Organization
MPRSA	Marine Protection, Research, and Sanctuaries Act

MSF	Multi-Stage Flash evaporation
MTBE	methyl tertiary butyl ether
MUN	drinking water
MW	megawatt
MWD	Metropolitan Water District of Southern California
MWELO	Model Water Efficient Landscape Ordinance
NAHC	Native American Heritage Commission
MWh	megawatt hour
NCAR	National Center for Atmospheric Research
NCCP	Natural Community Conservation Plan
NCWA	Northern California Water Association
NEPA	National Environmental Policy Act
NFIP	FEMA National Flood Insurance Program
NFP	National Fire Plan
NHPA	National Historic Preservation Act
NL	notification level
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NODOS	North-of-the-Delta Offstream Storage
NOI	notice of intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resource Conservation Service
NTNC	non-transient non-community water systems
O&M	operations and maintenance
NTNC	non-transient non-community (water system)
NWIS	National Water Information System
NWQMC	National Water Quality Monitoring Council
OHV	off-highway vehicle
OMRR&R	operation, maintenance, repair, rehabilitation, and replacement
OPR	Governor’s Office of Planning and Research
OWTS	on-site wastewater treatment systems
PAW	productivity of applied water
PCB	polychlorinated biphenyls PCE perchloroethylene

PG&E	Pacific Gas and Electric Company
PHG	public health goal
PIER	Public Interest Energy Research Program
PL	projection level
PM&E	protection, mitigation, and enhancement
POE	point-of-entry
Porter-Cologne Act	Porter-Cologne Water Quality Control Act
Poseidon	Poseidon Water
POTW	publicly owned treatment works
POU	point-of-use
PPCP	pharmaceuticals and personal care products
PPL	Project Priority List
ppm	parts per million
ppt	parts per thousand
PRC	Public Resources Code
PRO	industrial processing
PRV	pressure regulating valve
PSP	proposal solicitation packages
PSU	practical salinity units
PWS	public water systems
QSA	Quantification Settlement Agreement
RAP	Regional Acceptance Process
RCD	Resource Conservation District
RDI	regulated deficit irrigation
RHNA	regional housing needs assessment
RMS	resource management strategy
RO	reverse osmosis
ROD	Record of Decision
RRA	Reclamation Reform Act of 1982
RSM	regional sediment management
RTP	regional transportation plan
RTPA	Regional Transportation Planning Authorities
RWMG	Regional Water Management Group
RWQCB	regional water quality control board
SARI	Santa Ana River Interceptor
RWQCB	regional water quality control board

SARI	Santa Ana Regional Interceptor
SAWPA	Santa Ana Watershed Project Authority
SB X7-7	Water Conservation Act of 2009
SB	Senate Bill
SCADA	supervisory control and data acquisition systems
SCS	Sustainable Communities Strategies
SCWA	Sacramento County Water Authority
SDWA	California Safe Drinking Water Act
SDWSRF	Safe Drinking Water State Revolving Fund
SEMS	Standardized Emergency Management System
SFPUC	San Francisco Public Utilities Commission
SGC	Strategic Growth Council
SJRIP	San Joaquin River Water Quality Improvement Project
SLC	California State Lands Commission
SLWRI	Shasta Lake Water Resources Investigation
SMP	California Coastal Sediment Management Plan
SMUD	Sacramento Municipal Utility District
SMURRF	Santa Monica Urban Runoff Recycling Facility
SOM	soil organic matter
SRS	System Reoperation Study
STORET	U.S. Environmental Protection Agency STOrage and RETrieval Data Warehouse
Suisun Marsh MPRP	Suisun Marsh Habitat Management, Preservation, and Restoration Plan
SWAMP	Surface Water Ambient Monitoring Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
taf	thousand acre-feet
taf/yr.	thousand acre-feet per year
TCE	trichloroethylene
TDS	total dissolved solids
TEK	Traditional (or Tribal) Ecological Knowledge
TEW	Global Terrorism Early Warning Groups
TEWG	Local Terrorism Early Warning Groups
THP	timber harvesting plan
TLDD	Tulare Lake Drainage District
TMDL	total maximum daily load

TNC	transient non-community (water system)
TTHM	trihalomethanes
TWUF	total water use fraction
UCCE	University of California Cooperative Extension
ULFT	ultra low-flow toilet
Update 2009	*California Water Plan Update 2009*
Update 2013	*California Water Plan Update 2013*
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USBR	U.S. Bureau of Reclamation
USC	United States Code
USDA Forest Service	U.S. Department of Agriculture Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USJRSBI	Upper San Joaquin River Basin Storage Investigation
UST	underground storage tank
UV	ultraviolet
UWMP	urban water management plan
VAW	value of applied water
VMT	vehicle miles traveled
VOC	volatile organic compound
VSAT	Vulnerability Self-Assessment Tool
Water Bank	2009 Drought Water Bank
WDR	waste discharge requirements
WET	Waste Extraction Test
WHEAT	Water Health and Economic Analysis Tool
WISE	Water Infrastructure Security Enhancement
WMCP	Water Management Certification Program
WMF	water management fraction
WISE	Water Infrastructure Security Enhancement
WQP	Water Quality Portal
WST Notice	Well Stimulation Treatment Notice
Yuba Accord	Lower Yuba River Accord

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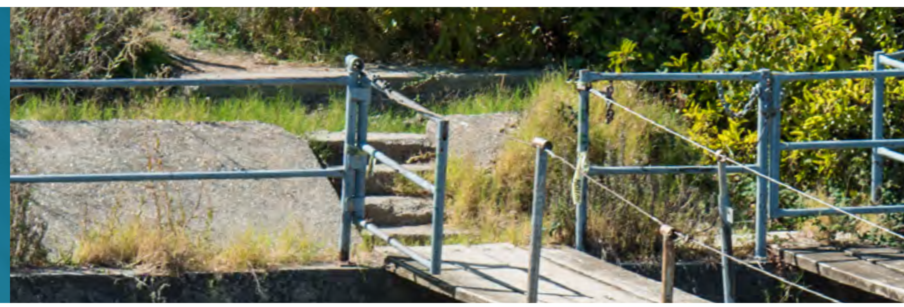
Metric Conversion Factors

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimeters (mm)	inches (in)	0.03937	25.4
	centimeters (cm) for snow depth	inches (in)	0.3937	2.54
	meters (m)	feet (ft)	3.2808	0.3048
	kilometers (km)	miles (mi)	0.62139	1.6093
Area	square millimeters (mm^2)	square inches (in^2)	0.00155	645.16
	square meters (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometers (km^2)	square miles (mi^2)	0.3861	2.590
Volume	liters (L)	gallons (gal)	0.26417	3.7854
	megaliters (ML)	million gallons (10)	0.26417	3.7854
	cubic meters (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic meters (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekameters (dam^3)	acre-feet (af)	0.8107	1.2335
Flow	cubic meters per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	liters per minute (L/mn)	gallons per minute (gal/mn)	0.26417	3.7854
	liters per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megaliters per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekameters per day (dam^3/day)	acre-feet per day (af/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lbs)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb.)	1.1023	0.90718
Velocity	meters per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.32456	2.989
Specific capacity	liters per minute per meter drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per liter (mg/L)	parts per million (ppm)	1.0	1.0
Electric conductivity	microsiemens per centimeter (µS/cm)	micromhos per centimeter (µmhos/cm)	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8X°C)+32	0.56(°F-32)

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 1

Introduction



Sutter County, Weir No. 2. Improvement to Weir No. 2, located approximately 27 miles upstream of the confluence of the Sacramento and Feather rivers, is an integral part of restoration of the Butte Creek System.

Contents

Tables

Chapter 1. Introduction

This volume of *California Water Plan Update 2013* (Update 2013) presents a comprehensive and diverse set of 30 resource management strategies (RMSs) that can help meet the water-related resource management needs of each region and the state. In Volume 1, Chapter 2 describes the importance of regional planning and presents general considerations for preparing integrated regional water management (IRWM) plans and integrated flood management plans that are sustainable and suitable for each region's unique character. Chapter 5 of Volume 1 emphasizes the need for decision-makers, water and resource managers, and land use planners to consider uncertainty, risk, and sustainability in planning for California's water future. The *Regional Reports* (Volume 2) discuss how the 12 regions of California are selecting, combining, and implementing RMSs. The 30 RMSs described in this volume can be combined in various ways to meet the water management goals and objectives of the California Water Plan.

The RMS narratives are written by subject matter experts from the State agencies that sit on the Water Plan Steering Committee, with considerable input from other experts and stakeholders. The RMSs have been vetted in public workshops and during several rounds of public comment.

Update 2013 has undertaken additional analyses on the costs and results of doing packages of RMSs in the Central Valley under different growth and climate scenarios. These analyses of RMS packages provide policy-makers and resource managers more quantitative information on the performance of various strategies, interactions between strategies, tradeoffs, and potential groupings of strategies. Update 2013 considers several different future scenarios that can be used by planners to test the performance of alternative strategy mixes.

Resource Management Strategies

An RMS is a technique, program, or policy that helps local agencies and governments manage their water and related resources. For example, urban water-use efficiency is a strategy to reduce urban water use. A pricing policy or incentive for customers to reduce water use also is a strategy, as described in the Economic Incentives RMS. New water storage to improve water supply, reliability, and quality is another strategy. Three new RMS chapters have been added for Update 2013 — "Outreach and Engagement" (Chapter 29), "Sediment Management" (Chapter 26), and "Water and Culture" (Chapter 30) — and are listed with the other strategies in Table 1-1, "Resource Management Strategies." The 30 strategies are organized alphabetically under eight categories in the table, which describe their primary objective and emphasis while recognizing interdependencies among many of the strategies. A category and narrative is included in this volume for Chapter 32, "Other Resource Management Strategies," which describes six subsidiary or emerging strategies. Additionally, Navigation was identified as another RMS, but because of limited time and resources for Update 2013, adding a related narrative will be considered for California Water Plan Update 2018.

The RMSs can be considered as tools in a toolkit. Just as the mix of tools in any given kit depend on the job to be accomplished, the combination of strategies will vary from region to region, depending on climate, projected growth, existing water system, environmental and social conditions, and regional goals. At the local level, it is important that the proposed strategies complement the operation of existing water systems. Some strategies may have little value in certain regions. For example, because of geology, the opportunity for groundwater development

Table 1-1 Resource Management Strategies and Management Objectives

Reduce Water Demand	**Improve Water Quality**
Agricultural Water Use Efficiency	Drinking Water Treatment & Distribution
Urban Water Use Efficiency	Groundwater / Aquifer Remediation
Improve Operational Efficiency & Transfers	Matching Quality to Use
Conveyance – Delta	Pollution Prevention
Conveyance – Regional / Local	Salt & Salinity Management
System Reoperation	Urban Stormwater Runoff Management
Water Transfers	**Practice Resource Stewardship**
Increase Water Supply	Agricultural Land Stewardship
Conjunctive Management & Groundwater	Ecosystem Restoration
Desalination — Brackish & Seawater	Forest Management
Precipitation Enhancement	Land Use Planning & Management
Recycled Municipal Water	Recharge Areas Protection
Surface Storage – CALFED	Sediment Management*
Surface Storage – Regional/Local	Watershed Management
Improve Flood Management	**People & Water**
Flood Management	Economic Incentives (Loans, Grants, & Water Pricing)
Other Strategies	Outreach and Engagement*
Crop idling, dew vaporization, fog collection, irrigated land retirement, rainfed agriculture, and waterbag transport	Water and Culture*
	Water-Dependent Recreation

Note:

* New resource management strategies for California Water Plan Update 2013

in the Sierra Nevada is not nearly as significant as in the Sacramento Valley. Other strategies may have little value in particular conditions. For example, precipitation enhancement may not be effective during droughts. Water managers at different geographical scales will have different perspectives on the assortment and cost-effectiveness of RMSs for meeting the needs and priorities of the locality or region, or statewide.

Planning a Diversified Portfolio

The new and continuing challenges of California's diverse and extreme conditions require local agencies to use new and different methods of managing water. Growing population, urban development patterns, global crop markets, changing regulations, and evolving public attitudes and values are a few of the conditions that water managers must navigate. Integrated water management (IWM) relies on a diversified portfolio of water strategies to achieve multiple and sustainable uses and benefits while balancing the risks of an uncertain future. Adapting to and mitigating climate change impacts have become increasingly important factors in selecting and implementing a package of RMSs.

RMSs are the tools that local agencies and governments should consider as they prepare their IRWM plans (see also Volume 2, *Regional Reports*). The intent is to prepare plans that are diversified and resilient; satisfy regional and state needs; meet multiple economic, environmental, and societal objectives; include public input; address environmental justice; mitigate impacts; protect public trust assets; and are affordable. Additional actions for planning and implementation can be found in Volume 1, Chapter 8, "Roadmap For Action."

Organization of Resource Management Strategy Chapters

Although the chapters were written by different experts, the narrative for each strategy is organized similarly. Each includes the following elements and sections:

- Short definition of the strategy.
- The current use of the strategy in California, including an overview of what is happening today and background on the strategy. In addition, the strategy narratives recognize the relationship of water, energy, and other resources; consider climate change scenarios; and, as appropriate, articulate related resource policies, programs, and legislation.
- "Potential Benefits," which includes a discussion on how strategy implementation will benefit water supply; drought preparedness; flood management; water quality; energy; environmental/resource stewardship; and other water management objectives, regionally and statewide, by 2030. Since the application of these strategies can vary widely among regions, as described in Volume 2, the strategy descriptions are from a broader, statewide perspective. More detailed information on some of the strategies is also presented in Volume 4, *Reference Guide*.
- "Potential Costs," which includes estimates of implementation costs statewide by 2030 and unit cost information, when available. In most cases, costs are highly dependent on where they are incurred and can only be estimated broadly in these brief narratives.
- "Major Implementation Issues," which discusses the tradeoffs, challenges, and considerations associated with implementing each strategy. For instance, ocean water desalination involves issues related to water intake and brine disposal. Each RMS discusses mitigation for and adaptation to climate change.
- "Recommendations," which discusses how the strategy could be implemented more effectively and efficiently over the next 30 to 40 years to address the implementation issues and promote additional implementation. Many of the recommendations are for State government to provide technical support to help regional groups make better decisions on the use of the strategies. The individual strategy narratives generally do not include specific recommendations for funding of individual strategies, though that discussion has been incorporated into Volume 1, Chapter 7, "Finance Planning Framework."
- Cited and additional references, including Web sites where some of the source materials can be found. In other cases, the sources involve documented personal communications.

Although the RMSs are presented individually, they can complement each other or accomplish different goals. For instance, water from a recycling project could contribute to ecosystem restoration and groundwater recharge, while water use efficiency might reduce the opportunity for recycling and reuse. In some cases, implementation of an RMS may conflict with other resource management goals. Some of the strategies may reduce energy demand, while others may increase energy demand.

Strategy Summary Table

Table 1-2 provides a summary of the potential benefits and costs for the 30 RMSs in Volume 3, as well as several essential innovation actions and support activities, organized in the following way:

- **Left column** shows the RMSs that are available to help regions achieve various water management objectives.
- **Center columns** show potential strategy benefits that can be achieved by implementing a particular strategy. The table shows icons where the RMS narratives indicate that the strategies could have direct and significant benefits for water management objectives. Note that most RMSs can help achieve multiple benefits.
- **Right column** shows cumulative implementation-cost information in billions of dollars to achieve the indicated benefits or perform a support activity by 2030. Note that descriptions for each cost estimate are contained in the strategy narratives; the assumptions vary per strategy. The financing of RMS implementation is discussed in Volume 1, Chapter 7, "Finance Planning Framework."

Benefit dots in the center columns can be viewed either horizontally for a given RMS or vertically for a given water management objective.

While most of the RMSs have multiple potential benefits, any individual site-specific project or program within an RMS may contribute only one, or perhaps a few, of the benefits. For example, it is unlikely that the agricultural lands stewardship practices on a single farm will contribute to all the potential benefits (as indicated in Table 1-2). In aggregate, however, the combined agricultural lands stewardship practices on many farms can contribute to all of the water management objectives, as shown in Table 1-2.

As part of the strategy narratives, the subject matter experts have indicated when strategies can provide significant water supply benefits, which may include water supply increases and water demand reductions. For eight strategies, an estimated range of potential additional statewide water benefits by 2030 is quantified. Water supply benefits and estimates are shown as dots and ranges in the second column of Table 1-2. The table shows that considerable capacity exists to benefit water supply among the eight strategies. In some cases, the values represent a local or regional benefit and may not provide statewide benefits. In addition, implementing some strategies, such as water-dependent recreation or ecosystem restoration, may increase total water demands. The water benefits of many strategies were not quantified because the potential for additional water supply is either incidental (small) or has not yet been estimated statewide. Also, some strategies do not produce water supply benefits.

Table 1-3 includes unit cost information for selected RMSs. Generally, the unit cost information is based on surveys of local projects.

Table 1-2 Resource Management Strategy Summary

	Potential Strategy Benefits[1]												Accumulated Cost by 2030 ($ Billion)[2]
	Water Supply Benefits by 2030[2] (million acre-feet/ year)		Reduce Drought Impacts	Improve Water Quality	Higher Operational Flexibility & Efficiency	Reduce Flood Impacts	Environmental Benefits	Energy Benefits	More Recreational Opportunities	Reduce Groundwater Overdraft	Improve Food Security	Public Safety & Emergency Response	
Reduce Water Demand													
Agricultural Water Use Efficiency	O	0.1 – 1.0[3]		O	O		O				O		0.3 – 0.5
Urban Water Use Efficiency	O	1.2 – 3.1	O	O	O		O	O					2.5 – 6.0
Improve Operational Efficiency & Transfers													
Conveyance — Delta	O	N/A	O	O	O	O	O		O	O	O	O	1.2 – 17.2
Conveyance — Regional / Local	O	N/A	O	O	O	O	O			O	O		N/A
System Reoperation	O	N/A	O	O	O	O	O	O		O		O	N/A
Water Transfers	O	N/A	O		O		O				O		N/A
Increase Water Supply													
Conjunctive Management & Groundwater	O	0.5 – 2.0	O	O	O	O	O			O	O		N/A
Desalination — Brackish Water & Seawater	O	0.3 – 0.4	O	O		O				O			2.0 – 3.0
Precipitation Enhancement	O	0.3 – 0.4						O					0.1 – 0.2
Recycled Municipal Water	O	1.8 – 2.3	O		O			O					6.0 – 9.0
Surface Storage – CALFED	O	0.1 – 1.1	O		O	O			O	O	O		0.7 – 9.2
Surface Storage – Regional / Local	O	N/A	O	O	O	O		O	O	O	O		N/A
Improve Flood Management													
Flood Management	O	N/A	O	O		O	O			O		O	32 – 100

	Potential Strategy Benefits[1]												Accumulated Cost by 2030 ($ Billion)[2]
	Water Supply Benefits by 2030[2] (million acre-feet/year)		Reduce Drought Impacts	Improve Water Quality	Higher Operational Flexibility & Efficiency	Reduce Flood Impacts	Environmental Benefits	Energy Benefits	More Recreational Opportunities	Reduce Groundwater Overdraft	Improve Food Security	Public Safety & Emergency Response	
Improve Water Quality													
Drinking Water Treatment & Distribution	O	N/A	O	O									44.5
Groundwater / Aquifer Remediation	O	N/A		O							O		20.0
Matching Quality to Use	O	N/A	O	O	O		O				O		0.1
Pollution Prevention	O	N/A		O		O	O	O	O	O		O	21.0
Salt & Salinity Management	O	N/A		O	O		O	O					> 10.0
Urban Stormwater Runoff Management	O	N/A	O	O	O	O	O	O	O	O		O	3.8
Practice Resource Stewardship													
Agricultural Land Stewardship	O	N/A	O	O		O	O	O	O	O	O		5.3
Ecosystem Restoration	O	N/A	O	O	O	O	O	O	O	O		O	N/A
Forest Management	O	0.1 – 0.5[4]	O	O		O	O	O	O	O		O	0.3 – 0.8
Land Use Planning & Management	O	N/A	O	O		O	O	O		O	O	O	N/A
Recharge Area Protection	O	N/A	O	O	O	O				O	O		N/A
Sediment Management*	O	N/A		O	O	O	O				O		N/A
Watershed Management	O	N/A	O	O	O	O	O	O	O	O	O		0.5 – 3.6
People & Water													
Economic Incentives (Loans, Grants & Water Pricing)	O	N/A	O		O		O						N/A

	Potential Strategy Benefits[1]											Accumulated Cost by 2030 ($ Billion)[2]
	Water Supply Benefits by 2030[2] (million acre-feet/ year)	Reduce Drought Impacts	Improve Water Quality	Higher Operational Flexibility & Efficiency	Reduce Flood Impacts	Environmental Benefits	Energy Benefits	More Recreational Opportunities	Reduce Groundwater Overdraft	Improve Food Security	Public Safety & Emergency Response	
Outreach and Engagement*		O			O	O	O			O	O	N/A
Water & Culture						O			O			N/A
Water-Dependent Recreation					O	O			O			N/A
Other — subsidiary or emerging												
Various strategies	Objectives vary by strategy											N/A
Innovation Actions and Essential Support Activities[5]												
Improve governance & decision-making (regionally focused)												N/A
Improve planning processes & public engagement												N/A
Strengthen government agency alignment (plans, policies, & regulations)												N/A
Advance information technology (data & analytical tools)												N/A
Advance water technology & science (research & development)												N/A

Notes:

N/A = unavailable

[1] Actual resource management strategy (RMS) benefits will depend on how strategies are implemented. The water supply benefits are not additive. Although presented individually, the RMSs are alternatives that can complement each other or compete for limited system capacity, funding, water supplies, or other components necessary for implementation. Assumptions, methods, data, and local conditions vary per strategy.

[2] Additional cost information is found in the RMS narratives and Volume 5, Technical Guide. Unit cost information for select RMSs is found in Table 1-3 of Volume 3.

[3] Value is Net Water to account for water reuse among agricultural water users.

[4] Numbers are for meadow restoration only.

[5] Innovation actions are essential for successfully integrating packages of the RMSs, and their effective and efficient implementation. The cost of innovation actions is noticeably small as compared with the cost of implementing the RMSs and their associated grey and green infrastructure (see Chapters 2 and 7 of Volume 1 for more on investing in innovation and infrastructure).

Table 1-3 Range of Strategy Unit Costs

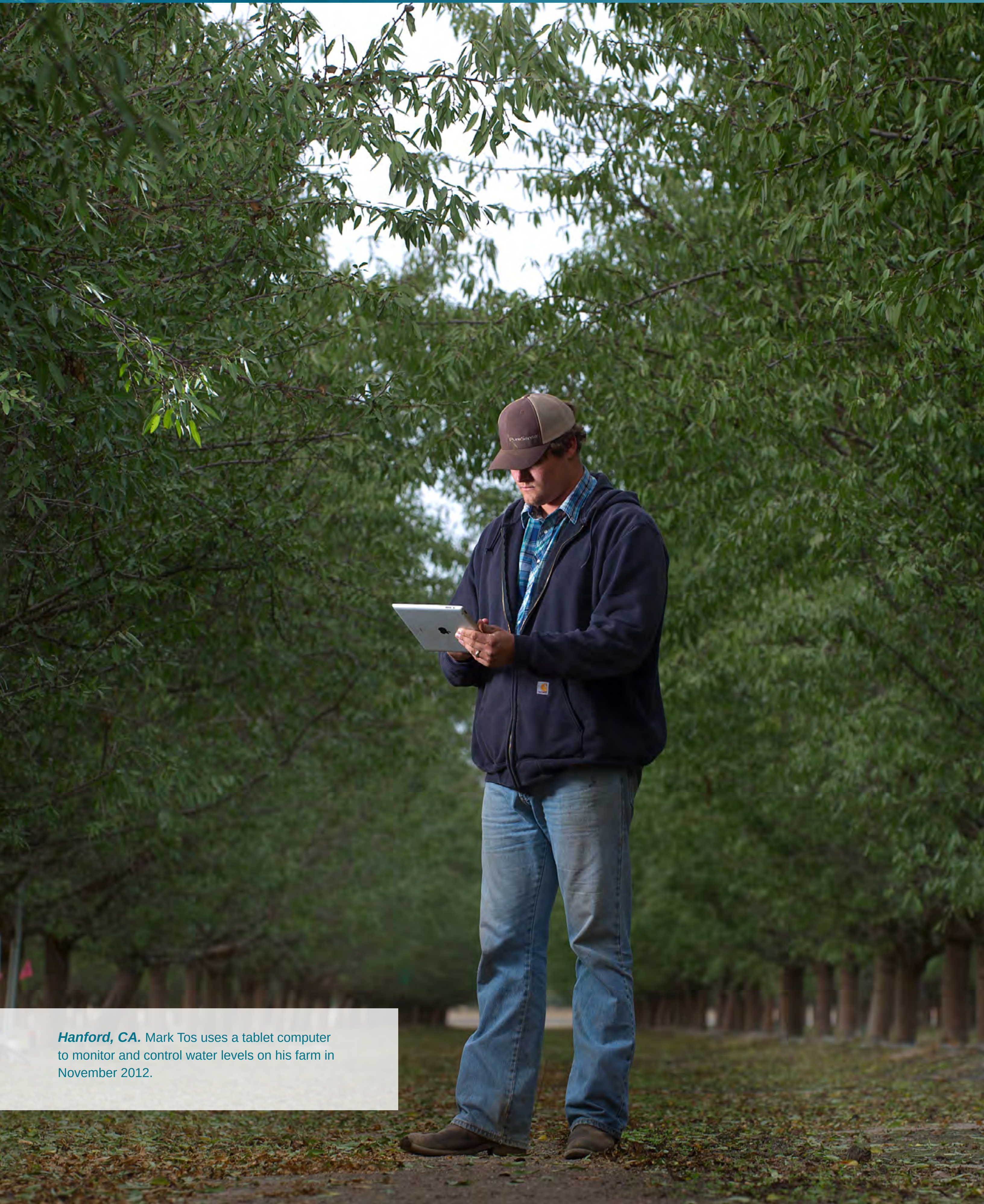
Unit Cost Information for Selected California Water Plan Update 2013 Resource Management Strategies	
Resource Management Strategy	**Range of Costs (Dollars/Acre-Feet)**
Agricultural Water Use Efficiency	$85-$675
Brackish Groundwater Desalination	$500-$900
Meadow Restoration	$100-$250
Ocean Desalination	$1,000-$2,500
Municipal Recycled Water	$300-$1,300
Surface Storage	$300-$1,100
Urban Water Use Efficiency	$223-$522
Wastewater Desalination	$500-$2,000

The information and data in Table 1-3 and the Volume 3 strategy narratives should be treated as preliminary indicators of the scale and type of statewide potential benefits and associated costs. In most cases, assumptions and methodologies are unique to given strategies, and neither benefits nor costs are additive among different strategies. The costs, benefits, and impacts of actually implementing these strategies in project-specific locations could vary significantly, depending on local objectives and project-level complexities. Project-level considerations include the extent of the management strategies already incorporated into the existing system; proposed locations of new strategies, operations, mitigation, and system integration; and the presence of cultural or environmental resources. Therefore, local and regional water management efforts should develop their own estimate of costs and potential benefits, as well as other trade-offs associated with the application of any particular strategy or package of strategies.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 2

Agricultural Water Use Efficiency



Hanford, CA. Mark Tos uses a tablet computer to monitor and control water levels on his farm in November 2012.

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Chapter 2. Agricultural Water Use Efficiency

The agricultural water use efficiency strategy describes the use and application of scientific processes to control agricultural water delivery and use to achieve a beneficial outcome. It includes an estimation of net water savings or increased production resulting from implementing efficiency measures as expressed by the ratio of output to input, resulting benefits, and strategies to achieve efficiency and benefits.

Water conservation is defined by California Water Code (CWC) Section 10817 as “the efficient management of water resources for beneficial uses, preventing waste, or accomplishing additional benefits with the same amount of water.” Improvements in agricultural water use efficiency are expressed as yield improvements for a given unit amount of water, and can be estimated over individual fields or entire regions. The net water savings is the reduction in the amount of water applied that becomes available for other purposes, while maintaining or improving crop yield and agricultural productivity. Net water savings (see Box 2-1) recognizes:

1. Uptake and transpiration of water for crop water use.
2. The role, benefits, and quantity of applied water that is recoverable and reusable in the agricultural setting.
3. The quantity of irrecoverable applied water that flows to salt sinks, such as the ocean and inaccessible or degraded saline aquifers, or that evaporates to the atmosphere and is unavailable for reuse.

Agricultural water use efficiency can be expressed as fractions that are the ratio of outputs from an agricultural system to inputs to that agricultural system in volumes or depths of water. A ratio of selected outputs (crop evapotranspiration [ET], crop agronomic use, and environmental water use) to inputs (applied water) can be used to quantify the efficiency of water use. This concept is discussed further in the section “Methodology for Quantification of Efficiency of Agricultural Water Use,” below.”

While inputs (rainfall and irrigation water) can readily be estimated and measured respectively, determining the amount of water required by the crop is a more complex undertaking. Crop water requirements during various growth stages have been modeled for most common crops. The models, however, assume an absence of typical real-world problems that are difficult to take into account such as diseases, insect infestations, and lack of uniform soils. As a result, models typically overestimate actual crop water requirements. Nevertheless, when used correctly, these models have provided valuable information in the past for better decision-making by farmers and irrigation districts. Recent approaches to estimating crop water requirements employ satellite imagery, often in conjunction with local weather stations, to estimate crop transpiration on a 30x30-meter grid of cells. The finer the grid, the better the accounting for the spatial non-uniformity of crop water use. Spatial non-uniformity of crop ET can be the result of many factors such as spatial variability of soil hydraulic characteristics, variability of field conditions, irrigation system non-uniformity, wheel traffic compaction, variability in farmers’ cultural practices (e.g., pesticide and fertilizer applications), and varying effects of different populations of insects, nematodes, and denitrifying bacteria.

Box 2-1 Net Water Savings and Applied Water Reduction

In California agriculture, water is seldom used only once. Applied water is often reused multiple times on the same farm or in the same region. Reuse of agricultural recoverable flows is a prominent characteristic of California agriculture. Water may be used only one time in the salt sink areas. Therefore, in agriculture it is necessary to focus on the net water savings and not on applied water reductions. Net water savings can be achieved by reducing irrecoverable flows going to salt sinks. Reduction of applied water that results in reduction of recoverable flows often does not save water. Nevertheless, reduction of applied water may have other benefits such as improvements in water quality, flow and timing, and energy conservation. Much of recoverable flows in California go to wetlands and managed wetlands and provide the only source of water for sustainability of such wetlands. Reuse of applied water is the main reason why the quantity of saved water in the agricultural setting is much smaller than in the urban setting. In the urban setting, applied water is used only once and any reduction of applied water will result in water savings.

Agricultural water use efficiency aims at providing increased productivity and may result in water savings. Other co-benefits may include water quality improvements, environmental benefits, improved flow and timing, and often increased energy efficiency. While pursuing efficiency in agricultural water use, it is important not to isolate farming and the agricultural operations from their environment. With a holistic view, agricultural water use efficiency efforts must go beyond the simplistic irrigation efficiency approach to embrace a management approach that addresses the co-benefits of water use in agriculture. Such approach aims at ensuring a sustainable food production while protecting and restoring the natural and human environments. Being more efficient in some circumstances may mean greater costs and more energy use. Thus, third party impacts should be fully considered before mandating any significant water conservation or efficiency measures.

Agricultural water use efficiency does not necessarily mean a reduction in the amount of water used to grow crops. Often, increased water use efficiency — along with other management practices — allow for an increase in crop yield without increasing the amount of irrigation water. For the same amount of water used, an increase in crop yield translates into increased water productivity. In addition to advances in irrigation technology and improvements in water management, crop yield and water productivity can also be enhanced through fertilizer technology, crop selection, and scientific advancement in the domain of genetically modified (GMO) crop breeding.

The strategy to achieve improved agricultural water use efficiency primarily includes improvements in technology and management of water at different scales — on farms, at the irrigation district level, and at the regional scale. The strategy enlists an array of factors, such as labor, crop market conditions, demographics, education, changes in government policies, funding availability, environmental stresses, desire to increase yield, grower awareness and practices, energy, water supply development, water delivery systems, legal issues, economics, and land use issues.

A list of best management practices (other than irrigation technology and management of water) that contribute to agricultural water use efficiency is included in Chapter 21, "Agricultural Land Stewardship." Chapter 21 includes a discussion of the costs and benefits of efficiency improvements in on-farm irrigation equipment, crop and farm water management, and water supply management and distribution systems.

Agricultural Water Use Efficiency Efforts in California

Agriculture is an important element of California's economy. According to a 2012 report of the California Department of Food and Agriculture, the state's 81,700 farms and ranches received a record $37.5 billion for their output in 2010, 1 percent more than the previous record achieved in 2008. California remained the No. 1 state in cash farm receipts in 2010, with its $37.5 billion in revenue representing 11.9 percent of the U.S. total. The state accounted for 16 percent of national receipts for crops and 7 percent of the U.S. revenue for livestock and livestock products. California's agricultural abundance includes more than 400 commodities. The state produces nearly half of the fruits, nuts, and vegetables grown in the United States. California's agricultural international exports broke a record in 2010, with $14.7 billion in value. It is estimated that every $1 billion in agricultural exports supports 8,400 jobs (U.S. Senate Committee on Agriculture, Nutrition, and Forestry 2012). The California Department of Water Resources (DWR) estimated that 2010 irrigated acreage was 8.13 million acres. The irrigated acreage changes from year to year. Agricultural water application varies significantly by year, depending on drought conditions. In a typical year, agriculture will irrigate about 9.6 million acres with 34 million acre-feet (maf) of water, or about one-third of the available surface water supplies (California Department of Water Resources Agricultural Water Use 2012a).

Many California growers and water suppliers implement state-of-the-art design, delivery, and management practices to increase production efficiency and conserve water. As a result, they continue to make great strides in increasing the economic value and efficiency of their water use. Among the indicators of agricultural water-use efficiency improvement is the real inflation-adjusted gross revenue for California agriculture increased to about 88 percent between 1967 and 2010, from $19.9 billion to $37.5 billion (both, year 2010 dollars). During that period, the total water applied to crops in California was reduced by 20 percent, from 31.2 maf to 24.9 maf. As a result, the "economic efficiency" of agricultural water use in California has more than doubled in the same period, from $638 per acre-foot (af) (year 2010 dollars) in 1967 to $1,506 per af in 2010, where most of the increase has occurred since 2000 (California Department of Food and Agriculture 2012).

It is important, however, to note that the economic output of California agriculture, expressed either as crop yield or the dollar value of produced crops, is a function of many variables. These include water quality, soil fertility, fertilizer applications, insect infestation, plant diseases, cultural practices, management, crop selection, and crop variety, as well as many other physical, biological, and socioeconomic factors (such as crop market, trade and market conditions, and weather conditions). Given the complex factors affecting agricultural productivity, any economic output indicator can only be used as an overall gauge of the efficiency and competitiveness of California's agriculture and its agribusiness establishment in general and can by no means be linked exclusively to water use efficiency.

The Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (Assembly Bill [AB] 3616, CWC Sections 10900-10904) and the federal Central Valley Project Improvement Act (CVPIA) of 1992 established guidance for improving agricultural water use efficiency. Per AB 3616, the Agricultural Water Management Council (AWMC) was formed through a memorandum of understanding (MOU) in 1996. Since its establishment and prior to its dissolution in 2013, the AWMC had enlisted close to 80 agricultural water suppliers and four environmental organizations to improve agricultural water use efficiency through the implementation of efficient water management practices. The AWMC worked in a voluntary and cooperative manner with agricultural water suppliers, environmental interest groups, government agencies, and other agricultural interest groups to establish a consistent endorsement process for agricultural water suppliers to demonstrate how they are managing water efficiently. Through a review and endorsement procedure, the AWMC helped with water suppliers' water management planning and the implementation of cost-effective, efficient water management practices and also tracked them. The signatory agricultural water suppliers voluntarily committed to implementing locally cost-effective management practices and submitted agricultural water management plans to the AWMC.

As part of a comprehensive package of water legislation in the 2009-2010 legislative session, the Agricultural Water Management Planning Act (AWMP Act), Part 2.8 of Senate Bill (SB) X7-7 requires agricultural water suppliers who provide water to 10,000 or more irrigated acres to develop and adopt a water management plan with specified components, and implement cost-effective efficient water management practices (EWMPs). However, any agricultural water supplier that provides water to less than 25,000 irrigated acres is exempt from implementing the bill's requirement unless sufficient funding has been provided to that water supplier to implement its provisions.

The bill also requires:

1. Agricultural water suppliers to submit their water management plan to DWR.
2. Agricultural water suppliers, on or before July 31, 2012, to implement EWMPs including the following critical EWMPs: 1) Measure the volume of water delivered to customers with sufficient accuracy to comply with provisions of the bill, and 2) Adopt a pricing structure for water customers based on at least in part on quantity of water delivered (see Box 2-2).
3. Agricultural water suppliers to use a standardized form to report which EWMPs have been implemented and are planned to be implemented, an estimate of water use efficiency improvements that have occurred since the last report, and an estimate of water use efficiency improvements estimated to occur five and 10 years in the future. If an agricultural water supplier determines that an EWMP is not locally cost-effective or technically feasible, the supplier shall submit information documenting that determination.
4. DWR, in consultation with the State Water Resources Control Board (SWRCB), the California Bay-Delta Authority or its successor agency, the California Department of Public Health, and the Public Utilities Commission, to develop a single standardized water use reporting form to meet the water use information needs of each agency.
5. DWR, in consultation with the SWRCB, to submit to the Legislature a report on the agricultural EWMPs that have been implemented, are planned to be implemented, and an assessment of the manner in which the implementation of those EWMPs has affected and will affect agricultural operations, including estimated water use efficiency improvements.
6. DWR to make available all submitted water management plans on the DWR Web site.
7. DWR, in consultation with the AWMC, academic experts, and other stakeholders, to develop a methodology for quantifying the efficiency of agricultural water use. Alternatives to be

Box 2-2 **Agricultural Efficient Water Management Practices (EWMPs)***

The Agricultural Efficient Water Management Practices (EWMPs) per SB X7-7 include:

Critical EWMPs

- Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of California Water Code Section 531.10 and to implement EWMP #2.
- Adopt a pricing structure for water customers based at least in part on quantity delivered.

Other EWMPs

- Facilitate alternative land use for lands with exceptionally high-water duties or whose irrigation contributes to significant problems including drainage.
- Facilitate use of available recycled water that otherwise would not be used beneficially, meet all health and safety criteria, and do not harm crops or soils.
- Facilitate the financing of capital improvements for on-farm irrigation systems.
- Implement an incentive pricing structure that promotes one or more of the following goals:
  - More efficient water use at the farm level.
  - Conjunctive use of groundwater.
  - Appropriate increase of groundwater recharge.
  - Reduction in problem drainage.
  - Improved management of environmental resources.
  - Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.
- Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage.
- Increase flexibility in water ordering by, and delivery to, water customers within operational limits.
- Construct and operate supplier spill and tailwater recovery systems.
- Increase planned conjunctive use of surface water and groundwater within the supplier service area.
- Automate canal control structures.
- Facilitate or promote customer pump testing and evaluation.
- Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.
- Provide for the availability of water management services to water users. These services may include, but are not limited to, all of the following:
  - On-farm irrigation and drainage system evaluations.
  - Normal year and real-time irrigation scheduling and crop evapotranspiration information.
  - Surface water, groundwater, and drainage water quantity and quality data.
  - Agricultural water management educational programs and materials for farmers, staff, and the public.
- Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.
- Evaluate and improve the efficiencies of the supplier's pumps.

(*) These EWMPs may be updated by DWR as per SB X7-7, California Water Code Section10608.48(h).

assessed, shall include, but not be limited to, determination of efficiency levels based on crop types or irrigation system distribution uniformity.

The SB X7-7 requirements do not apply to an agricultural water supplier that is a party to the Quantification Settlement Agreement which allows the state to implement water conservation and transfer programs from the Colorado River, as defined in subdivision (a) of Section 1 of Chapter 617 of the Statutes of 2002, during the period within which the Quantification Settlement Agreement remains in effect (San Diego County Water Authority 2003). After the expiration of the Quantification Settlement Agreement, to the extent conservation water projects implemented as part of the Quantification Settlement Agreement remain in effect, the conserved water created as part of those projects shall be credited against the obligations of the agricultural water supplier pursuant to SB X7-7.

Box 2-3 lists SB X7-7 mandates related to agricultural water use efficiency and identifies DWR as the lead agency.

Agricultural Water Measurement

Lack of data, mainly farm-gate irrigation water delivery data, has been an obstacle for assessing irrigation efficiencies and planning further improvement. The State lacks comprehensive statewide data on cropped areas under various irrigation methods, applied water, crop water use, irrigation efficiency, water savings, and the cost of irrigation improvements per unit of saved water. Collection, management, and dissemination of water use data to growers, water suppliers, and water resource planners are necessary for furthering water use efficiency. An identified concern by some members of the California Water Plan Advisory Committee is a lack of statewide guidance to assist regions and water suppliers to collect the data needed for future Water Plan updates in a usable format.

The 2003 Independent Panel on the Appropriate Measurement of Agricultural Water Use convened by California Bay-Delta Authority made specific recommendations for measuring water supplier diversions, net groundwater use, crop water consumption, and aggregate farm gate deliveries (Independent Panel on the Appropriate Measurement of Agricultural Water Use 2003). In addition, the panel recommended increasing efforts to measure water quality, return flows, and streamflow. As a result, AB 1404, Water Measurement Information, was signed into law in 2007, requiring agricultural water suppliers to submit water use measurement reports to DWR. Agricultural water suppliers providing 2,000 or more acre-feet of surface water annually for agricultural uses or serving 2,000 or more acres of agricultural lands are required to submit a report annually that includes aggregated farm-gate delivery data on a monthly or bimonthly basis. Farm-gate delivery data is the volume of water delivered from the supplier's distribution system to its customers, measured at the point where the water is delivered.

The passage of the SB X7-7 in 2009 required certain agricultural water suppliers (those providing water to 10,000 or more acres of irrigated land) to measure the water they deliver to their customers. This legislation also required DWR to adopt a regulation that sets criteria and accuracy standards for farm-gate measurement and reporting. This regulation provides a range of water measurement options that would allow agricultural water suppliers to implement the aforementioned critical EWMPs (measurement and volumetric pricing) and comply with the reporting of aggregate farm-gate water deliveries. All agricultural water suppliers serving more

Box 2-3 SB X7-7 Agricultural Water Use Efficiency DWR Mandates*

A1. Quantification of Efficiency of Agricultural Water Use (Section 10608.64).
The California Department of Water Resources (DWR), in consultation with the Agricultural Water Management Council (AWMC), stakeholders, and academics, shall develop and report to the Legislature on a proposed methodology for quantifying the efficiency of agricultural water use. The report is to include an implementation plan, estimated implementation costs and types of data to support the methodology. Alternatives shall include determination of efficiency levels based on crop type or irrigation system distribution uniformity.

A2. Agricultural Water Measurement Regulations (Section 10608.48(i)(1)).
DWR will adopt a regulation providing a range of options for water measurements that agricultural water suppliers may use to measure volume of water delivered to customers with sufficient accuracy to comply with the farm-gate delivery measurement requirement (531.10) and to implement pricing structure.

A3. Update Ag Efficient Water Management Practices (EWMPs) Section 10608.48(h)).
DWR may update the EWMPs in consultation with AWMC, US Bureau of Reclamation and SWRCB. EWMPs shall be adopted or revised only after public hearings.

A4. Ag EWMP Report to Legislature (Section 10608.48(g)).
DWR shall submit a report to the Legislature on agricultural EWMPs that have been and are planned to be implemented and an assessment of the manner in which the implementation of EWMP has affected and will affect agricultural operations an estimate of water use efficiency improvements. Subsequent reports will be prepared in 2016 and 2021.

A5. Ag Water Mgmt Plan Report to Legislature (Sections 10845(a) through (c)).
DWR shall prepare and submit to the Legislature a report summarizing the status of the submitted plans, their outstanding elements, effectiveness of promoting efficient ag practices and recommendations relating to proposed EWMP changes, as appropriate. The report will subsequently be submitted in years ending in six and one.

A6. AWMP Guidebook (Section 10608.50(a)(1)).
DWR, in consultation with the State Water Resources Control Board (SWRCB), may revise the requirements for AWMPs. An AWMP Guidebook will be developed to address legislative and procedural issues for submittal of AWMPs to DWR.

A7. Revise Ag Funding Criteria (Section 10608.56(b)).
DWR will develop grant/loan criteria to make agricultural water suppliers ineligible for state funding unless they comply with the specific provisions of 10608.56.

B1. Standardized Water Use Reporting (Sections 10608.52(a) and (b)).
DWR, in consultation with California Bay Delta Authority, California Department of Health, California Public Utilities Commission, and SWRCB, shall develop a single standardized water use reporting form to meet the water use information needs of each agency. The form will be used by urban water suppliers to report on their progress in meeting their targets (10608.40) on an individual or regional basis at a minimum and by agricultural water suppliers to report compliance with implementation of EWMPs.

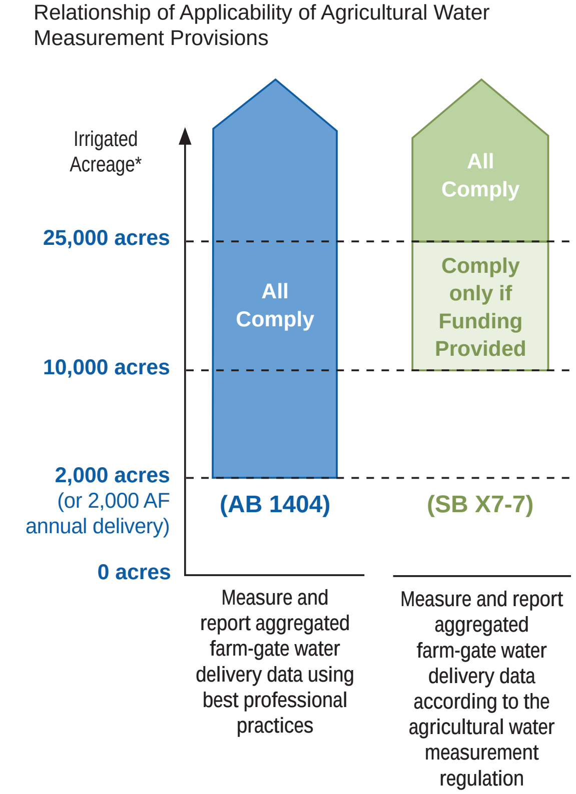
B2. Promote Regional Water Management (Section 10608.50(a)).
DWR, in consultation with the board, shall promote implementation of regional water resources management practices through increased incentives and removal of barriers.

B3. Statewide Targets for Regional Practices (Section 10608.50(b)).
DWR shall propose new statewide targets or review and update existing statewide targets for regional water resources management practices including but not limited to recycled water, brackish groundwater desalination and infiltration and direct use of urban stormwater runoff. Updated targets should be included in the California Water Plan.

(*) B1-B3 are agricultural as well as urban projects.

than 2,000 acres or providing 2,000 acre-feet are subject to AB 1404, but only certain large agricultural water suppliers, those serving more than 25,000 acres or 10,000 acres if funding is provided and outside the Quantification Settlement Agreement (QSA), are also subject to SB X7-7. Suppliers subject to AB 1404 must measure using Best Professional Practices; suppliers subject to SB X7-7 must use the criteria and accuracy standards in Agricultural Water Measurement regulation (Title 23, Division 2 of the California Code of Regulations, Chapter 5.1, Sections 597, 597.1, 597.2, 597.3, and 597.4) (See Figure 2-1, which shows AB 1404 vs. SB X7-7 applicability.)

Figure 2-1 AB 1404 vs. SB X7-7



*Acres that receive only recycled water are excluded from SB X7-7 thresholds.

Subsequently, DWR convened an agricultural stakeholders committee (ASC) and a stakeholders' sub-committee focusing on water measurement. Based on input from the ASC, stakeholders, and the general public, DWR adopted an emergency agricultural water measurement regulation that went into effect in July 2011. DWR followed-up and developed a regulation through the rulemaking process. On July 2012, the Office of Administrative Law approved the Agricultural Water Measurement Regulation. The Regulation adds Sections 597 to 597.4 of the California Code of Regulations (CCR) Title 23, Division 2, Chapter 5.1. The process leading to the development and adoption of this regulation benefitted from the participation and input of various stakeholders, academic experts, and the general public. The process included several meetings of the ASC and its water measurement sub-committee, two public hearings, two listening sessions, a 45-day public comment period, and an additional six 15-day public comment periods.

Agricultural Water Management Planning

SB X7-7 Part 2.8 (AWMP Act) requires agricultural water suppliers that meet certain criteria must prepare an Agricultural Water Management Plan (AWMP). This act provided a list of required elements that must be included in the AWMP (see Box 2-4). CWC Section 10820 (a) states, "An agricultural water supplier shall prepare and adopt an agricultural water management plan in the manner set forth in this chapter on or before December 31, 2012, and shall update that plan on December 31, 2015, and on or before December 31 every five years thereafter." SB X7-7 defines an "Agricultural Water Supplier" as "a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water." "Agricultural

Box 2-4 Required Elements of an Agricultural Water Management Plan (AWMP)*

SB X7-7 (2009), California Water Code Section 10826, lists the required elements of an AWMP as follows:

1. Describe the agricultural water supplier and the service area, including all of the following:

    A. Size of the service area.
    B. Location of the service area and its water management facilities.
    C. Terrain and soils.
    D. Climate.
    E. Operating rules and regulations.
    F. Water delivery measurements or calculations.
    G. Water rate schedules and billing.
    H. Water shortage allocation policies.

2. Describe the quantity and quality of water resources of the agricultural water supplier, including all of the following:

    A. Surface water supply.
    B. Groundwater supply.
    C. Other water supplies.
    D. Source water quality monitoring practices.
    E. Water uses within the agricultural water supplier's service area, including all of the following:

        i. Agricultural.
        ii. Environmental.
        iii. Recreational.
        iv. Municipal and industrial.
        v. Groundwater recharge.
        vi. Transfers and exchanges.
        vii. Other water uses.

    F. Drainage from the water supplier's service area.
    G. Water accounting, including all of the following:

        i. Quantifying the water supplier's water supplies.
        ii. Tabulating water uses.
        iii. Overall water budget.

    H. Water supply reliability.

3. Include an analysis, based on available information, of the effect of climate change on future water supplies.

4. Describe previous water management activities.

5. Include in the plan the water use efficiency information required pursuant to CWC Section 10608.48.

(*) Additional elements may be required to be included in the AWMP to document compliance with the Agricultural Water Measurement Regulation (California Code of Regulations Title 23, Division 2, Chapter 5.1, Sections 597-597.4).

water supplier" includes a supplier or contractor for water, regardless of the basis of right that distributes or sells water for ultimate resale to customers" (CWC Section 10608.12).

CWC Section 10842 requires an agricultural water supplier to implement its adopted plan in accordance with the schedule set forth in the plan, as determined by the governing body of the agricultural water supplier. An agricultural water supplier is also required to submit a copy of its plan and amendments or changes to the plan to the following:

1. California Department of Water Resources.
2. Any city, county, or city and county in which the agricultural water supplier provides water supplies.
3. Any groundwater management entity in which jurisdiction the agricultural water supplier extracts or provides water supplies.
4. Any urban water supplier in which jurisdiction the agricultural water supplier provides water supplies.
5. Any city or county library in which jurisdiction the agricultural water supplier provides water supplies.
6. The California State Library.
7. Any local agency formation commission serving a county in which the agricultural water supplier provides water supplies.

Agricultural water suppliers providing water to equal or greater than 25,000 irrigated acres (and water supplier providing 10,000 to 25,000 acres if adequate funding is available), excluding recycled water are also affected by the AWMP Act. Agricultural water suppliers that submit water management plans in compliance with the U.S. Bureau of Reclamation (USBR) Central Valley Project Improvement Act (CVPIA) or the Reclamation Reform Act of 1982 (RRA) requirements may be able to submit those plans or modify those plans with additional information to satisfy SB X7-7 AWMP Act (CWC Section 10827).

CWC Section 10608.50(a)(1) mandated DWR, in consultation with the SWRCB, to promote implementing regional water resources management practices through increased incentives and removing barriers, consistent with state and federal law. Among the potential tasks enumerated by the Legislation are the revisions to the requirements for urban and agricultural water management plans. As a result, and to assist agricultural water suppliers in complying with the requirements of the AWMP Act, DWR developed an Agricultural Water Management Planning Guidebook in 2012. The guidebook is meant to help agricultural water suppliers better understand the SB X7-7 requirements and assist them in developing their AWMPs. The guidebook also provides information on how agricultural water suppliers may meet the requirements of the Agricultural Water Measurement Regulation and associated compliance documentation, as well as aggregated farm-gate delivery reporting format. The guidebook is available at http://www.water.ca.gov/wateruseefficiency/sb7/docs/AgWaterManagementPlanGuidebook-FINAL.pdf.

When applicable, an AWMP shall also include in addition to the required elements as specified by CWC Section 10820 (a), other elements such as documentation to show compliance with the Agricultural Water Measurement Regulation (CCR Title 23, Division 2, Chapter 5.1, Sections 597-597.4). The Agricultural Water Measurement Regulation requires specific documentation to demonstrate compliance. For example, if water cannot be measured at the farm-gate or delivery point, agricultural water suppliers that provide water to 25,000 irrigated acres or more must include certain agricultural water measurement documentation in their AWMP in accordance with Agricultural Water Measurement Regulation (CCR Section 597.4(e)). Additionally, if an existing water measurement device is not compliant with the regulation and cannot be modified to be compliant, the AWMP must then include a schedule, budget, and finance plan for taking corrective action in three years or less (CCR Section 597.4(e)(4)). Agricultural water suppliers providing water to 10,000 to 25,000 irrigated acres who are required to prepare an AWMP may have to incorporate agricultural water measurement documentation in their AWMP if implementation of agricultural water measurement has been funded as specified in CCR Section 597.4(e).

Methodology for Quantification of Efficiency of Agricultural Water Use

The SB X7-7 directed DWR, in consultation with the AWMC, academic experts, and other stakeholders, to develop and report to the Legislature a proposed methodology for quantifying the efficiency of agricultural water use and an implementation plan that includes estimated implementation costs, roles and responsibilities, and the type of data needed to support the methodology. To carry out the mandate, DWR formed a second subcommittee of the ASC focusing on the quantification of agricultural water use efficiency. DWR held numerous public listening sessions, stakeholder committee and subcommittee meetings, and public workshops to develop the methodology and prepare a report to the Legislature, which was submitted in July 2012. The legislation did not authorize DWR to implement the methodology. However, DWR recommends that if the proposed methodology is authorized for implementation, the Legislature should appropriate the necessary funding to cover its implementation costs as described in its report to the Legislature.

To develop a methodology to quantify the agricultural water use efficiency, a water balance approach was considered to look into the various components of agriculture water use (environmental water use associated with irrigated lands). Other uses of water in agriculture — dairy production areas, washing products — are not included in the water balance because they represent small fractions of the total water use in most cases and are difficult to quantify. The methodology proposed is composed of four consistent and practical methods for quantifying the efficiency of water use by irrigated agriculture and are stated below. To develop the methods, DWR considered the components of a water balance at three spatial scales — basin, water supplier, and field — to understand and estimate through measurements or calculations how much water enters and leaves these areas. As a result, DWR proposed four methods for quantifying the efficiency of agricultural water use to help identify opportunities to improve the water use efficiency at different spatial scales. The methodology is suitable for evaluating current conditions and strategies for improving agricultural water management on the diverse array of agricultural irrigation systems and operations found throughout California. The anticipated users of these methods are farmers, water suppliers, basin water management groups, nongovernmental organizations, and local, state, federal, and tribal water planners.

The methods presented for quantifying the efficiency of agricultural water use are based on water use efficiency fractions that are a ratio of outputs from an agricultural system to an input to the agricultural system in volumes and/or depths of water. Input to an agricultural system is the volume of applied water. Outputs from agricultural systems include ET from crops, agronomic uses such as leaching salts, evaporation during seed germination, climate control (frost protection and cooling), environmental water use, tailwater, deep percolation, evaporation from open water surfaces, and ET by non-crops (weeds, for example). The ratio of selected outputs (crop ET, crop agronomic use, and environmental water use) to inputs (applied water) is used to quantify the efficiency of water use. Other outputs (evaporation from soil or water surfaces in excess of ET, ET by non-crop vegetation, and flow to salt sinks, etc.) are not quantified and may be estimated in total as residual in the water balance. Crop ET, crop agronomic uses (leaching, evaporation during seed germination, evaporation for cooling or application for frost control), and evaporation and ET for environmental purposes are intended uses (outputs). Crop ET is generally estimated using theoretical or empirical models that assume field uniformity. Actual ET can be estimated from remotely sensed satellite imagery. Some remote sensing methods use an energy balance approach; others use a vegetation index approach that is calibrated to the crop coefficient; and others couple remotely sensed parameters with numerical models or point measurements to generate ET information.

Each of the four methods below evaluates a different portion (fraction) of applied water:

1. **Crop Consumptive Use Fraction (CCUF)**. This method evaluates the relationship (ratio) between the consumptive use of crop(s) and the quantity of water applied. CCUF is a fraction that shows the proportion of applied water that is consumed by the crop. It is applicable at the basin, water supplier, and field scales.

2. **Agronomic Water Use Fraction (AWUF)**. This method calculates the ratio of agronomic use (salinity management, germination, etc.) and consumptive uses of crop(s) to the quantity of water applied. AWUF is a fraction that shows the portion of applied water used to grow the crop including crop consumptive use and agronomical use. It is applicable at the basin, water supplier, and field scales.

3. **Total Water Use Fraction (TWUF)**. This method further expands on the CCUF and AWUF by evaluating the relationship (ratio) between water applied for crop consumptive use, crop agronomic use, and for environmental objectives and the quantity of applied water. TWUF accounts for all intended water uses. As a result, this fraction can be used as a measure of total water use efficiency. It is applicable at the basin, water supplier, and field scales.

4. **Water Management Fraction (WMF)**. This method evaluates the relationship between crop consumption use and recoverable flows and quantity of applied water. This method estimates the recoverable water available for reuse at another place or time in the system. It is applicable at the basin and water supplier scales and is not intended for field scale.

The DWR report to the Legislature on the proposed methodology included an implementation plan as well as the potential associated costs. The plan included a three-phase schedule of implementation and identified implementing entities, roles, data needs and sources, and data management. Implementing the methodology would require new funding for DWR and water suppliers. The cost to DWR to implement the proposed methodology is approximately $400,000 per year in addition to a one-time cost of $500,000 for developing a database. Estimated costs to water suppliers serving water to more than 25,000 acres or irrigated land (these suppliers account for approximately 6 million acres of irrigated land) would be about $6 to $30 million per year. Water measurement costs are excluded from this estimate, since water delivery measurement to fields is required by the CWC for these suppliers. Estimated costs to water suppliers serving water to more than 10,000 but less than 25,000 acres or irrigated land (these suppliers account for approximately 757,000 acres of irrigated land) would be about $8.8 million per year and a one-time cost of $15 million for installing water measurement devices.

In addition to the four methods for quantifying the efficiency of agricultural water use, DWR included four indicators in this report that would provide supplemental information about irrigation and delivery system performance and crop productivity. These indicators do not quantify the agricultural water use efficiency, but help estimate the limits of potential efficiency and productivity. Two of the indicators help describe the performance of the growers' irrigation system. These are distribution uniformity (DU) and delivery fraction (DF).

1. **Distribution Uniformity (DU)** is a measure of irrigation system performance—how evenly water is applied and infiltrates into the soil across a field during an irrigation event. It is not a measure of how efficiently water is used on the field. A well-designed irrigation system applies water to crops as uniformly as possible to optimize crop production. DU is applicable at the field scale. Under CWC Section 10608.48(c), many water suppliers may provide on-farm irrigation evaluation service, if locally cost effective, that include the determination of DU and other information of the irrigation system.

2. **Delivery Fraction (DF)** evaluates the relationship (ratio) between the water delivered to water supplier customers and the agricultural water supplier's water supply. It is applicable only at the water supplier scale. Under CWC Sections 531.10 and 10608.48, many water suppliers are required to determine and report aggregated farm-gate delivery and water supply. These are the components used to calculate delivery fraction.

The other two indicators help describe crop productivity (relationship of the volume of water applied to an area to the total crop yield and gross crop revenue) — Productivity of Applied Water (PAW) and Value of Applied Water (VAW).

3. **Productivity of Applied Water (PAW)** illustrates the relationship (ratio) between crop production in tonnage and the volume of applied water. It is most applicable at a statewide or county scale.

4. **Value of Applied Water (VAW)** illustrates the relationship (ratio) between gross crop value in dollars and the volume of applied water. It is most applicable at the statewide and county scales.

The crop productivity indicators provide information about the relationship and trends of crop yield and/or monetary value to the volume of irrigation water applied during production. They can indicate long-term changes or trends in agricultural production and income relative to applied water at larger spatial scales. However, these indicators neither quantify the efficiency of agricultural water use nor the economic efficiency. Crop production depends on many factors other than the water to meet crop consumptive and non-consumptive needs, including water quality, climate, soil type, soil depth, crop parameters (variety), crop management (fertilizer and pest management, etc.), and water management (irrigation system, irrigation management, and water supply flexibility and reliability). As a result, the crop productivity indicators should not be used to draw conclusions about regional crop selection because many factors other than applied water affect crop selection, crop production, and crop value.

The crop productivity indicators can be used to inform interregional comparisons of long-term averages of the amounts of water necessary to achieve competitive yields. However, long periods are needed to attain dependable averages. Additionally, the value of such comparisons will be limited by the inability to act on the information without unprecedented interference with the ability of growers to respond to price signals. Maximal crop yields are frequently not the most water efficient yields and yields do not decrease at a constant rate with decreasing irrigation.

As a result, the optimal economic yield per unit of water for a specific crop may not correspond to the maximal yields. In this regard, the crop productivity indicators can be used to produce comparisons of yields as a function of irrigation levels. Developing such models for various crops would be a significant contribution, one which may serve growers well as demands on the State's water supplies increase. Knowledge of optimal water efficient irrigation levels for various crops may increase the resilience of the agricultural sector when challenged by drought.

Efficient Water Management Practices

Pursuant to SB X7-7, certain agricultural water suppliers, as defined in CWC Section 10608.12, shall implement on or before July 31, 2012 two specific critical EWMPs. These are stated in CWC Section 10608.48(b):

1. Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).
2. Adopt a pricing structure for water customers based at least in part on quantity delivered.

Agricultural water suppliers have to implement 14 additional EWMPs if they are locally cost-effective and technically feasible (CWC Section 10608.48 (c)). The 16 EWMPs, as stated in SB X7-7, are listed in Box 2-2.

As part of the agricultural water use efficiency provisions, SB X7-7 states that DWR may update the EWMPs in consultation with the AWMC, USBR, and SWRCB (CWC Section 10608.48(h)). These EWMPs for agricultural water use shall be adopted or revised only after DWR conducts public hearings to allow participation by stakeholders from the diverse geographical areas and interests of the state. Planning for this task is underway. Also, CWC Section 10608.48(g) requires that DWR submit a report to the Legislature on agricultural EWMPs (implemented or planned) and an estimate of water use efficiency improvements on or before December 2013. Subsequent reports will be prepared in 2016 and 2021. Additionally, DWR shall also prepare and submit a report to the Legislature summarizing the status of the submitted Agricultural Water Management Plans, their outstanding elements, effectiveness of promoting EWMPs, and recommendations relating to proposed EWMPs changes as appropriate. Similar reports will be submitted subsequently in years ending in six and one (CWC Sections 10845(a) through (c)).

As part of their AWMPs, agricultural water suppliers also required to "Report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five to 10 years in the future. If an agricultural water supplier determines that an efficient water management practice is not locally cost effective or technically feasible, the supplier shall submit information documenting that determination" (CWC Section 10608.48 (d)).

Note that in addition to the EWMPs listed in Box 2-2, there are important farming cultural practices such as soil management, cover crops, changes in tillage practices, land management practices, winter storm water capture and use, dry farming and rain-fed farming that can reduce applied water and increase water use efficiency.

The State Water Resources Control Board and the Delta Stewardship Council published a report in 2011 that examines the "reasonable use doctrine" (i.e., the constitutional principle that forbids waste and mandates that state water resources be used reasonably and beneficially) as it relates to agricultural water use efficiency. The report, titled *The Reasonable Use Doctrine and Agricultural Water Use Efficiency*, addresses how the State's Reasonable Use Doctrine may be employed to promote more efficient water use in the agricultural sector. The report shows that there is a wide array of irrigation practices in place today that result in the more efficient and, therefore, a more reasonable use of water. The report concludes that the Reasonable Use Doctrine may be employed to promote a wider use of such efficient practices (Wilson 2011). The report recommends that the State Water Resources Control Board convene a Reasonable Water Use Summit and contain specific recommendations for consideration during the summit. The recommendations range from a wider employment of efficiency practices such as improvements to the irrigation systems that deliver water to farms, weather-based irrigation scheduling, and more efficient irrigation methods. The report is available at http://www.waterboards.ca.gov/board_info/agendas/2011/jan/011911_12.pdf.

A report by the Pacific Institute, *California Farm Water Success Stories*, a follow-up to the Institute's 2009 report, identified and analyzed some successful case studies of sustainable agricultural water management policies and practices in California. The examples highlighted both on- and off- farm activities that led to more efficient applied water use or enhanced water quality, increased crop yields or quality, and provided multiple benefits. Such activities included planning and management practices, technological improvements, information dissemination, use of recycled water, and incentive and assistance programs (Christian-Smith et al. 2011).

In June 2011, the California Roundtable on Water and Food Supply issued a set of recommendations in a report entitled *Agricultural Water Stewardship: Recommendations to Optimize Outcomes for Specialty Crop Growers and the Public in California* that was addressed to state agencies, water suppliers, local water management groups, the agricultural community, and the research community. The California Roundtable is a forum of leaders in food production and water to uncover obstacles, identify strategic and widely accepted solutions, and generate recommendations to ensure a reliable, long-term supply of water to California's specialty crop producers while optimizing other beneficial uses of water. The Roundtable defines agricultural water stewardship as on-farm water use in a manner that optimizes beneficial uses of water and recognizes the co-benefits of water for food production and environmental and human health. Going further, the Roundtable identified agricultural water stewardship as a key area of importance for sound long-term water management. The specific recommendations center around three key solution themes with the goal of improving and promoting agricultural water stewardship:

1. Create a stronger knowledge base.
2. Improve support mechanisms for growers.
3. Move toward outcome-based policy and regulatory frameworks that foster agricultural water stewardship (California Roundtable on Water and Food Supply 2011).

The report is available at http://aginnovations.org/images/uploads/CRWFS_Water_Stewardship_Recs_electronic.pdf.

A July 2011 report prepared for the Northern California Water Association (NCWA), titled *Efficient Water Management for Regional Sustainability in the Sacramento Valley,* presented a framework for addressing agricultural water use efficiency in the Sacramento Valley while considering the Valley's hydrologic characteristics and existing conditions. The report outlined a technical framework to guide water use efficiency efforts in the Sacramento Valley by providing water resources managers with tools to identify, assess, and pursue specific water use efficiency opportunities while emphasizing the need for achieving regional sustainability. While recognizing that potential water use efficiency improvements have statewide as well as local and regional benefits, the report pointed out the challenge to Sacramento Valley water managers to develop coalitions within and outside the Valley to garner the necessary resources to advance water use efficiency for achieving regional sustainability and statewide benefits (Northern California Water Association 2011). The report is available at http://www.norcalwater.org/wp-content/uploads/2012/01/Technicalreport-jul2011.pdf.

Growers invest in on-farm water management improvements to stay economically competitive. Likewise, local water suppliers invest in cost-effective, systemwide water management improvements in order to provide quality service at a fair and competitive price. Substantial financial support for research, development, and the demonstration of efficient water management practices in agriculture comes from the agricultural industry, state, and federal efforts. Support also comes from the early adopters of new technology who often risk their crops, soils, and money when cooperating to develop and demonstrate technology innovations. Further investment in research, demonstration, and technical assistance for growers is critical, especially in support of university-based research, field station studies, Cooperative Extension demonstration projects, and technical assistance and outreach through Resource Conservation Districts.

Ways to Improve Agricultural Water Use Efficiency

Improvements in agricultural water use efficiency primarily occur from three activities:

1. Hardware — improving on-farm irrigation systems and water supplier delivery systems.
2. Water management — reducing non-beneficial ET and improving management of on-farm irrigation and water supplier delivery systems.
3. Agricultural technology — breeding, GMO crops, insect and disease control, fertilizers, technology, etc.

Hardware Upgrades

Due to water delivery system limitations, growers are often unable to apply the optimal amount of irrigation water. Water delivery system improvements such as integrated supervisory control and data acquisition systems (SCADA), canal automation, regulating reservoirs, and other hardware and operational upgrades, can provide flexibility to deliver water at the time, quantity, and duration required by the grower. At the on-farm level, many old and most new orchards and vineyards as well as some annual fruits and vegetables, are irrigated using pressurized irrigation systems, as shown in Figure 2-2 (sample percentages are based on voluntary survey responses).

Almost all trees and vines established since 1990 are irrigated using micro irrigation. Between 1991 and 2011, the crop area under micro irrigation in California grew from 1.26 million to 3.12

million acres, a 150 percent increase (see Figure 2-3 and Table 2-1).

A survey of more than 10,000 growers in California (excluding rice, double cropping, dry land, and livestock producers) was conducted by the DWR Land and Water Use program to investigate current trends in irrigation methods used statewide. Results from the survey indicate that the land acreage irrigated by low-volume irrigation methods (drip and micro sprinklers) has increased by 16 percent between 2001 and 2011, while the acreage of land irrigated by surface irrigation methods has decreased by 13 percent (Orang et al. 2011) See Figure 2-4.

Many growers use advanced irrigation systems for irrigation, fertilizer application, and pest management. Advanced technologies include

Figure 2-2 Acres of Irrigated Agricultural Land by Irrigation Method in California in 2010

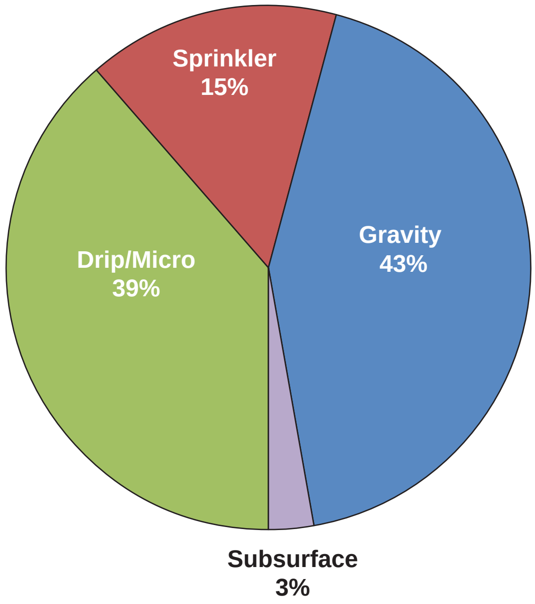


Figure 2-3 Change in Irrigation Methods in California (1977-2010)

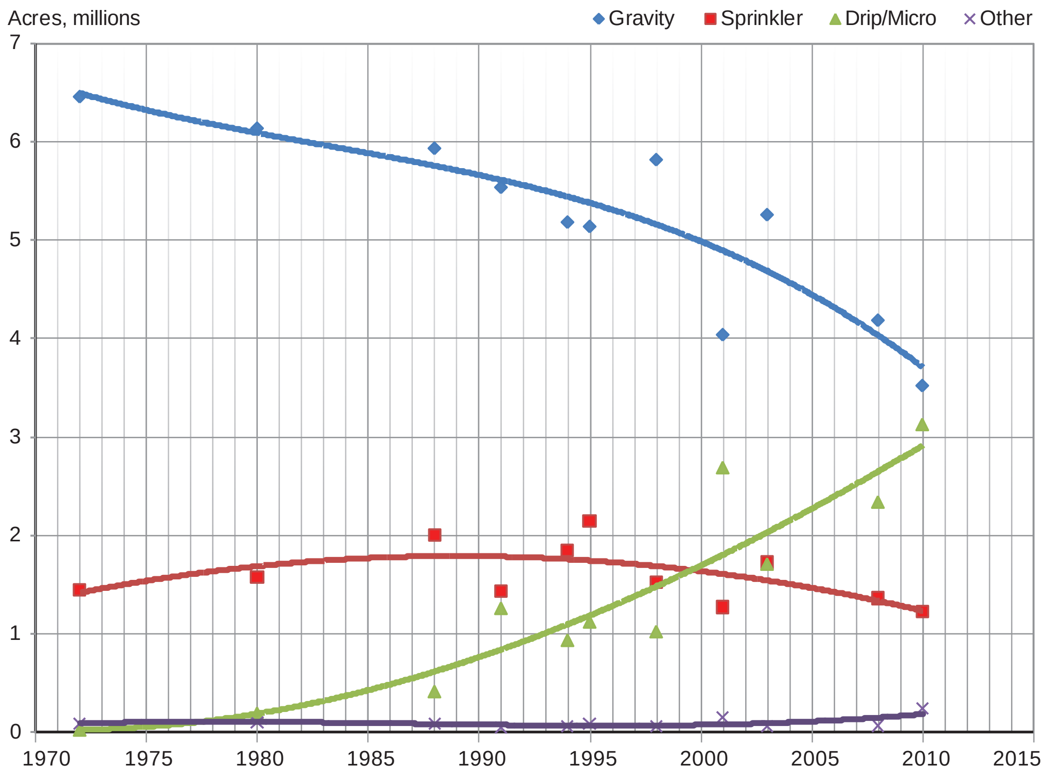


Figure 2-4 Statewide Trends in Irrigation Method Area from 1991 to 2011

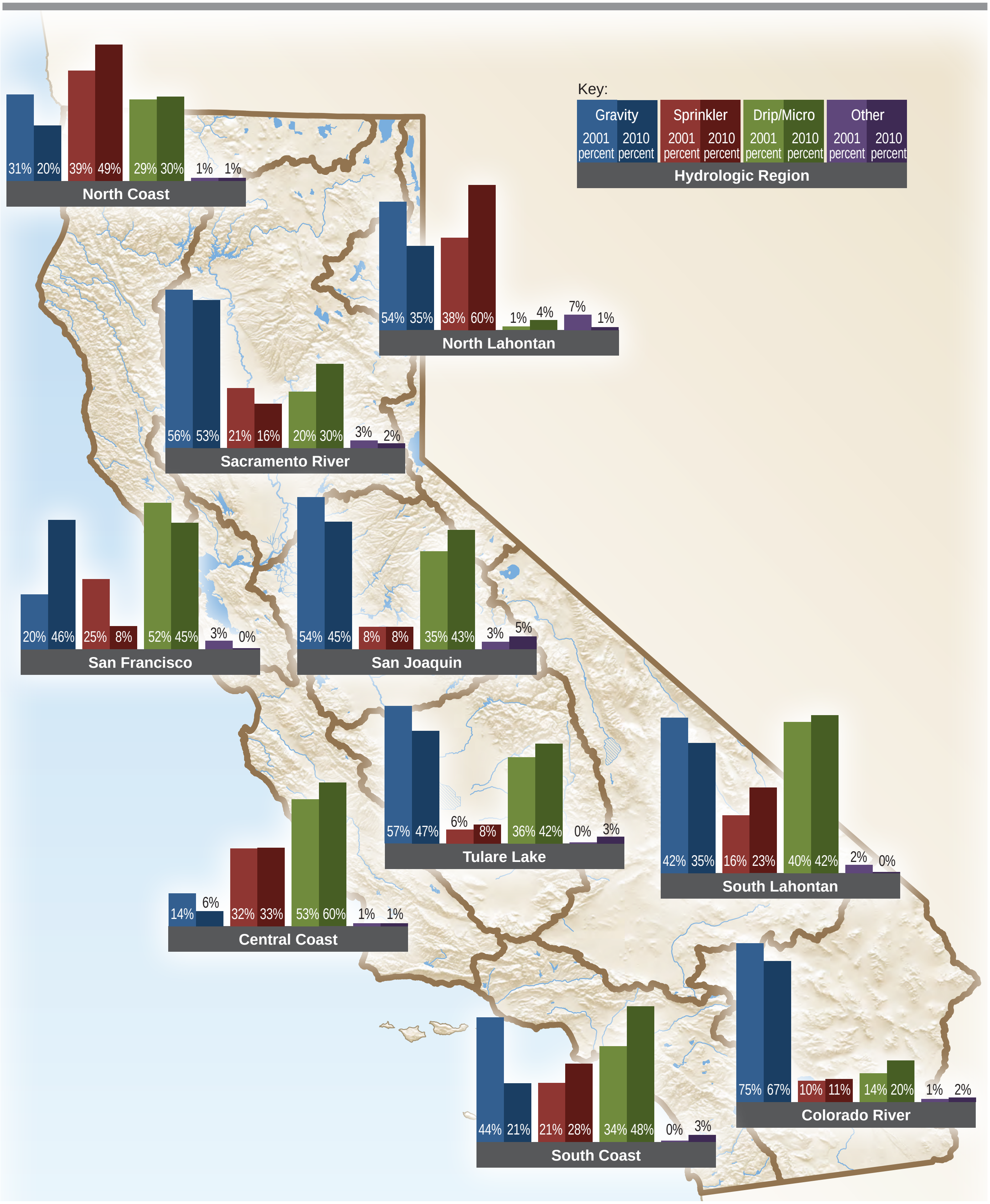


Table 2-1 **Trends in Irrigation Method Area (in million acres)**

Irrigation Method	1991 Area (MA)	1991 % of Total	2001 Area (MA)	2001 % of Total	2010 Area (MA)	2010 % of Total	Change from 1991 to 2010: Percent Change in Acreage and Reduction/Increase of Area	
Gravity (furrow, flood)	5.54	67	4.04	50	3.53	43	-36%	-2.01 MA
Sprinkler	1.43	17	1.28	16	1.24	15	-13%	-0.19 MA
Drip/micro	1.26	15	2.69	33	3.12	39	+150%	+1.86 MA
Subsurface	0.05	1	0.15	2	0.24	3	+380%	+0.19 MA
Total	**8.28**	**100**	**8.16**	**100**	**8.13**	**100**	**2.01 MA reduction in gravity systems 1.86 MA increase in pressurized systems**	

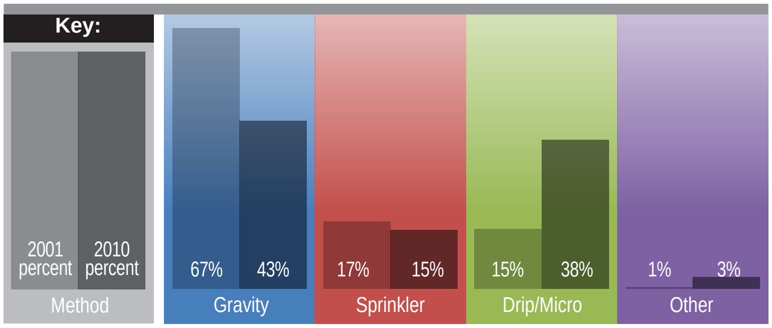
Note: MA = million acres.

geographic information system (GIS), global positioning system (GPS), and satellite crop and soil moisture sensing systems. These technologies help growers to improve overall farm water management.

Using pressurized irrigation systems, such as sprinkler, drip, and micro spray, in addition to being energy intensive often require modernization of water supplier delivery systems to provide irrigation water at the time, quantity, and duration required by the grower. An increasing trend is water suppliers upgrading and automating their systems to enable accurate, flexible, and reliable deliveries to their customers. Also, suppliers are lining canals, developing spill recovery and tail water return systems, employing flow-regulating reservoirs, improving pump efficiency, and managing surface water conjunctively with groundwater. Because of the advancement of both water supplier and on-farm water management systems, there is potential to improve irrigation efficiencies at both the on-farm and water supplier levels.

Growers continue to make significant investments in on-farm irrigation system improvements, such as lining head ditches and using micro irrigation systems (Figure 2-5). Many growers take advantage of mobile laboratory services to conduct in-field evaluation of their irrigation systems. These were once considered to be innovative technologies, but are standard practices now. In terms of future improvements, the California Polytechnic State University, San Luis Obispo Irrigation Training and Research Center estimates that an additional 3.8 million acres could be converted to precision irrigation such as drip or micro-spray irrigation (Burt et al. 2002). While this will not reduce crop water consumption, it can improve the uniform distribution of water and reduce evaporation, thus allowing more efficient use of water. Research on drip irrigation of alfalfa has shown an applied water reduction of two to three percent with yields increasing from 19 to 35 percent, an increase in productivity of 30 percent with the same amount of applied water (Crop Life America 2012). Conversion of traditional irrigation systems to pressurized systems

Figure 2-5 Statewide Trends in Irrigation Methods



and installing advanced technologies on water supplier delivery systems require more investment in facilities as well as using additional energy that increases farm production costs and water supplier operational costs. The additional cost of such improvements is a challenge for many water suppliers. California Farm Water Coalition, based on industry contacts, reports that in the six-year period, 2003 through 2008, San Joaquin Valley farmers invested more than $1.5 billion in high efficiency irrigation equipment.

Trends in irrigation methods used vary by region and such variation is mainly linked to the type of crops grown. Where more fruit trees and row crops (e.g., tomatoes) are grown, there is greater adoption of drip and micro irrigation systems.

Water Management

Both on-farm and water supplier delivery systems must be managed to take advantage of cost-effective new technologies, science, and hardware. Personal computers connected to real-time communication networks and local area networks transmit data to a centralized location. These features let water supplier staff monitor and manage water flow and to log data. They also enable water supplier staff to spend less time manually monitoring and controlling individual sites and allow them more time to plan, coordinate system operation, and potentially reduce costs. These systems also improve communications and provide for flexible water delivery, distribution, measurement, and accounting.

Some growers use satellite weather information and forecasting systems to schedule irrigation. Many growers employ ET and soil moisture data for irrigation scheduling. Users generate more than 70,000 inquiries per year to the California Irrigation Management Information System (CIMIS), and to the DWR weather station program that provides ET data. Universities, water suppliers, and consultants also make this information available to a much wider audience via newspapers, Web sites, and other media.

Growers use many other water management practices. Furrow, basin, and border irrigation methods have been improved to ensure that watering meets crop water requirements while limiting runoff and deep percolation. Growers use organic or plastic mulch to reduce non-essential evaporation of applied water, minimize weed growth, and improve crop growth and productivity value. Agricultural land stewardship practices (see Chapter 21, “Agricultural Land Stewardship,” in this volume) also reduce water use and contribute to sound on-farm water management.

Box 2-5 Regulated Deficit Irrigation

Some growers use regulated deficit irrigation (RDI) to stress trees or vines at specific developmental stages to improve crop quality, decrease disease or pest infestation, and reduce production costs while maintaining or increasing profits. Conventional irrigation management strategy has been to avoid crop water stress. Research on RDI began in California in the 1990s on tree and vine crops. Initial results show potential for reducing ET while increasing or maintaining crop profitability and allowing optimum production.

Wine grapes are a clear example. Mild stress imposed through the growing season decreases canopy growth, but produces grapes with higher sugar content, better color, and smaller berries with a higher skin-to-fruit volume ratio. This is a very common practice in the premium wine regions of California.

RDI has been primarily used as a production management practice and the extent of its application in California, in terms of crops and acreages under RDI, has not been quantified. Before RDI can be applied to other crops, information on its costs, risks, long-term impacts, and potential benefits, including water savings, must be determined. Once that is done, practical guidelines for growers on how to initiate, operate, and maintain RDI should be developed and disseminated (see Volume 4, *Reference Guide,* for details on RDI.)

Reducing Evapotranspiration

ET is the amount of water that evaporates from the soil and transpires from the plant. Growers can reduce ET by reducing unproductive evaporation from the soil surface, eliminating weed ET, and shifting crops to plants that need less water, or reducing transpiration through deficit irrigation, which is the application of water below full crop-water requirements. It is a strategy used to stabilize crop yields in drought areas, rather than maximizing it (see Box 2-5 for more on deficit irrigation). In addition, some growers use deficit irrigation for their crops during water short periods, or for agronomic purposes, such as improving the quality of the crop. Management practices such as mulching, use of cover crops, no-till and minimum tillage, and dust-mulching associated with dry farming reduce unnecessary evaporation from soil surfaces. Some of these management/cultural practices have energy conservation components as well.

It should however be noted that there is a close correlation between yield and transpiration. In most cases, an increase in crop yield is proportionally related to an increase in transpiration. However, an increase in yield does not necessarily result into a proportionate increase in crop water consumption. Transpiration is proportional to the crop yield in terms of total plant biomass. Nonetheless, in terms of the "economic yield" (i.e., fruit, seed, and other economic parts of the biomass), there can be increase in the yield without increasing the total biomass and therefore without increasing transpiration.

Potential Benefits and Costs

Several analyses have been performed since 2000 to quantify water savings and associated costs. The following is a summary of those analyses.

The CALFED Programmatic Record of Decision (ROD) estimates of 2000 reported that efficiency improvements could result in a water savings (reduction in irrecoverable flows are also referred to as net water savings) ranging from 120,000 to 563,000 acre-feet per year (af/

yr.) by 2030, at a cost ranging from $35 to $900 per acre-foot (CALFED Bay-Delta Program 2000a). The total cost of this level of agricultural water use efficiency to 2030 is estimated to be $0.3 billion to $2.7 billion, which includes $220 million for lining the All-American Canal and Coachella Branch Canal. The cost estimates are derived from potential on-farm and water supplier efficiency improvements associated with savings in irrecoverable flows. Details of estimates and assumptions are in the CALFED Water Use Efficiency Program Plan (CALFED Bay-Delta Program 2000b).

The analysis used the assumption that on-farm efficiency would improve to 85 percent. The analysis assumed that the achieved 85 percent on-farm efficiency would be maintained afterward. Efficiency levels higher than 85 percent are not attainable because of technical management and hardware limitations. Further, beyond 85 percent efficiency, a loss of productivity will occur. Increased soil salinity and soil degradation will result in an unsustainable and unhealthy soil environment.

The study also estimated a 1.6 maf /yr. reduction in applied water (recoverable flows) that provide environmental and crop production benefits. The estimated water savings are from all of California's hydrological regions.

Estimates of water savings and benefits resulting from land retirement, crop shifts, crop idling, and reducing crop transpiration through regulated deficit irrigation were not quantified in the ROD estimates. See Box 2-5 for discussion of regulated deficit irrigation.

Water use efficiency measures in the Colorado River Hydrologic Region are being driven by the Quantification Settlement Agreement (QSA). QSA projects will reduce irrecoverable flows by 67,700 acre-feet per year (af/yr.) at a cost of $135.65 million by lining the All-American Canal and by 26,000 af/yr. at a cost of $83.65 million by lining the Coachella Branch Canal, for a total of 93,700 af/yr. (CALFED Bay-Delta Program 2000b).

Under the QSA, agricultural water use efficiency measures adopted by the Imperial Irrigation District (IID) by 2026 will result in a reduction in delivery of Colorado River water to IID of 487,200 af/yr. inclusive of 67,700 af/yr. reductions from the All-American Canal lining. The 26,000 af/yr. Coachella Branch Canal lining is subtracted from the Coachella Valley Water District (CVWD) use. However, CVWD will receive conserved water from IID, and over the term of the QSA, its overall consumptive use will increase by 77 thousand acre-feet per year (taf/yr.) by 2026 and for the duration of the QSA (U.S. Department of the Interior 2003). Note that the IID/Metropolitan Water District of Southern California (MWD) transfer has been fixed at 105 taf/yr. instead of 110 taf/yr. Water conserved under the QSA will not result in new water supplies for California; rather, it provides a portion of the reduction needed for California water users to reduce their use of Colorado River water by 800,000 af/yr. from 5.2 to 4.4 million acre-feet per year (maf/yr.) (California Department of Water Resources 2009a; U.S. Bureau of Reclamation 2003).

The 2006 CALFED Water Use Efficiency Comprehensive Evaluation estimated potential water savings for different projection levels, ranging from 34,000 to 190,000 af/yr. of irrecoverable water and 150,000 to 947,000 af/yr. of recoverable water (CALFED Bay-Delta Program 2006). These were estimates for different projection levels, based on costs ranging from $15 million to $40 million annually (Table 2-2). These costs are for implementing efficiency measures that are not locally cost-effective. It is also assumed that implementing all locally cost-effective efficiency

Table 2-2 On-Farm and Water Supplier Recoverable and Irrecoverable Flow Reductions

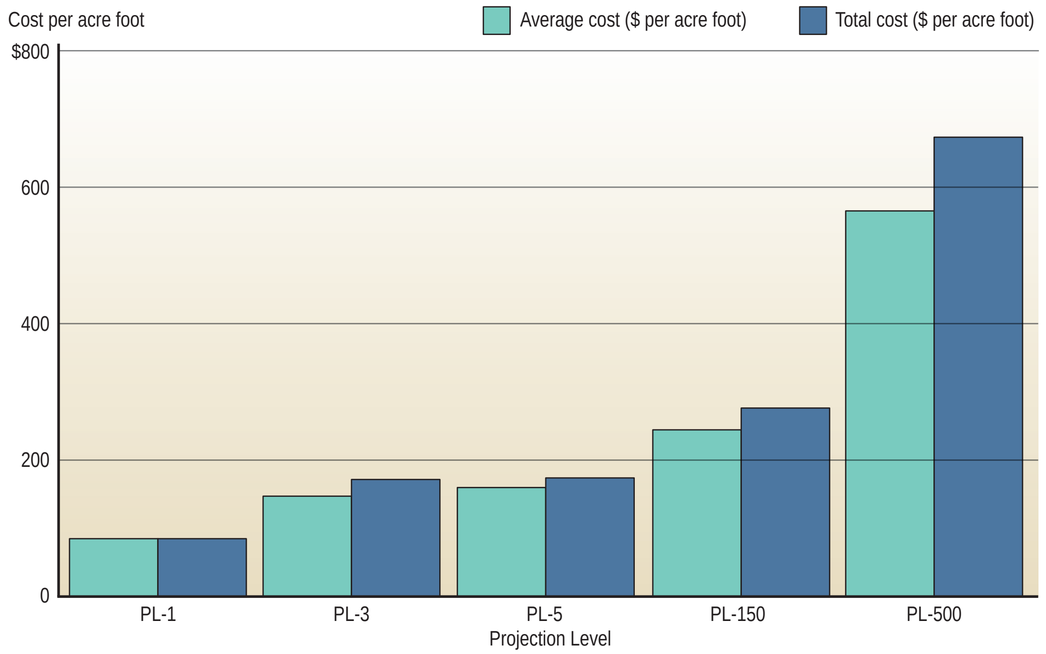
Estimates of 2030 On-farm and District Agricultural Water Use Efficiency Potential					
Projection Level (PL)	Local Agency Investment Assumption	CALFED Grant Funding Assumption	Recoverable Flows (1,000 af/yr.)	Irrecoverable Flows (1,000 af/yr.)	Regulated Deficit Irrigation (1,000 af/yr.)
PL-1	Historic Rate	Prop. 50 only	150	34	142
PL-2	Locally Cost-Effective	Prop. 50 only	No change in locally cost-effective rate-results, same as PL-1		
PL-3	Historic Rate	Prop. 50 + $15 million/year	565	103	142
PL-4	Locally Cost-Effective	Prop. 50 + $15 million/year	No change in locally cost-effective rate-results, same as PL-1		
PL-5	Locally Cost-Effective	Prop. 50 + $40 million/year (2005-14) $10 million/year (2005-30)	947	190	142
PL-50	Locally Cost-Effective	Prop. 50 $150 million/year (2006-2030)	2006	620	142
PL-00	Locally Cost-Effective	Prop. 50 $500 million/year (2006-2030)	2,930	888	142
Funding assumptions are based on implementation costs of not locally cost-effective efficiency measures and are not divided between local and public funding.					

Source: Water Use Efficiency Comprehensive Evaluation. CALFED Bay-Delta Program Water Use Efficiency Element Final Report (CALFED, 2006). The CALFED report is an updated analysis to the CALFED Bay-Delta Program Water Use Efficiency Element.

Note: af/yr. = acre-feet/year

measures are, and will continue to be, paid by local agencies and growers. The analysis also provided the maximum water savings achievable at the field and district levels if cost is not a barrier. Water savings at this projection level (PL) is called technical potential (Projection Level 6 or PL-6). Technical potential was defined as the savings resulting from 100 percent adoption of all agricultural water use efficiency actions/measures statewide, and assumed that all technically demonstrated practices would be implemented regardless of cost. The technical potential, or PL-6 water savings, at an estimated cost of $1.6 billion, are 1.8 maf/yr. irrecoverable water savings and 4.3 maf/yr. per year recoverable water savings. PL-6 was determined to be unrealistic both with respect to State's ability to provide such large funds and level of water savings. PL-6 represents a perfect irrigation system and management performance that is not attainable in production agriculture. The analysis also indicates a potential for additional water savings of 142,000 af annually from regulated deficit irrigation. Figure 2-6 presents average and incremental costs per acre-foot of irrecoverable flows for all projection levels in this study. The study estimated water conservation based on on-farm hardware and irrigation management improvements and district improvements. The study did not include potential savings in the Colorado River Hydrologic

Figure 2-6 Average and Incremental Cost per AF of Irrecoverable Loss Reduction



Region that are already committed to and funded by efficiency conservation water transfer agreements. Nor, as noted above, will these be included in potential agricultural water use efficiency reductions for the state because they only account for reductions to meet California's Colorado River water rights.

On-farm water use improvements were analyzed based on natural replacement from lower to higher performing systems over time (as systems age out and are replaced with new technology) as well as various funding levels. Water supplier improvements were based on implementation of efficient water management practices and various funding levels. The potential savings estimated in the study are based on a set of specific assumptions about the distribution and effective use of investments in agricultural water use efficiency (CALFED 2006). The cost information in Table 2-2 represents the investment in water use efficiency actions beyond the estimated locally cost-effective actions.

A July 2009 report from the Pacific Institute, *Sustaining California Agriculture in an Uncertain Future*, is another analysis to quantify agricultural water savings (Cooley et al. 2009). The report estimates potential water savings from 1) efficient irrigation technologies, 2) improved irrigation scheduling, and 3) regulated deficit irrigation, under three statewide hydrologic scenarios — wet, average, and dry year conditions. The total potential water savings range between 4.5, 5.5, and 5.9 maf/yr. for wet, average, and dry years respectively. The report does not separate its quantitative estimates between recoverable and irrecoverable water savings, thus the potential water savings are applied water savings only.

There is no doubt that agricultural water use efficiency can still be improved by continuing current trends such as improving irrigation efficiency, adopting drip and micro irrigation, adopting reduced deficit irrigation, selecting water efficient crops, etc. However, the potential for water savings from agricultural water use efficiency has been the subject of a broad debate.

At the high end, some reports mention potential savings to be as much as five million acre-feet of water per year by 2030 (Gleick et al. 2005). Others caution that any approach to estimate the potential of developing new water supplies through agricultural water conservation must acknowledge the difference between recoverable and irrecoverable flows. More important is that potential water savings should be tied to different levels of investment (Canessa et al. 2011). A report from the Center for Irrigation Technology at California State University, Fresno concludes that the potential of large volumes of "new water" from agricultural water conservation does not exist unless large swaths of agricultural land are taken out of production (land retirement), which technically is not water use efficiency (Canessa et al. 2011). See the land retirement section in Chapter 32, "Other Strategies," in this volume. Also among the Center for Irrigation Technology report findings are:

1. The estimated potential of new water from agricultural water use efficiency is 1.3 percent of the current amount used by the farmers or approximately 330,000 acre-feet per year (at funding level PL-5 identified in Update 2009). That represents about 0.5 percent of California's total water use.

2. Changes in irrigation practices, such as switching from flood irrigation to drip, have the effects of rerouting flows within the region (or basin), but generally do not create new water outside of the basin.

3. On-farm water conservation efforts can affect downstream water distribution patterns with potential impacts on plants and animals, recreation, as well as human and industrial consumptive uses. Effects can be positive or negative and also inconsistent (e.g., on-farm conservation could reduce a city's water supply but decrease non-point source pollution (Canessa et al. 2011). (See Chapter 18, "Pollution Prevention," in this volume.)

Water Supplier Water Use Efficiency

Water use efficiency estimates at the water supplier level are based on cost and performance of supplier management changes and infrastructure improvements. A baseline of water supplier improvements was developed for every hydrologic region by the former CALFED Bay-Delta Program based on water availability and knowledge of local delivery capabilities and practices. In addition, it assumed that all locally cost-effective efficient water management practices would be implemented. The initial investment for improvements was allocated for management changes that provide an improved level of delivery service mainly through additional labor and some system automation. Higher levels of water supplier delivery system performance would be achieved through infrastructure improvements such as regulating reservoirs, canal lining, additional system automation, and spill prevention.

At the water supplier level, most benefits may occur as a result of managing recoverable flows through return flows and spill recovery systems. However, since recoverable flows, especially surface return flows, are typically being used by downstream farming operations, the location of the water diversion in the basin is critical for determining if implementing a water use efficiency measure would adversely reduce the supply of downstream agricultural water users. Consequently, many consider the reduction of irrecoverable flows (or net water use) a better estimate of potential agricultural water use efficiency.

On-Farm Water Use Efficiency

On-farm water use efficiency estimates are based on cost and performance information for feasible irrigation systems. Depending on crop type, irrigation systems can include various forms of unpressurized surface irrigation (furrow and border strip), and pressurized irrigation systems (variety of sprinkler and drip). The performance of any irrigation system also depends on how well it is managed. For a given crop, the irrigation system and management will determine the water use characteristics — how much of the applied water is used beneficially and how much is irrecoverable. Irrecoverable flows include those to transpiration, saline sinks, and non-beneficial evaporation. Recoverable flows encompass surface runoff and deep percolation to usable water bodies. The recoverable flow results are based on instream flow needs for Bay-Delta tributaries. It is important to note the assumption that all recoverable flows may end up benefiting instream flows may not be valid. Much of efficiency improvements may increase water use as a result of larger plants, higher yields, and increased irrigated acreage. Although recoverable and irrecoverable flow reductions are reported separately for on-farm and water suppliers, it is not appropriate to assign benefits solely to on-farm or water suppliers due to the strong connection between on-farm recoverable flows and water supplier efficiency improvements. (See Box 2-6, Interrelation between On-farm and Regional Efficiencies and Role of Water Reuse.)

A primary environmental benefit of water use efficiency actions is the improvement in aquatic habitat through changes to instream flow and timing. Additional benefits may include water quality improvements by reducing water temperature, subsurface drainage flows, and reducing contaminant loads. Growers may reduce pumping costs and may provide and/or receive water quality benefits by complying with pollutant reduction rules under the State's total maximum daily load (TMDL) requirements. However, depending on the timing of flow changes, improvements in water use efficiency can cause negative environmental effects, such as reduced runoff to downstream water bodies, and increased concentration of pollutants in drain water unless the drain water contaminants, such as selenium, are isolated and properly disposed.

Major Implementation Issues

Funding

Beginning in 2000, DWR implemented several cycles of grant programs for water use efficiency improvements. The funds have been awarded through successive competitive proposal solicitation packages (PSP) for projects on a cost-sharing basis for water use efficiency projects that may not be locally cost-effective for the implementing agency. The grant cycles are summarized in Table 2-3. Grant funding has been provided statewide for a variety of projects including:

- Urban and agricultural water use efficiency implementation projects that are not locally cost-effective and that provide water savings or contribute to instream flows that are beneficial to the Bay-Delta or the rest of the state. Consideration is also given to projects that address water quality and energy efficiency.
- Urban and agricultural water use efficiency non-implementation projects including:
    - Planning.
    - Research and development projects.

Table 2-3 Projects Funded through Water Use Efficiency Grant Cycles Since 2001

	Urban Grants		Agricultural Grants		Total Grants	
GRANT SOURCE	FUNDING (MILLION)	NUMBER OF PROJECTS	FUNDING (MILLION)	NUMBER OF PROJECTS	FUNDING (MILLION)	TOTAL # OF PROJECTS
2013 Prop 50	-	-	$15	39	$15	39
2008 Prop 50	$17.2	53	-	-	$17.20	53
2007 Prop 50	$18.2	35	$9.9	22	$28.10	57
2005 Prop 50	$16.9	46	$11.7	28	$28.60	74
2003 Prop 13	$18.0	25	-	-	$18.00	25
2002 Prop 13	$8.5	21	$0.7	8	$9.20	29
2001 Prop 13	$0.7	7	$0.5	5	$1.20	12
2001 SB 23	$5.9	30	$5.9	23	$11.80	53
Total	**$85.4**	**217**	**$47.1**	**86**	**$132.50**	**303**

- Feasibility studies.
- Pilot studies or demonstration projects.
- Training, education, or public outreach programs.
- Technical assistance programs related to water use efficiency.

Cost-effectiveness criteria do not apply to these projects, but their outcome should be transferable to other areas of the state.

Funds dedicated to water use efficiency have fallen below estimates of the 2000 CALFED ROD that called for an investment of $1.5 to $2 billion from 2000 to 2007. The CALFED ROD stated that state and federal governments would fund approximately 50 percent (25 percent each), and local agencies would pay for the remaining 50 percent of CALFED water use efficiency activities. Table 2-3 shows the total funding for urban and agricultural water use efficiency projects (implementation as well as non-implementation) has been $132.5 million from 2000 through 2013.

Although small and disadvantaged communities must have grants for sorely needed water system improvements, they may not be able to apply because they have limited resources and matching funds. In addition, such water suppliers rarely have the technical and financial abilities to develop plans or implement expensive water management practices. During previous Proposition 50 water use efficiency grant cycles, DWR has made significant efforts to provide technical and financial assistance to disadvantaged communities. SB X7-7 requires DWR to give consideration to disadvantaged communities when allocating funds.

For some water suppliers, funding for water use efficiency comes from the ability to transfer water, such as in the Colorado River Region. While transfers to urban areas may reduce the amount of water available to grow crops, they are expected to play a significant role in financing future water-use efficiency efforts.

Box 2-6 Interrelation between On-farm and Regional Efficiencies and Role of Water Reuse

It should be recognized that saved or conserved water may or may not constitute new water for use for other purposes. Saved water constitutes new water only if it is prevented from evaporating from soil or flowing to salt sinks, such as saline surface or groundwater, or to the ocean. In California, over-application of irrigation water that flows out of a field in excess of crop water requirements provides irrigation water to another field directly via surface water flows or indirectly via groundwater recharge and pumping. Agricultural flows reused for irrigation seldom need treatment. Much of the water in the agricultural setting is used and reused many times over, including re-use of water in wetlands. It is because irrigation water is reused that on-farm efficiency improvements will not result in regional water savings. Regional efficiencies, with few exceptions such as drainage problem areas and salt sink areas, are always greater than individual field efficiencies. Indeed, reuse of water may be the least expensive mechanism and easily implemented measure to achieve very high regional efficiencies. The extensive reuse of recoverable flows in the agricultural setting also explains relatively small real water savings (which can be used for other purposes) compared with huge amounts of recoverable flows.

Implementation

Implementing agricultural water use efficiency depends on many interrelated factors. Farmers strive to maximize agricultural profits per unit of land and water without compromising agricultural economic viability, water quality, or the environment. Success depends not only on availability of funds but also on technical feasibility, cost-effectiveness, availability of technical assistance, and ability and willingness of growers, the irrigation industry, and water suppliers. Other factors such as soils and topography, micro-climate, markets, etc., play important roles as well. Implementation of efficiency measures requires consideration of crops grown, groundwater and/or surface water availability, and water quality within each geographic area. Opportunities exist to implement efficiency measures beyond basic efficient water management practices to provide water quantity, water quality, flow and timing, energy efficiency, and other benefits to the growers and local water suppliers and to provide regional or statewide benefits. Comprehensive implementation of efficiency measures must include, to the extent possible, multi-purpose and multi-benefit projects.

Regulated Deficit Irrigation

Reducing ET requires precise application of water. Stressing crops through regulated deficit irrigation (RDI) is one approach that requires careful scheduling and application of water and may have additional costs and adverse impacts on crop quality or soil salinity. RDI long-term studies are underway and results differ by crop, location, and year. (See Box 2-5 for a discussion of regulated deficit irrigation.)

Water Rights

Many growers and irrigation districts are concerned about existing and potential water use efficiency legislation and believe that implementing efficiency measures could affect their water rights. They believe that conserved water may be taken away, hence losing their rights to use the conserved water. This belief may impede implementing water use efficiency strategies. It should be noted that the water rights of agencies implementing efficiency measures have been protected. One example is the conservation efforts of IID, funded by MWD, SDWA, and others, where water was transferred to urban uses while IID's water rights were protected.

Energy and Water Relationship

The relationship between water use efficiency and energy use/carbon footprint is complex and needs to be thoroughly studied and understood. Improved agricultural water use efficiency may or may not help to reduce energy use and thus reduce greenhouse gases (GHGs). This is because of the complex relationship between GHG emissions, the use of energy (use of natural gas and the use of fossil fuel), and efficient use of water. It appears that decreased use of one resource, through implementation of efficiency measures, increases the use of another resource, which may neutralize or greatly impact net outcome, and often has more overall adverse effects than intended or desired. There have not been enough studies and research conducted to quantify the relationship between agricultural water use efficiency and energy use.

By considering the embedded energy of irrigation water, which is the energy required to deliver water to the field, California State University at Fresno's Center for Irrigation Technology showed in its 2011 report that water use efficiency may reduce or increase energy use. By reducing irrigation water through water use efficiency, generally the embedded energy would always be saved. However, the water use efficiency method employed might require a change in the irrigation system (e.g., changing the irrigation system from flood to drip). In such a case, even though the embedded energy is reduced, the energy required to apply the water to the field is increased. As a result, whether water use efficiency results in a net decrease or increase in energy use depends on the amount of water saved, the level of embedded energy, and the additional energy required to pressurize the irrigation system.

Climate Change

One of the most critical impacts on California agriculture may be the projected reduction in the Sierra Nevada snowpack, which is California's largest surface "reservoir." Snowmelt currently provides an annual average of 15 maf of water, which is slowly released between April and July each year. Much of the state's water infrastructure was designed to capture the slow spring runoff and deliver it during the peak of the agricultural water use season. Based on historical data and modeling, DWR projects that the Sierra snowpack will experience a 25-40 percent reduction of its historical average by 2050. Climate change is also anticipated to bring warmer storms that result in less snowfall at lower elevations, which reduces the total snowpack. The snowpack will melt earlier in the season due to warmer temperatures and there will be less late-season runoff. Warmer temperatures and increased atmospheric concentrations of carbon dioxide (CO_2) also increase ET and crop water demand. All of these factors will further stress California's agricultural community (California Department of Water Resources 2008, 2009b, 2010).

Mitigation

On-farm and water use efficiency improvements often require additional energy. Converting furrow irrigation to drip or sprinkler would require significant energy, even though growers and/or water suppliers may pump less water, which may reduce energy use. Therefore, the overall result of such efficiency practices may be a net increase of energy use. Water supplier infrastructure improvements often affect upstream-downstream water use. Also, increasing the use of pressurized irrigation systems by growers requires additional energy resources such as electricity, gas, and diesel. Pressurized systems also require pipelines, pumps, filters and filtration systems, chemicals for cleaning drip systems, and replacement and disposal of the hardware after its useful life. Consequently, significant additional energy is required for manufacturing pipelines, pumps, filters and filtration systems, chemicals, and the replacement and disposal of the hardware. Likewise, pressurized irrigation systems will need energy to produce the required pressure in the pipelines for irrigation. Such additional energy will significantly increase GHG emissions, which contribute to climate change. Within the agricultural setting, the net impact of reduced water use and increased water use efficiency on the energy use and consequently on net carbon footprint, water footprint, and GHG emissions calls for study and quantification of such impacts.

Adaptation

Agricultural water use efficiency is an adaptive strategy to climate change. Using water in a way that is most effective to the crop while minimizing losses helps the grower to be resilient and flexible. Climate change is a major challenge to agriculture's sustainability. The water use efficiency strategies discussed above are part of California's adaptive capacity, but growers must find a way to store more water in preparation for having access to less water during peak growing months in addition to using that water efficiently. Cover cropping and organic material build-up in soil are other methods of increasing soil water retention, which lessens the amount of irrigation water needed.

Other Implementation Issues

Other water use efficiency implementation issues that need to be evaluated include 1) concerns over groundwater impacts, overdraft, and loss of recharge, 2) increase in the vulnerability of trees and vines to hardening of demand, and 3) unpredictability of a changing climate. Climate change is expected to impact water use since rising temperatures will result in higher ET and higher crop water use requirements.

Education and Training

Improving agricultural water use efficiency depends on 1) disseminating information on the use, costs, benefits, and impacts of technologies, 2) providing technical assistance and training on the site specific nature of implementing technology, and 3) providing incentives for implementation. Experience shows that water suppliers and growers respond strongly to financial incentives. In addition, while the CWC provides certain water rights protections and incentives to conserve water, reaffirming and reinforcing such mechanisms could significantly improve results statewide. Education and training programs can emphasize the both the potential benefits and the risks of efficiency improvements, including the risks to soil sustainability from a salinity standpoint, or that energy use may increase. On-site technical assistance can assist growers in successfully implementing new technologies more efficiently and in site-specific ways.

With limited water resources and recurring droughts, California farmers, irrigation specialists, water resources planners, and water managers use a multitude of information sources for informed decision- making and to stay current on the latest issues and advances in irrigation technology and water management practices. Such sources of information include, but are not limited to: State and federal agencies and research stations; U.S. Department of Agriculture, Natural Resources Conservation Service; resource conservation districts; UC Cooperative Extensions and Agricultural Experiment Stations; Cal Poly Irrigation Training and Research Center; California State University, Fresno, Center for Irrigation Technology; California Irrigation Institute; California Irrigation Districts Association; independent crop advisors; and many growers associations and irrigation equipment vendors.

Dry-Year Considerations

In dry years, California's water supply is inadequate to meet the current level of use, and agriculture often must deal with a reduction in water deliveries. Growers are compelled to reduce irrigated acreage to cope with the lack of water and implement extraordinary water use efficiency practices or even fallow land. While agricultural water suppliers deal in a variety of ways with water shortages and droughts, there is a need for an agricultural drought guidebook.

Overall, water scarcity impacts California growers and as climate change continues to reduce the average annual snowpack, it is likely that droughts in California may increase in severity and frequency in years to come. In the 1970s and early 1990s, DWR partnered with the University of California Agriculture and Natural Resources (UCANR) to develop a series of drought management fact sheets. There is a need to update these facts sheets and make them more readily available. DWR, in cooperation with UCANR, is embarking on a project to revisit and update existing drought tips and fact sheets on drought and agriculture in California and potentially develop new ones. As more and more people get their information from the web, it is important to provide the updated information using a variety of digital formats that will achieve broader outreach such as a drought information clearinghouse Web site.

Recommendations

The following recommendations can help facilitate greater agricultural water use efficiency.

Implementation

1. The State should clarify policy and improve incentives, assurances, and water rights protections to allay fears over the loss of water rights resulting from improved water use efficiency. The State should verify and clarify in its programs, especially loans and grant programs, that efforts to conserve water do not alter water rights. SB X7-7 legislation declares that it "does not require a reduction in the total water used in the agricultural or urban sectors, because other factors, including, but not limited to, changes in agricultural economics or population growth may have greater effects on water use. This part does not limit the economic productivity of California's agricultural, commercial, or industrial sectors" (CWC Section 10608.8(3)(c)).

2. DWR, in cooperation with academic institutions, resource conservation districts, and independent crop advisors should provide technical assistance to water suppliers and farmers to evaluate their agricultural water use efficiency by computing the efficiency quantification methods outlined in the DWR 2012 report to the Legislature, A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use.

3. DWR should continue developing, in consultation with the State Water Resources Control Board, the California Department of Public Health, and the Public Utilities Commission, a single standardized water use reporting form to meet the water use information needs of each agency.

4. DWR should provide technical assistance to water suppliers to help them implement the Agricultural Water Measurement Regulation and report aggregate farm-gate deliveries to comply with the regulation.

Data Measurement and Evaluation

5. DWR should create a statewide system of water use monitoring data available to all users.

6. The State should expand water efficiency information, evaluation programs, and on-site technical assistance provided through agricultural extension services, resource conservation districts, independent crop advisors, and other agricultural outreach efforts.

7. The State should improve online data collection and dissemination networks to provide farmers with immediate meteorological and hydrological information on climate, soil conditions, and crop water needs.

8. The State should collect, manage, and disseminate statewide data on the cropped area under various irrigation methods, amount of water applied, crop water use, and the benefits and costs of water use efficiency measures. The State should also develop statewide guidance to assist regions and water suppliers to collect the type of data needed in a form usable for future Water Plan Updates. DWR should cooperate with the agricultural community to develop methods to quantify water savings and costs associated with hardware upgrades, water management, and ET reduction projects identified in this strategy.

9. The State should incorporate into its definitions of "efficiency measures" and "cost-effectiveness" ownership and operating costs, including labor, energy, and cost of maintenance.

10. The State should develop performance measures for water use efficiency goals and inform the public and stakeholders of accomplishments toward those goals. These performance measures should be updated to reflect new findings and changing conditions.

11. DWR, in cooperation with the Department of Food and Agriculture and irrigation districts, should establish an on-farm irrigation system evaluation program, such as mobile labs, statewide. The irrigation system evaluation program provides valuable assistance to growers to improve the performance of their irrigation systems further.

12. Using data and information from on-farm efficiency improvements collected by mobile labs, DWR should quantify changes in irrigation system distribution uniformity improvements. Protocols for confidentiality should be followed to ensure that information identifying

individual fields, owners, or operators is not improperly disclosed in order to assure farmers and encourage voluntary participation. In addition to quantifying on-farm and regional efficiency, collected data — stripped of any personal or business information — can also be used for improving local, regional, and statewide water management planning.

Education and Training

13. Expand CIMIS (including remote sensing technology, satellite imagery, etc.), mobile laboratory services, and other training and education programs to improve irrigation distribution uniformity, irrigation scheduling, and on-farm irrigation efficiency. These program expansions should also be used for improvements in pumping system efficiencies, remote control technologies and telemetry, canal automations, flexible water delivery systems, and irrigation system design.

14. Based on long-term ET reduction studies and research, DWR should develop informational guidelines that define the crop water consumption reduction practices, identify how to implement them for each crop, and estimate the potential crop benefits and impacts, water savings, and costs for growers and water suppliers.

15. DWR, with the participation of agricultural and water industries and environmental interests, should develop community educational and motivational strategies for conservation activities to foster water use efficiency.

16. The State should explore and identify innovative technologies and techniques to improve water use efficiency and develop new water use efficiency measures based on the new information. Consider fast-track pilot projects, demonstrations, and model programs exploring state-of-the-art water saving technologies and procedures, and publicize the results widely.

17. The State should foster a closer cooperative relationship among growers, water suppliers, irrigation professionals, technical assistance providers, and manufacturers who play an important role in research, development, manufacturing, distribution, and dissemination of new and innovative irrigation technologies and management practices.

18. The State should initiate collaboration with county governments to offer tax credits for installation of more efficient irrigation systems.

19. Incorporate a comprehensive educational, informational, and awareness component regarding sustainability of consumption of local products in the water use efficiency programs for growers, water suppliers, post-harvesting processors, consumers, and others. Encourage reducing long distance commodities transporting and importing commodities and thus, reduce energy use and greenhouse gas emissions.

Dry-Year Considerations

20. DWR, the Department of Food and Agriculture and stakeholders should compile measures currently used by growers and water suppliers to deal with water shortages and droughts and develop a comprehensive agricultural drought guidebook as a storehouse of information and procedures for drought mitigation, including new and innovative methods.

21. Review and adopt standard water use efficiency approaches to meet water needs during dry years. New approaches should be explored such as alfalfa summer dry-down and regulated deficit irrigation to cope with water shortages.

22. Drought water management should be fully incorporated in agricultural water management plans.

Department of Water Resources' Near-Term Core Programs

23. Continue developing a single standardized water use reporting form, in consultation with the State Water Resources Control Board, the Department of Food and Agriculture, Department of Public Health, and Public Utility Commission. DWR will involve agricultural water suppliers and stakeholders in the process through the existing Urban Stakeholders Committee and Agricultural Stakeholders Committee. Agricultural water suppliers will use the form to report water use data and information, at a minimum to show compliance with the implementation of EWMPs as required in SB X7-7.

24. Continue developing an on-line submittal portal for water suppliers to use in reporting water use data, EWMPs, and AWMPs.

25. Prepare and submit reports on the results of efficiency improvements in irrigation systems to the Legislature.

26. Make all submitted agricultural water management plans available for public inspection on the DWR Web site.

27. Prepare and submit to the Legislature reports summarizing the status of the Agricultural Water Management Plans and adoption by the agricultural water suppliers. These reports shall be prepared on or before December 2013 and in subsequent years ending with six and one (e.g., 2016, 2021).

References

References Cited

Agricultural Water Management Council AB 3616 Advisory Committee. 1999. Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California. Sacramento (CA): California Department of Water Resources. 87 pp. Viewed online at: http://www.agwatercouncil.org/images/stories/pdfs/awmcmou.pdf.

Burt CM, Mutziger A, Howes D, Solomon K. 2002. *Evaporation from Irrigated Agricultural Land in California.* San Luis Obispo (CA): Irrigation Training and Research Center, California Polytechnic State University. 478 pp.

CALFED Bay-Delta Program. 2000a. Programmatic Record of Decision (ROD). Sacramento (CA): CALFED Bay-Delta Program. 846 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/ROD.pdf.

———. 2000b. "Water use efficiency program plan. Programmatic EIR/EIS technical appendix." Sacramento (CA): California Bay-Delta Program. 29 pp. [Web site.] Viewed online at: http://calwater.ca.gov/calfed/library/Archive_EIS.html.

———. 2006. *Water Use Efficiency Comprehensive Evaluation. CALFED Bay-Delta Program Water Use Efficiency Element. Final Report*. Sacramento (CA): California Bay-Delta Program. 181 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf.

California Department of Food and Agriculture. 2012. *California Agricultural Statistics Review.* 2011-2012. Sacramento (CA): California Department of Food and Agriculture. 15 pp. Viewed online at: http://www.cdfa.ca.gov/statistics/pdfs/AgStatOverview2011-12.pdf.

California Department of Water Resources. 2008. *Managing an Uncertain Future*. Sacramento (CA): California Department of Water Resources. 34 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf.

———. 2009a. Colorado River Hydrologic Region. In: *California Water Plan Update 2009*. Chapter 11. Volume 3. Sacramento (CA): California Department of Water Resources. 58 pp. [Book.] Viewed online at: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v3_coloradoriver_cwp2009.pdf.

———. 2009b. "Climate Change." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/climatechange/. Accessed: Dec., 2009.

———. 2012a "Agricultural Water Use." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/wateruseefficiency/agricultural/.

———. 2012b. *A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use. A Report to the Legislature Pursuant to Section 10608.64 of the California Water Code*. Sacramento (CA): California Department of Water Resources. 105 pp. Viewed online at: http://www.water.ca.gov/wateruseefficiency/sb7/docs/AgWaterUseReport-FINAL.pdf.

California Roundtable on Water and Food Supply. 2011. *Agricultural Water Stewardship: Recommendations to Optimize Outcomes for Specialty Crop Growers and the Public in California*. Sebastopol (CA): Ag Innovations Network. 12 pp. Viewed online at: http://aginnovations.org/images/uploads/CRWFS_Water_Stewardship_Recs_electronic.pdf.

Canessa P, Green S, Zoldoske D. 2011. *Agricultural Water Use in California: A 2011 Update*. Fresno (CA): Center for Irrigation Technology California State University, Fresno. 80 pp. Viewed online at: http://www.californiawater.org/docs/CIT_AWU_Report_v2.pdf.

Center for Irrigation Technology. 2009. "Center for Irrigation Technology." Fresno (CA): California State University, Fresno. [Web site.] Viewed online at: http://www.fresnostate.edu/jcast/cit/index.html. Accessed: Dec., 2009.

Christian-Smith J, Allen L, Cohen MJ, et al. 2011) *California Farm Water Success Stories*. Oakland (CA): Pacific Institute. 74 pp. Viewed online at: http://www.pacinst.org/reports/success_stories/.

Cooley H, Christian-Smith J, Gleick P. 2009. *Sustaining California Agriculture in an Uncertain Future*. Oakland (CA): Pacific Institute. 81 pp. Viewed online at: http://www.pacinst.org/reports/california_agriculture/final.pdf.

Crop Life America. 2012. *Annual Report*. Washington (DC): Crop Life America. 24 pp. Viewed online at: http://www.croplifeamerica.org/sites/default/files/CLA_Annual%20Report_FINAL_9%2012%2012.pdf.

Gleick P, Cooley H, Groves D. 2005. *California Water 2030: An Efficient Future*. Oakland (CA): Pacific Institute. 48 pp. Viewed online at: http://www.pacinst.org/reports/california_water_2030/ca_water_2030.pdf.

Independent Panel on Appropriate Measurement of Agricultural Water Use. 2003. *Final Report on the Definition of Appropriate Agricultural Water Use Measurement*. Sacramento (CA): California Bay-Delta Authority. 131 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/library/WUE/FinalReport_Sept03.pdf.

Northern California Water Association. 2011. *Efficient Water Management for Regional Sustainability in the Sacramento Valley*. Sacramento (CA): Prepared by CH2M Hill, Davids Engineering, and MBK Engineers for the Northern California Water Association. 50 pp. Viewed online at: http://www.norcalwater.org/wp-content/uploads/2012/01/Technicalreport-jul2011.pdf.

Orang M, Matyac S, Snyder R. 2008. "Survey of irrigation methods in California in 2001." Journal of Irrigation and Drainage Engineering. 134(1):96-100. [Technical note.]

San Diego County Water Authority. 2003. Quantification Settlement for the Colorado River. San Diego (CA): San Diego County Water Authority. 2 pp. Viewed online at: http://www.sdcwa.org/sites/default/files/files/publications/qsa-fs.pdf.

U.S. Bureau of Reclamation. 2003. Colorado River Water Delivery Agreement: Federal Quantification Settlement Agreement for purposes of Section 5(B) of Interim Surplus Guidelines. Prepared for Secretary of the Interior, Imperial Irrigation District, Coachella Valley Water District, Metropolitan Water District of Southern California, and San Diego County Water Authority. Washington (DC): U.S. Bureau of Reclamation. 14 pp. Viewed online at: http://www.usbr.gov/lc/region/g4000/QSA/crwda.pdf.

U.S. Senate Committee on Agriculture, Nutrition, and Forestry. 2012. "The Farms Bill is a Job Bill. Agriculture Reform, Food, and Jobs Act of 2012." Washington (DC): U.S. Senate Committee on Agriculture, Nutrition, and Forestry, U.S. Senator Debbie Stabenow, Chairwoman. [Executive summary.] Viewed online at: http://www.stabenow.senate.gov/files/documents/fb-jobs.pdf.

Wilson CM. 2011. *The Reasonable Use Doctrine and Agricultural Water Use Efficiency*. Sacramento (CA): 17 pp. Prepared for the State Water Resources Control Board and the Delta Stewardship Council. Viewed online at: http://www.waterboards.ca.gov/board_info/agendas/2011/jan/011911_12_reasonableusedoctrine_v010611.pdf.

Additional References

Agricultural Water Management Council. 2009. "Agricultural Water Management Council." Fresno (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.agwatercouncil.org/. Accessed: Dec., 2009.

California Department of Water Resources. 2009c "Grants and Loans." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/nav/nav.cfm?loc=t&id=103. Accessed: Dec., 2009.

——. 2009d. "California Irrigation Management Information System (CIMIS)" Sacramento (CA): California Department of Water Resources, Office of Water Use Efficiency. [Web site.] Viewed online at: http://wwwcimis.water.ca.gov/cimis/welcome.jsp. Accessed: Dec., 2009.

California Farm Water Coalition. 2009. "California Farm Water Coalition." Sacramento (CA): [Web site.] Viewed online at: http://www.cfwc.com/. Accessed: Dec., 2009.

California Polytechnic State University. 2009. "Irrigation Training and Research Center." San Luis Obispo (CA): California Polytechnic State University. [Web site.] Viewed online at: http://www.itrc.org. Accessed: Dec. 2009.

Imperial Irrigation District. 2009. "Agreements with the Federal Government and Southern California Agencies." Imperial (CA): Imperial Irrigation District. [Web site.] Viewed online at: http://www.iid.com/index.aspx?page=208. Accessed: Dec., 2009.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 3

Urban Water Use Efficiency

Rancho Cucamonga, CA. The Frontier Project Foundation, a non-profit founded by the Cucamonga Valley Water District, constructed the Frontier Project to demonstrate water and energy conservation strategies. The building reduces water consumption by 50 percent and energy usage by 30 percent.

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Chapter 3. Urban Water Use Efficiency

Over the past few decades, Californians have made great progress in urban water use efficiency. Once viewed and invoked primarily as a temporary strategy in response to a drought or emergency water shortage situation, water use efficiency has become a permanent part of the long-term management of California's water supply. At the individual level, the benefits of water use efficiency may appear small, incremental, or difficult to see, but when Californians act together as a community to conserve water, the cumulative effect is significant, and the benefits are widespread.

There are several factors that have contributed to increased water use efficiency: outreach efforts that have increased awareness and changed behaviors; urban water suppliers' implementation of demand management measures (DMMs); plumbing codes requiring more efficient fixtures; the Model Water Efficient Landscape Ordinance (MWELO); advances in irrigation technology; new technologies in the commercial, institutional, and industrial (CII) sectors; and mandates requiring that unmetered connections become metered.

However, with tighter environmental constraints on the Sacramento-San Joaquin Delta (Delta), increasing population, and the necessity of adapting to climate change, even greater efficiencies will be needed and are achievable. When faced with an increasing demand for water, water agencies can consider options for increasing supplies or reducing demand, or a combination of both, to meet this need. Increasing water supply can be expensive and can include costs of purchasing additional water, capital cost of production and distribution systems, water supply treatment facilities, energy costs, and wastewater treatment facilities. Reducing demand through increased water use efficiency is generally lower cost and quicker to implement.

In an effort to emphasize and increase water use efficiency, the State Legislature has directed urban retail water suppliers to reduce urban per-capita water use by 20 percent by the year 2020. This legislation, the Water Conservation Act of 2009 (Senate Bill [SB] No. 7 of the 7th Extraordinary Session, or SB X7-7), was enacted as part of a five-bill package aimed at improving the reliability of California's water supply and restoring the ecological health of the Delta. SB X7-7 had multiple urban and agricultural water use efficiency provisions. The key urban conservation measure established a statewide goal of reducing urban per-capita water use by 20 percent by 2020. Meeting this statewide goal of a 20-percent decrease in demand will result in a reduction of just over 2 million acre-foot (maf) of urban water use in 2020.

This chapter will present the practices already employed in urban water conservation, as well as describing how further efficiencies can be achieved and how the goal of 20-percent reduction by 2020 can be met.

Urban Water Use Efficiency Today in California

Demand Management Measures and Best Management Practices

Demand management measures (DMMs) shown in Table 3-1 and best management practices (BMPs) are practices that can be used by urban water suppliers to conserve water, and the implementation of these practices has been a major driving force behind urban water conservation in California.

The Urban Water Management Planning Act placed the DMMs in the California Water Code (Section 10631) and required urban water suppliers to include a description of their DMM implementation in their urban water management plans (UWMPs), due every five years.

These DMMs were also included in the California Urban Water Conservation Council's (CUWCC's) memorandum of understanding (MOU). The CUWCC was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The council's goal is to integrate DMMs into the planning and management of California's water resources. When the DMMs were incorporated into the MOU, they were labeled as BMPs. Water agencies that became signatories to the MOU pledged to implement the BMPs to specified levels and to report progress on their BMP implementation biannually to the CUWCC.

Originally, the CUWCC BMPs were the same as the DMMs listed in the Urban Water Management Planning Act. But in 2008, the CUWCC BMPs underwent a significant revision. The BMPs were reorganized as either "Foundational" or "Programmatic" BMPs and re-numbered. More details on the revised BMPs can be found at http://www.cuwcc.org.

To be eligible for grant or loan funding from the State of California, an urban water supplier, whether a signatory to the CUWCC MOU or not, must demonstrate that its efforts in implementing each DMM or BMP will be implemented at the coverage level determined by the CUWCC MOU.

Some of the DMMs/BMPs provide quantifiable water savings, and others do not. For example, DMM N is the practice of toilet retrofits; replacing a 5-gallon-per-flush toilet with a 1.6-gallon-per-flush toilet yields water savings of 3.4 gallons per flush. Contrast that with DMM H, school education programs. Although education is critical to conservation and necessary to move people to new behaviors, it is not possible to correlate each educational effort with specific water savings.

20x2020: A New Direction

Box 3-1 describes the history, process, and impact of the *20x2020 Water Conservation Plan* (20x2020 Plan).

Baseline Water Use

The period used for baseline water use estimations is roughly 1996 to 2005, though suppliers could choose any 10 consecutive years from between 1995 and 2010.

After compiling baseline water use from 342 water agencies, the statewide average baseline water use was calculated to be 198 gallons per capita per day (gpcd) (California Department of Water Resources 2012).

Table 3-1 Demand Management Measures

Demand Management Measure	Description
DMM A	Water survey programs for single-family residential and multi-family residential customers.
DMM B	Residential plumbing retrofit.
DMM C	System water audits, leak detection, and repair.
DMM D	Metering with commodity rates for all new connections and retrofit of existing connections.
DMM E	Large landscape conservation programs and incentives.
DMM F	High-efficiency washing machine rebate programs.
DMM G	Public information programs.
DMM H	School education programs.
DMM I	Conservation programs for commercial, industrial, and institutional accounts.
DMM J	Wholesale agency programs.
DMM K	Conservation pricing.
DMM L	Water conservation coordinator.
DMM M	Water waste prohibition.
DMM N	Residential ultra-low-flush toilet replacement programs.

Notes:

DMM = demand management measure

The California Water Code, Section 10631(f), requires urban water suppliers to provide a description of their demand management measures in their urban water management plans. Implementation of these measures has been a driving force behind urban water conservation in California.

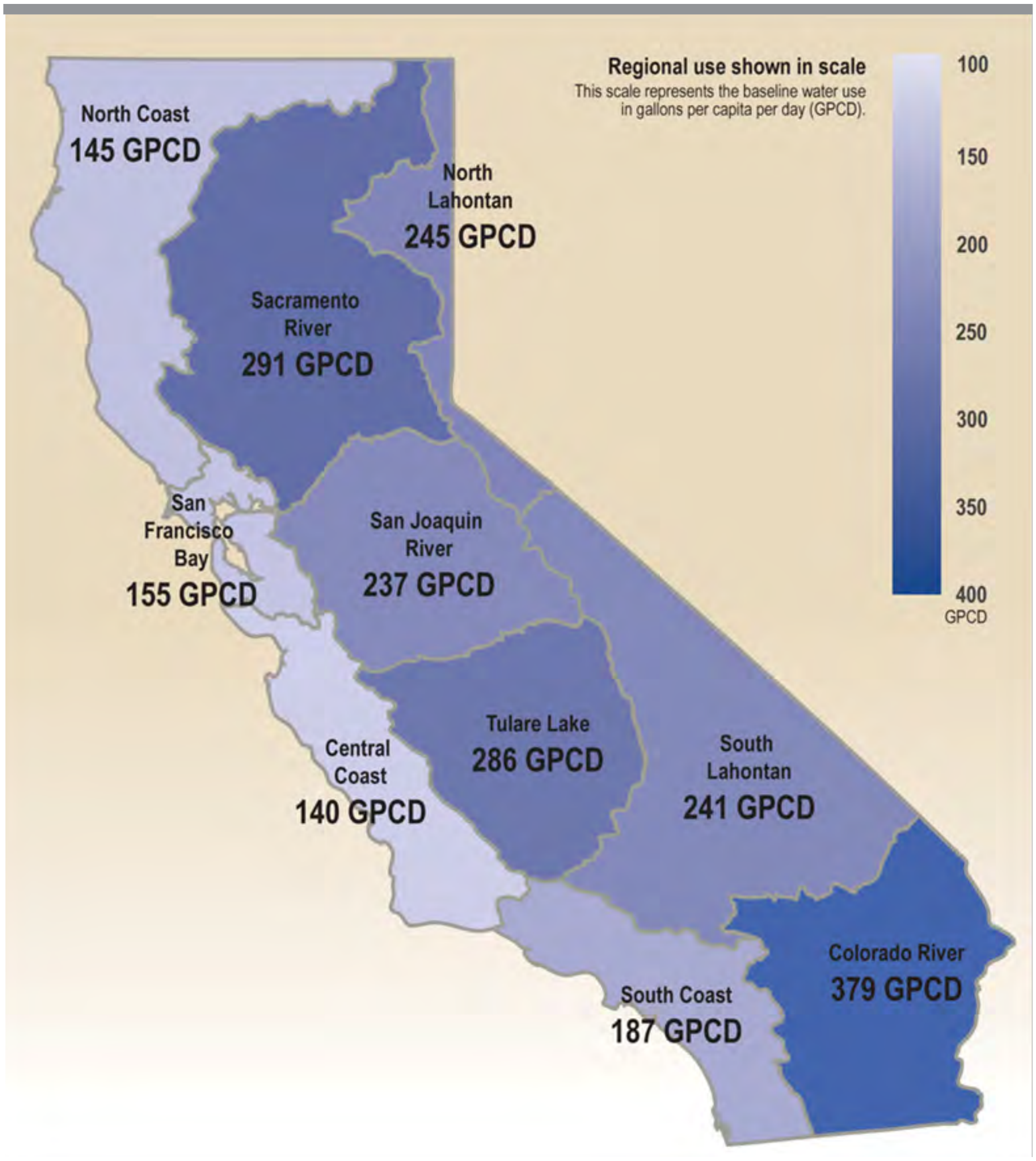
Figure 3-1 shows how baseline water use differs regionally across the state, and Figure 3-2 displays the range of per-capita water use reported by the water agencies in their 2010 urban water management plans (UWMPs). Generally, lower water use is seen along the coast, with increasing water use in the inland valleys; however, low or high per-capita water use is not necessarily an indicator of efficiency. Climate and land use factors can have a significant effect on water use. The coastal areas generally use less water in their landscapes because the marine climate provides a lower rate of evapotranspiration and because the sizes of coastal residential landscapes tend to be smaller than those of inland areas. Increased efficiencies have also been needed on the coast, because these communities were strongly affected by the 1988-1992 drought and a number of conservation programs were implemented to improve water supply reliability.

Baseline Water Use by Sector

The total volume of urban water use, statewide, as reported in *California Water Plan Update 2009* (Update 2009) is 8.8 maf per year (California Department of Water Resources 2009). This is an eight-year average for the time period of 1998-2005.

There is some variation in water use reporting between Update 2009 and the 20x2020 calculations used in UWMPs. When estimating urban water use, Update 2009 calculations included the use of recycled water, self-supplied industrial water, potable water supplied

Figure 3-1 Average Baseline Water Use by Hydrologic Region



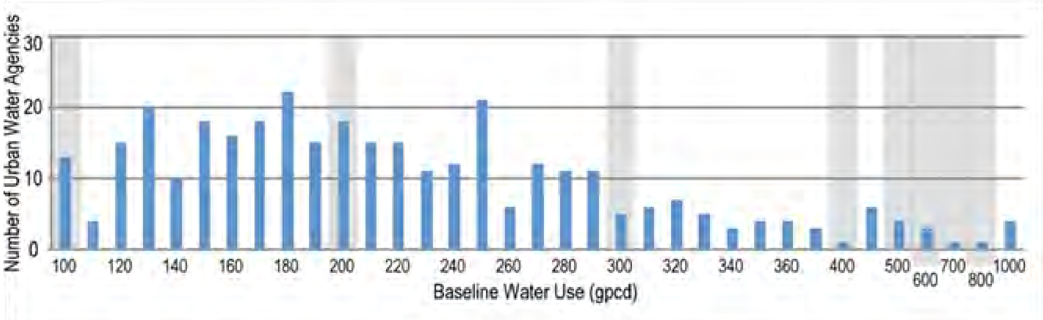
Source: California Department of Water Resources 2012

Note: This map displays the average water use, by hydrologic region, during the baseline period, roughly 1996 through 2005. The numbers displayed are in gallons per capita per day (GPCD). The hydrologic regions near the coast generally have smaller landscapes and cooler climates compared with inland regions, which have larger irrigated landscapes and warmer climates.

to agriculture, conveyance losses, and water used for groundwater recharge. The 20x2020 calculations used in UWMPs do not include these urban water uses.

Table 3-2 and Figure 3-3 show the division of the 8.8 maf of urban water use (California Department of Water Resources 2009) into water use sectors.

Figure 3-2 Range of Reported Baseline Water Use



Source: California Department of Water Resources 2012

Note: This figure illustrates the range of reported baseline water use. Blue bars show the number of agencies reporting a particular baseline. Gray bars indicate a separation of 100 gallons per capita per day (gpcd).

Water Use in 2010 — Progress in Achieving 20-Percent Reduction by 2020

Because of the economic downturn, the 2007-2009 drought, and a cool summer in 2010, many suppliers have reported significant drops in water use in the last few years, and some are already below their 2020 water use target. These suppliers are now focused on ways to keep water use low once the economy improves and a more typical weather pattern returns.

2015 and 2020 Water Use Targets

In the 2010 UWMPs, water suppliers reported an average 2020 water use target of 166 gpcd. This target is a 16-percent reduction from the statewide average baseline of 198 gpcd, which is less than the 20-percent goal. The legislation provided four methods for calculating the 2020 target, and this allowed some suppliers to select targets lower than the 20-percent goal, but none of the methods require suppliers to select targets higher than 20 percent.

After receiving the 2015 UWMPs, DWR is required to report to the Legislature on progress toward the 20-percent reduction goal. Suppliers are expected to be halfway between the baseline and the 2020 target by 2015. If the state, overall, is not on track to meet the 20-percent target, DWR is directed to provide recommendations to the Legislature on how the goal can be achieved.

A list of the individual water supplier’s baselines and targets and more information on statewide and hydrologic region averages is available in DWR’s report to the Legislature on the 2010 UWMPs (California Department of Water Resources 2012).

Meeting the Targets — Potential Savings by Sector

Since the early 1990s, voluntary implementation of DMMs, new codes and regulations has increased water use efficiency in California. However, abundant opportunities still exist to increase urban water use efficiency, and many of these opportunities will need to be tapped in order for California to achieve its 20-percent reduction goal by 2020.

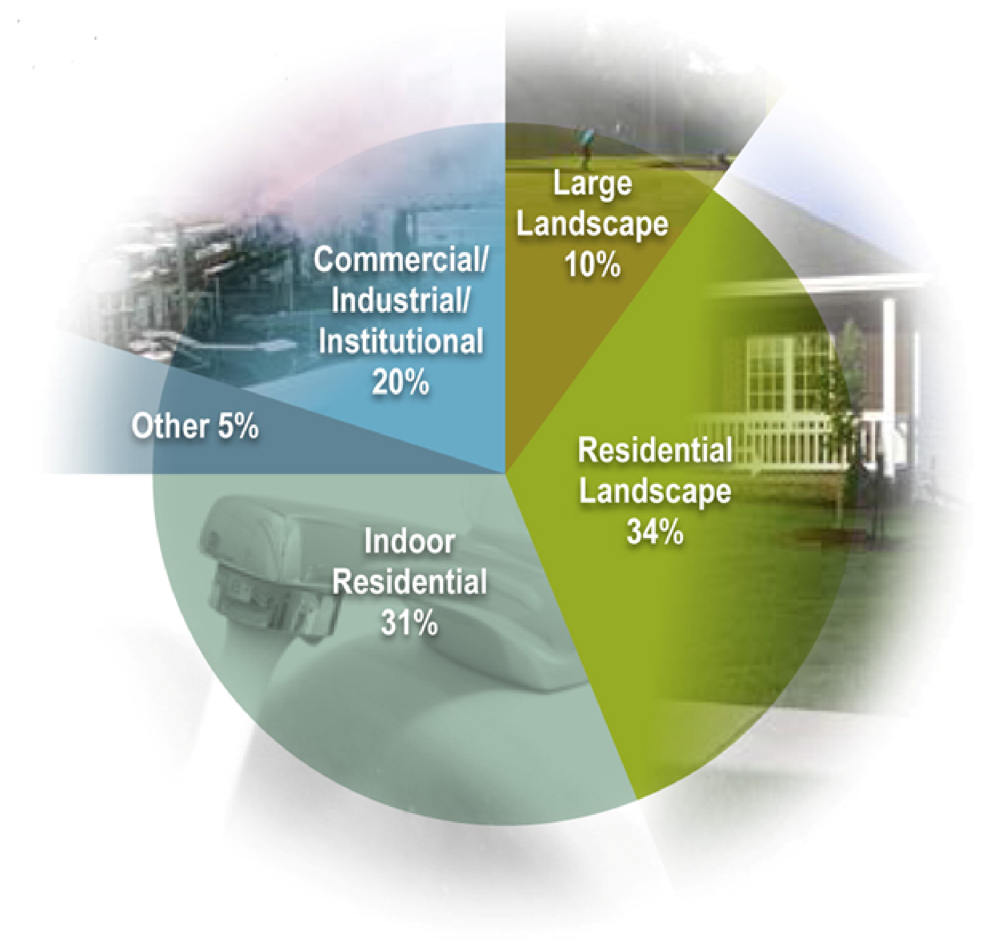
Table 3-2 **Statewide Urban Water Uses**

Sector	Percentage	Volume
Residential landscape	34%	3.0 maf
Large landscape	10%	0.9 maf
Indoor residential	31%	2.7 maf
Commercial, institutional, and industrial	20%	1.7 maf
Other	5%	0.5 maf
Total	100%	8.8 maf

Source: California Department of Water Resources 2009

maf = million acre-feet.

Figure 3-3 **Statewide Urban Water Use: Eight-Year Average, 1998-2005**



Source: California Department of Water Resources 2009

Note: This pie chart illustrates the relative water use of different sectors as a statewide average. The water use by sector will vary for each individual water agency.

Box 3-1 20x2020 Plan: History, Process, and Impact

History

In 2008, the Delta Vision Blue Ribbon Task Force called for improved water use efficiency and conservation to reduce exports from the Sacramento-San Joaquin Delta (Delta). The task force specifically recommended a statewide 20-percent per-capita reduction in water use by the year 2020. In response to this recommendation, the 20x2020 Agency Team on Water Conservation was formed. The agency team subsequently wrote the *20x2020 Water Conservation Plan* (20x2020 State Agency Team on Water Conservation 2010) outlining recommendations on how statewide per-capita water use reductions could be successfully implemented to meet the goal of 20-percent reduction by 2020.

In November 2009, the Water Conservation Act of 2009, Senate Bill No. 7 of the 7th Extraordinary Session (SB X7-7), was enacted by the California Legislature (California Water Code Section 10608). The urban water conservation provisions of SB X7-7 reflect the approach taken in the *20x2020 Water Conservation Plan* and set an overall goal of reducing per-capita urban water use statewide by 20 percent by 2020.

The 20x2020 Plan Process

Water suppliers play a fundamental role in carrying out the statewide water reduction goal of 20 percent by 2020. Each urban water supplier is required to set water use targets based on its historical water use, the local climate, and locally implemented conservation programs. ("Urban water supplier" is defined in California Water Code Section 10617.) The statewide goal will be met by compiling the water reductions from each water supplier.

The legislation does not require a reduction in the total volume of water used in the urban sector. That is because other factors, such as changes in economics or population, will affect water use. Rather, the legislation requires a reduction in per-capita water consumption. Water consumption is calculated in gallons per capita per day (gpcd).

As set out in the SB X7-7 legislation, and through the use of methodologies and criteria in *Methodologies for Calculating Baseline and Compliance Urban Per Capita Water Use* (California Department of Water Resources 2011), water suppliers:

- Must determine their baseline water use and target water uses for 2015 and 2020. Wholesale suppliers are not required to set targets but are directed to assist their retail suppliers in meeting the targets.
- Must report their gross water use during the final year of the reporting period (years 2015 and 2020). This is known as "Compliance Water Use."
- May revise their baseline water use calculations and change the method used to set their targets after submitting their 2010 urban water management plans.

Impact of the 20x2020 Plan

Projecting forward to the year 2020, with statewide population expected to be in the range of 44 million people, a decrease in per-capita water use of 20 percent would equate to an annual demand reduction of just over 2 million acre-feet of water.

The requirement that all urban retail water suppliers quantify per-capita baseline water use, set water use targets, and then show actual reductions in 2015 and 2020 has caused suppliers across California to pay particularly close attention to the effectiveness of their water conservation programs.

Descriptions of the potential for increased savings are presented below. These represent a statewide overview and are not intended as a blueprint for individual water agencies, because each agency will have its own unique strategy for achieving its 2015 and 2020 water use targets.

All water savings noted in the following sections are comparisons of potential savings by 2020 to the baseline water use reported by water suppliers in their 2010 UWMPs. Because baselines and targets are reported in gallons per capita per day, the descriptions presented below will state the current water use and potential savings in gallons per capita per day (gpcd).

Landscape Irrigation

Annual water demand for residential and large landscape irrigation amounts to approximately 4 maf, or about 45 percent, of urban demand. Because this sector represents such a large portion of urban water demand and because water waste from landscapes is common — water running down street gutters, leaks, watering during rainstorms, etc. — landscape irrigation presents a significant opportunity for increasing efficiency and reducing unnecessary demand. (For more information on reducing landscape irrigation runoff, see Box 3-2.)

Increased landscape water use efficiency can be accomplished with a variety of tools that are effective in any landscape sector, whether residential, commercial, or institutional. Some of these tools include regular maintenance of irrigation systems, irrigation audits to identify deficiencies, development of landscape water budgets, and selection of low-water-using plants. Some tools are available at low- or no-cost and can provide immediate and significant savings.

Urban landscapes can be divided into three categories: residential; large landscape; and commercial, institutional, and industrial (CII) mixed meter. Each of these uses is addressed more specifically below.

Residential Landscapes

Residential landscape irrigation represents the single largest end use of urban water, accounting for 34 percent of total urban use (California Department of Water Resources 2009).

Many factors contribute to the large amount of water used in residential landscapes, including population shifts to hotter interior regions, which often have larger residential landscapes (Hanak and Davis 2006); the prevalence of cool-season turf grasses and other high-water-use plants; irrigation systems that are inefficient and poorly maintained; and widespread overwatering of all plant types.

When comparing homeowners' actual landscape water use to a theoretical water requirement, one sees a mix of irrigation behaviors: homeowners who under-irrigate and those who over-irrigate (Irvine Ranch Water District 2011). It can be assumed that most of those who under-irrigate are nevertheless satisfied with the quality and appearance of their landscapes; otherwise, those homeowners would have increased their water use.

There are at least two possible explanations for this phenomenon: Either some landscapes require less water than previously thought, because actual plant water needs, soil conditions, and cultural factors contribute to a lower demand, or the standard used to estimate the theoretical

Box 3-2 Landscape Irrigation Runoff

Photo A below shows an example of irrigation runoff, frequently seen in landscapes throughout California.

Fortunately, many opportunities exist to improve efficiency in landscape irrigation. These include the use of evapotranspiration controllers, soil moisture sensors, reduction of cool season turf, and education of water users.

The Residential Runoff Reduction Study (Municipal Water District of Orange County and Irvine Ranch Irrigation District 2004) demonstrated that a combination of evapotranspiration controllers and user education can greatly reduce dry season irrigation runoff.

In this study, dry season irrigation runoff was measured from 138 residential and non-residential landscapes. After the runoff was measured, the landscapes were retrofitted with evapotranspiration controllers, and the water users were educated in efficient irrigation practices. A second set of runoff measurements was taken after the retrofit and user education.

A comparison of the first and second measurements showed that irrigation runoff had been reduced by 50 percent by the installation of evapotranspiration controllers and user education.

Photo A Irrigation Runoff

water requirements needs to be reevaluated. It is apparent that many landscapes are successfully irrigated at rates below the current theoretical requirement.

In light of these findings, water suppliers would benefit from targeting their most resource-intensive landscape conservation efforts to water users that are over-irrigating (Irvine Ranch Water District 2011). As a marketing tool, a cost-benefit analysis based on water rates and other factors can help determine which customers would be the best candidates for intervention, both in terms of maximizing water supplier resources and customer buy-in. Furthermore, because most residential users underestimate the quantity of water used in their landscape (California Urban Water Conservation Council 2007c), education components remain a vital tool for increasing the water savings potential.

Landscape water budgets, based on landscape area and climate, are employed in the Model Water Efficient Landscape Ordinance (MWELO). (California Code of Regulations Title 23, Division

2, Chapter 2.7, Section 490). The MWELO formula for calculating water budgets was updated in 2010, thus lowering the amount of water in a landscape water budget. After more research is completed in plant water needs, it may be appropriate to lower the evapotranspiration adjustment factor (ETAF) used in the water budget calculation. (See Box 3-3 for more information on landscape water budgets.)

Several water use studies (Pacific Institute 2003; Irvine Ranch Water District 2001; Hanak and Davis 2006; Irvine Ranch Water District 2011) indicate that residential landscape water demand can potentially be reduced by at least 20 percent, with some researchers estimating savings potential of 45 percent or more (Pacific Institute 2003).

The statewide average baseline water use for residential landscape irrigation is estimated at 79 gpcd. This is derived as follows: Baseline residential landscape use is 3.0 maf (see Table 3-2), divided by a 2000 population of 33,780,000, and then converted to gallons per capita per day (gpcd).

A conservative estimate of 20-percent reduction in residential landscape water use would represent a savings of 16 gpcd, equating to an annual statewide reduction of 789,000 acre-feet (af) by 2020.

Large Landscapes (Dedicated Meters)

Large landscapes are commercial, industrial, and institutional (CII) landscapes that are a category of landscapes set apart by the presence of dedicated irrigation meters. Dedicated metering serves the purpose of accurately measuring the water use of a landscape and making it possible to assign and monitor water budgets and detect leaks. The CUWCC landscape BMP requires water use budgets to be assigned at 70 percent of local reference evapotranspiration (ETo).

Based on an eight-year average of DWR data (see Table 3-2 and Figure 3-3), large landscapes with dedicated meters accounted for 10 percent of urban water use, equivalent to 0.9 maf. Water use through a dedicated landscape meter can be monitored by the irrigator and can provide immediate feedback on the amount of water moving through the meter. Programs such as the California Landscape Contractors Association (CLCA) Water Management Certification Program (WMCP) (California Landscape Contractors Association 2012) enable irrigation managers to monitor and track water use and manage a landscape at 80 percent of ETo or less. (See Box 3-4 for information on dedicated water meters and California Water Code requirements.)

The numbers and total acreage of sites designated as large landscapes will increase over time as mixed-use meters at existing CII landscapes are retrofitted to dedicated meters. All new CII landscapes over 5,000 square feet require a dedicated irrigation meter and are more accurately known as “large landscapes.”

A CII landscape water use efficiency study (California Landscape Contractors Association 2003) collected data from 449 CII landscapes. The results indicate that approximately 50 percent of CII landscapes were irrigated in excess of 100-percent ETo. If those sites reduced water use to maintain a water budget of 100-percent ETo, the author estimates a 15-percent demand reduction could be achieved. Potential landscape efficiency gains could be much greater than 15 percent if conversions from cool-season turf to water efficient plants were included and if the water budget were reduced to seventy or eighty percent of ETo.

Box 3-3 The Value of Landscape Water Budgets

Landscape water budgeting is a straightforward method for determining whether a site is receiving the correct amount of water to keep the plants healthy without wasting water. A water budget is calculated using local reference evapotranspiration data, an evapotranspiration adjustment factor, and the area (in square feet) of the irrigated landscape. The landscape area can be captured from landscape plans, by measuring the site, or through aerial imagery. Historically, obtaining the landscape area has been a challenge for water suppliers, especially when more than one meter may serve a parcel, but new tools and technology are becoming available that will simplify the process.

When the volume of water allowed in the water budget is compared with water use data, the irrigation manager can evaluate whether water use is on track and, if it is not, can make immediate changes to the irrigation schedule. Because weather conditions influence the water needs of plants, irrigation managers should assess compliance with the water budget weekly or at least monthly.

Water budgets are valuable communication tools. An irrigator that keeps a site within a water budget can show its customer the water savings and cost savings achieved when compared with historical use. Water suppliers can assign a water budget to an account and notify the customer and the irrigation manager when the budget is exceeded. Water budgets, coupled with tiered water rates, send a pricing signal that discourages wasteful water use.

Recent WMCP information from the CLCA Water Forums indicates that many sites maintained and managed under the WMCP are performing at water budgets of 80 percent of ETo or less, with average irrigation rates of 64 percent of ETo for the 704 sites enrolled in the WMCP in 2012 (California Landscape Contractors Association 2012).

However, some water suppliers have found that after assigning water budgets and conducting outreach efforts, they are still not seeing the savings estimated in the 2003 CLCA CII landscape study, nor do they believe potential for further savings is as great (Brown pers. comm. Oct. 26, 2012). Other suppliers have seen a drop in landscape water use but attribute these savings not only to the training programs, but also to pricing, shortages, and other factors as well (Granger pers. comm. Oct. 19, 2012).

Newer study results will give a more current picture of CII landscape water use efficiency, but it is clear that sites that are actively managed by trained personnel are generally the most efficient and still retain potential for further savings.

Statewide average baseline water use for large landscapes is estimated at 24 gpcd. This is derived as follows: Baseline large landscape water use is 0.9 maf (see Table 3-2), divided by a 2000 population of 33,780,000 and then converted to gallons per capita per day (gpcd).

A conservative estimate of a 15-percent reduction in large landscape water use would represent a savings of 3 gpcd, equating to an annual statewide reduction of 148,000 af by 2020.

Commercial, Industrial, and Institutional Landscapes (Mixed-Use Meters)

Opportunities for water savings in CII landscapes with mixed-use meters are probably as high as residential landscapes; however, significant data gaps exist due to inconsistencies in water use reporting. Suppliers voluntarily report their water deliveries and, depending on the agency,

Box 3-4 Dedicated Water Meters: California Water Code Section 535

Since 2008, water suppliers must install a dedicated landscape meter on new non-residential water service with a landscape area of more than 5,000 square feet. The California Green Building Standards Code requires dedicated meters, metering devices, or sub-meters to facilitate water management on non-residential landscapes from 1,000 square feet up to 5,000 square feet.

landscape water use may be included in CII, multi-family, or "other" categories. Because of these data gaps, potential water savings in CII landscapes with mixed-use meters cannot be separated from CII water use and are included as part of CII water savings, discussed later in this chapter.

Indoor Residential Water Use

Indoor residential water use (both single and multifamily housing) accounts for about 31 percent of total urban water use in California (see Figure 3-3 and Table 3-2). This equates to a statewide average baseline water use for indoor residential of 62 gpcd. This is derived by using 8.8 maf for the total annual urban water use (California Department of Water Resources 2009) and 33,780,000 for the 2000 population.

A comparison of California's baseline indoor residential water use, 62 gpcd, to a study of homes retrofitted with WaterSense and Energy Star fixtures and appliances (U.S. Environmental Protection Agency 2008), which had water use of 43 gpcd, shows that significant savings remain to be captured in this sector.

Residential indoor water is delivered through only a small number of fixtures — toilets, clothes washers, showers, faucets, and dishwashers. The percentage of water use by fixture is displayed in Figure 3-4. The following paragraphs address these fixtures, and potential savings, in more detail. Several regulations mandate high-efficiency fixtures. A discussion and comparison of these regulations is provided by the California Urban Water Conservation Council (2010).

Toilets

A study by American Water Works Association (AWWA) Research Foundation (1997) revealed that toilets were the biggest component of indoor water use at that time. Many older, inefficient toilets have been replaced with more efficient models since then, but, years later, it appears that toilets are still the largest user of indoor residential water use. More current studies (Pacific Institute 2003; Irvine Ranch Water District 2011) show that toilets account for 20 percent to 33 percent of indoor water use, which equates to an average of 13-19 gpcd.

Older toilets use 3.5 or 5 gallons per flush (gpf), but regulations have mandated increased efficiency. The 1992 California code required that new toilets sold in the marketplace have a flush volume of 1.6 gpf. These are called ultra low-flow toilets (ULFTs). In 2014 the code will require an even greater efficiency of 1.28 gpf. These toilets are known as high-efficiency toilets (HETs) and have been mandated in new construction since 2011.

Figure 3-4 **Estimated Indoor Residential Water Use in California (Year 2000)**

Source: Pacific Institute 2003

Many existing toilets remain to be converted to efficient models. Estimates are that the saturation of ULFTs and HETs is 54 percent to 60 percent. (Irvine Ranch Water District 2011; 20x2020 Agency Team on Water Conservation 2010)

The 20x2020 Plan calculates that retrofitting residential toilets, so that 81 percent are ULFT or HET, could save roughly 5 gpcd.

Clothes Washers

Clothes washers account for 14 percent to 18 percent of indoor residential water use (Pacific Institute 2003; Irvine Ranch Water District 2011), which is about 9.0-10.5 gpcd. However, according to the *California Single Family Home Water Use Efficiency Study* (Irvine Ranch Water District 2011), only about 20 percent of homes studied in 2007 were using efficient washers. This indicates that there is great potential for decreasing per-capita water use for clothes washing through appliance replacement.

The water efficiency of clothes washers is rated using the term "water factor." The water factor is measured by the quantity of water (gallons) used to wash each cubic foot of laundry. The lower the water factor rating, the more water-efficient the clothes washer.

Standards for the water efficiency of residential clothes washers have been put in place by the U.S. Department of Energy. These water factor standards have been moving progressively lower over several years. The most current standard will culminate in 2018 with a maximum water factor of 6.0 for standard top-loading machines and a maximum water factor of 4.5 for standard front-loading machines. For comparison, conventional washers have a water factor of 12 to 13.

The 20x2020 Plan estimated that potential savings from efficiency codes, active rebate programs, and natural turnover of clothes washers would be approximately 5 gpcd.

Leaks

Studies from Pacific Institute (2003) and Irvine Ranch Water District (2011) reveal that the water lost to leakage in the residential sector averages from 7 to 10 gpcd. This number is relatively large; however, the majority of the water loss was concentrated in a small number of homes. The median loss was found to be small, between 1.4 and 3.9 gpcd. Yet, 14 percent of the homes lost more than 17 gpcd to leaks, and 7 percent of the homes were leaking more than 34 gpcd. This variability suggests that leak reduction programs that target the homes with the highest leakage rates would be the most cost-effective for a water supplier.

Water suppliers can employ several methods to detect homes with high rates of leakage, including:

- Developing water budgets. Homes with leaks will exceed their water budgets and pay excess use rates, thus encouraging repair.
- Installing advanced metering infrastructure (AMI). AMI monitors water usage in real time, sampling hourly to every 15 minutes. Because of the frequent monitoring and collection of water use data, a constant flow (leak) can be detected quickly and efficiently. (For a case study, see Box 3-5.)
- Identifying excessive water users (by comparison of water bills with similar properties) and offering water audits to these customers.

If leaks were to be detected and repaired at homes with high leak rates, so that the average losses due to leaks were reduced to the median values (1.4-3.9 gpcd), the savings would be 6.0-7.5 gpcd (Pacific Institute 2003; Irvine Ranch Water District 2011).

Conservatively estimating that, on a statewide average, water agencies were able to work with their residential customers so that just less than half of this potential leakage could be detected and repaired, the savings would then be 3 gpcd.

Water agencies are also beginning to evaluate the water-saving potential of pressure regulating valve (PRVs) replacement programs. PRVs reduce water supply pressure, protecting home appliances, while decreasing excess flows through plumbing fixtures and leaks. PRVs are typically installed when the house is built and they generally last 8 to 12 years. Since PRVs are installed on the customer side of the meter, it is the customer's responsibility to maintain the PRV. Many water agencies already offer their customers information and technical assistance regarding PRV function and maintenance, and they are now beginning to consider additional programs to encourage PRV replacement.

Showers

Showers account for about 22 percent of indoor residential use, equivalent to about 11.8-13.5 gpcd.

A study by Irvine Ranch Water District (2011) found that nearly 80 percent of all homes had showerheads operating at 2.5 gallons per minute (gpm) or less (the federal standard, as specified

Box 3-5 Case Study: City of Sacramento Advanced Metering Infrastructure

After installing advanced metering infrastructure (AMI) in more than 17,600 residences, the City of Sacramento reported the following successes during the two-year period of 2010-2011:

- 1,076 single-family homes showed leak alerts.
- 75 percent of leaks were verified in the field.
- 367 million gallons of aggregate annual water loss were calculated through AMI reports.
- 236 million gallons of water were saved, which equates to 12.6 gallons per capita per day.

AMI can play a major component in helping the City of Sacramento reach the State mandate of a 20-percent per-capita reduction by 2020.

2011 California Urban Water Conservation Council Advanced Metering Infrastructure Symposium, Sacramento

by the Energy Policy Act of 1992). WaterSense-rated showerheads have a maximum flow rate of 2.0 gpm or less, producing even greater savings. Further savings in shower water use can be achieved by continued retrofitting of inefficient shower heads and public education campaigns that include messages to take shorter showers.

The 20x2020 Plan estimates that the potential water savings remaining to be captured in shower water use are roughly 1 gpcd.

Faucets

Faucets account for about 18 percent of indoor use, approximately 11-12 gpcd.

The maximum flow rate for new faucets, set by federal standards in 1994, is 2.5 gpm, though some faucets, especially bathroom faucets, can operate as low as 0.5 gpm. The 1997 AWWA Research Foundation study estimated a 50-percent penetration of 2.2-gpm faucet aerators.

Savings in faucet water use can be achieved by continued retrofitting with low-flow fixtures and aerators and public education campaigns that include messages to "turn off the tap" when water is simply going down the drain. (See Box 3-6 regarding the use of sub-metering to encourage conservation in multi-family dwellings.)

The *California Single Family Home Water Use Efficiency Study* (Irvine Ranch Water District 2011) assumes a reduction of 10 percent in faucet water use (11.5 gpcd times 10 percent = 1 gpcd). This equates to a savings of 1 gpcd.

Total Projected Savings for Indoor Residential

The statewide average baseline water use for indoor residential is estimated at 71 gpcd. This is derived as follows: Baseline indoor residential use is 2.7 maf (see Table 3-2), divided by a 2000 population of 33,780,000 and then converted to gallons per capita per day (gpcd). An East Bay Municipal Utility District pilot project used a new behavioral approach to encourage conservation (see Box 3-7).

Box 3-6 Multi-Family Dwellings and Sub-Metering

Multi-family units are often served by a single water meter, and the water bill is included as a fixed part of a tenant's rent payment. This makes tracking individual tenants' water use virtually impossible and removes the consumers' incentive to conserve water in response to a high water bill.

When each dwelling unit within a multi-family property is individually metered, this is called sub-metering. A 2004 study (Aquacraft and East Bay Municipal Utility District 2004) found water savings of 15.3 percent when comparing sub-metered properties with rental properties that do not bill water separately from rent.

There are, however, numerous obstacles to capturing these savings, even in new buildings. Meter installation may lead to unacceptable pressure drop at some locations, and vertical plumbing layouts that supply water to each unit through multiple locations may make installation of traditional in-line water meters impractical. Important consumer protection issues must also be addressed if the interests of occupants dealing with water billing service companies are to be fully protected.

Sub-metering in multi-family dwellings could present an opportunity for significant water conservation in the future.

Adding the savings from each of the fixtures and appliances above, total projected water savings for indoor residential use is 15 gpcd, equating to an annual statewide reduction of 739,000 af by 2020. (See Table 3-3.)

Commercial, Industrial, and Institutional Sectors

The CII sectors cover a broad range of water uses, from schoolyard playgrounds and drinking faucets to bottling plants and restaurants. It is, therefore, a challenge to address these sectors, whether trying to make broad generalizations about CII water use as a whole or trying to drill down and find detailed data on any particular use. The State does not currently have the data necessary to establish the baseline of use in each CII subsector, and the information needed to estimate statewide savings must await the development of baselines and metrics.

The CII sectors (not including large landscapes) use about 20 percent of urban water, which equates to 1.7 maf per year, or approximately 48 gpcd (California Department of Water Resources 2009, 2014; Pacific Institute 2003; 20x2020 Agency Team on Water Conservation 2010).

If water used for large landscapes is added to CII water use, the total CII water use would then be approximately 30 percent of urban water use. The 30-percent figure is often quoted for CII water use. However, water use for large landscapes will not be discussed in this section, as it has been addressed in the "Landscape Irrigation" section earlier in this chapter. The CII landscapes with mixed-use meters (indoor and outdoor use on one meter) are included in this section, because they are distinctly different from large landscapes, such as parks and golf courses.

Commercial, Industrial, and Institutional Water Uses

There are limited centralized data concerning how much water is used in the CII sectors. Data on the numerous end uses are even more scattered. However, water uses within the CII sectors

Table 3-3 Potential Savings for Indoor Residential Water Use

Use	Savings
Toilets	5 gpcd[a]
Showers	1 gpcd[a]
Leaks	3 gpcd[c]
Faucets	1 gpcd[b]
Clothes washers	5 gpcd[a]
Total	15 gpcd

Notes:

gpcd = gallons per capita per day.

[a] Source: 20x2020 Agency Team on Water Conservation 2010.

[b] Source: Irvine Ranch Water District 2011.

[c] Sources: Derived from Irvine Ranch 2011 and Pacific Institute 2003.

can be grouped into the following common uses (Pacific Institute 2003; California Department of Water Resources 2014): process, restrooms, cooling, landscaping, kitchen, and laundry. With the exception of process water use, these end uses are very similar among CII users (see Box 3-8 regarding process water use).

- Process — Process water inefficiencies include poorly adjusted equipment; leaks; use of outdated technology or equipment that is not water-efficient, or both; and use of potable water where alternatives, such as recycled or reused water, or waterless processes may be appropriate.
- Restrooms — Restroom usage is one of the higher end uses in CII. Inefficiencies in this area are similar to those in the residential sector; these include older toilets with high-volume flush rates and high-volume faucets. Waterless and low-flow urinals are components unique to the CII sectors, and these have brought significant savings to CII customers.
- Cooling — Water is used for cooling heated equipment, cooling towers, and air conditioning. Inefficiencies include improper adjustments made by system operators; system leaks; and the use of older, inefficient equipment.
- Landscape — Inefficiencies in CII landscape, as with other landscapes, include poorly designed and maintained irrigation systems, excessive watering schedules, and landscape designs that rely on high-water-using plants, especially cool-season turf, where low-water-using plants could provide the same benefit.
- Kitchen — The majority of the water used in the kitchens is for pre-rinsing, washing dishes and pots, making ice, preparing food, and cleaning equipment. Pre-rinse spray-valve retrofit programs have been, and continue to be, effective water efficiency programs. Inefficiencies in kitchen water use include usage of old machines, high-volume spray valves, and cooking practices and techniques.
- Laundry — Water savings can be achieved through use of more efficient washers.

Box 3-7 Behavioral Water Efficiency — A New, Proven Conservation Tool

In addition to using conservation rate structures to incentivize water conservation, some water suppliers are using a new behavioral approach to encourage conservation. Based on insights from psychological research, behavioral water efficiency programs inform consumers of prevailing social norms, such as the average water use of neighbors, to drive conformity to a more efficient standard. This comparison creates a social framework in which water conservation is seen as highly valued by residents of a community.

The effectiveness of behavioral water efficiency programs has been tested in several communities, including in an East Bay Municipal Utility District pilot project. In this pilot, residents received home water reports with information about their water consumption, the consumption of similar households, and personalized recommendations on ways to save. The year-long pilot project involved 10,000 homes and a randomized control group. Households that received the home water reports reduced their water use from 4.6% to 6.6%, were more likely to participate in utility audit and rebate programs, and reported higher customer satisfaction. The unit cost of saved water was between $250 and $590 per acre-foot, with a mid-point cost of $380 per acre-foot.

Water Recycling and Reuse in the Commercial, Industrial, and Institutional Sectors

The use of recycled water (treated municipal effluent) or the reuse of process water within an industrial facility can play an important part in reducing CII water demand. With appropriate management, many non-potable water uses can be supplied with these alternate sources, such as cooling, washing, irrigation, and toilet flushing.

Recycled water provides 209,500 af of fresh water a year to CII sectors, including power plants. Saline water use from coastal sources also provides additional water primarily to the mining and steam electric power plants, estimated at 14.5 maf per year (California Department of Water Resources 2014).

Water reuse opportunities exist in almost all industrial plants and are a growing focus of industry. Water reuse can range from reusing relatively clean rinse water for initial washing processes to the capture of rainwater or air conditioning condensate for use in irrigation or a cooling tower.

Water Agency Actions

Each water agency will face a unique blend of CII customers and will need to tailor the implementation of their CII water conservation program to fit local needs and opportunities. However, certain actions will assist water agencies in increasing CII water use efficiency to meet 2020 targets. These include identifying the highest users of CII water within the agency and offering or otherwise supporting water use surveys for these customers, continued and more aggressive conversions of mixed-use meters to dedicated landscape meters, and continued retrofitting of older toilets to ULFT and HET.

Commercial, Industrial, and Institutional Task Force

In response to the complexity of the CII sectors and the lack of data available on CII water use, the SB X7-7 legislation called for a Commercial, Industrial, and Institutional Task Force (CII Task Force) to address CII water use efficiency, including development of alternative BMPs and metrics for water use in CII sectors, as well as identifying barriers to the use of recycled

Box 3-8 **The Value of Landscape Water Budgets**

Process water is water used by industrial water users for producing a product or product content, or water used for research and development. Process water is highly specific to each industrial user.

Process water, within certain parameters, may be excluded from calculations of baselines and targets in order to avoid a disproportionate burden on another customer sector.

California Code of Regulations, Title 23, Section 596

water. The CII Task Force wrote a report of its findings and recommendations to the Legislature (California Department of Water Resources 2014).

Assessment for Appropriateness of Best Management Practices

The CII Task Force identified a wide range of BMPs for use in the CII sectors. All of these BMPs are technically feasible and cost-effective in certain situations; however, the appropriateness of using any single BMP must be assessed for each site by the site operator or owner. The CII water user would need to conduct an audit of the site to determine which BMPs would be technically feasible and conduct a cost/benefit analysis to determine whether it is cost-effective to implement the BMPs. Organizations representing business and industry, water suppliers, the CUWCC, and DWR should educate CII businesses on the BMPs and approaches to doing audits and a cost-effectiveness analysis.

Commercial, Industrial, and Institutional Task Force Recommendations

The CII Task Force draft report (California Department of Water Resources 2014) includes the following recommendations:

- **Best Management Practices**
    - All stakeholders should endorse and adopt a formal process and commit to ongoing support for CII water conservation measures..
    - Technical and financial assistance and advice should be provided to those implementing the BMPs.
    - Local, sector-specific, and statewide approaches should be developed to track the success and effectiveness of BMP implementation.
    - CII water users should perform audits to identify opportunities for implementing all cost-effective BMPs.
- **Metrics and Measuring Progress**
    - CII establishments should use metrics to improve and track their water use efficiency over time.
    - Tools, guidance, and training should be provided to constituents and customers on the establishment and use of metrics-based benchmarking.
    - Efficiency standards should be set for certain water use devices.
    - Data should be collected on market penetration levels for particular devices and practices for which water use efficiency standards exist.

- **Recycled and Alternative Water Use**
  - Improve statutory and regulatory requirements to overcome barriers to the use of recycled water in a manner that is protective of public health and the environment.
  - Encourage financial and technical assistance to increase recycled and alternative water use.
- **Legislative Opportunities**
  - Provide the State with a mechanism and authority for collecting water use data for the purpose of tracking the progress of CII water use.
  - Promote plumbing code updates to encourage development and use of alternative water supplies and implementation of cost-effective BMPs.

(See Box 3-9 for information regarding how California prisons managed to become a water conservation model.)

Projected Commercial, Industrial, and Institutional Savings

Because of the lack of sufficient water use data for the CII sectors, and the fact that water conservation potential varies greatly among technologies, industries, and regions, determining a value for projected savings is challenging.

However, the SB X7-7 legislation and the CUWCC MOU both point to a target savings in the CII sectors of 10 percent from the baseline. In order to maintain consistency with the legislation and the MOU, DWR will also use the value of 10 percent to project CII water savings.

These potential CII water savings exclude savings from large landscapes, which are included in the "Large Landscapes (Dedicated Meters)" portion of this chapter.

The statewide average baseline water use for CII is estimated at 48 gpcd. This is derived as follows: Baseline CII water use is 1.7 maf (see Table 3-2), divided by a 2000 population of 33,780,000 and then converted to gallons per capita per day (gpcd).

Potential water savings for CII use is estimated at 10 percent, which is approximately 5 gpcd, equating to an annual statewide reduction of 170,000 af by 2020.

Water Loss Control in Distribution Systems

This section addresses water loss due to leaks in the distribution system of a water supplier. Leaks in the residential and CII sectors are addressed in their respective sections of this chapter.

Water loss control consists of the auditing of water supplies and implementation of controls to keep system losses to a minimum. A report by Southern California Edison (2009) estimated that 10 percent of the total volume of water supplied statewide is lost to leaks, which equals 0.88 maf. Addressing this loss is a major challenge to water suppliers, many of whom have aging water distribution systems in need of repair yet lack adequate funding for extensive water main replacement.

Box 3-9 California Prisons Reduced Annual Water Use by 21 Percent

By implementing a water conservation program, the California Department of Corrections and Rehabilitation (CDCR) achieved an annual water use reduction of 21 percent. The CDCR's water conservation program began in 2006, ramped up in 2008 in response to the drought declaration, and achieved a 21-percent reduction by 2009.

CDCR headquarters issued a document titled Best Management Practices Water Management & Conservation, which covered:

- Eliminating nonessential water use.
- Water-efficient landscaping and irrigation.
- Leak detection and repair.
- Laundries and vehicle washing.
- On-site water consumption surveys.

The CDCR enacted the following measures:

- Toilet flush meters were installed in nearly one-third of all adult institutions.
- Institutions report monthly water consumption to CDCR headquarters.
- Enacted low- or no-cost water conservation methods.

California Department of Corrections and Rehabilitation 2009

Audits

Water auditing is crucial to identifying the economically viable options that can be implemented for water loss control. Water utilities that do not perform water audits are most likely to be unaware of the level of real losses in their systems, making it unlikely for them to implement practices to curb these loss volumes.

A new standard method for conducting water audits was co-developed by the American Water Works Association (AWWA) and the International Water Association (IWA). The AWWA/IWA water audit method is effective because it features sound, consistent definitions for the major forms of water consumption and water loss encountered in drinking water utilities. It also features a set of rational performance indicators that evaluate utilities on system-specific attributes, such as the average pressure in the distribution system and the total length of water mains.

The AWWA/IWA water audit method is detailed in the AWWA's manual *Water Audits and Loss Control Programs* (2009). The AWWA also offers free software for this auditing method that assists in tracking water consumption and losses and calculates the costs of losses, giving agencies important information for assessing the cost-effectiveness of leak reduction measures.

This new standard water audit is now a requirement for implementation of the California Urban Water Conservation Council's MOU. All water agencies that are members of the CUWCC, as well as any agencies that seek funding from the State of California, are obligated to complete the standard water audit annually, to improve the quality of data collected on water loss, and to reduce water losses to the extent that is cost-effective.

Trenchless Pipe Repairs

Repairing leaky pipes can be an expensive and difficult proposition for agencies. Trenchless pipe repair is an emerging, cost-effective technology that offers an efficient alternative in pipe repair. Using this new technology, the damaged pipe is lined with a new cured-in-place pipe that seals all cracks, splits, and faulty joints. This trenchless technology requires no trenching or digging and can be done in much less time without large excavations, saving money, time, and labor and making repairs and maintenance more cost-effective.

Meters

Measurements of water use are a necessary component in developing water budgets and detecting leaks. Consumers and water agencies are aware of water use when it is being metered and monitored. The water use data can be mapped for trends to detect water loss.

The 2010 DWR Public Water Systems Statistics estimates that 6 percent to 7 percent of connections in California are still unmetered. There are huge potential savings by metering water use. The CUWCC, in its memorandum of understanding (MOU), BMP 1.3, estimates a 20-percent savings when water meters are installed (California Urban Water Conservation Council 2009).

As of 2012, the California Water Code required full metering for customers of all urban water suppliers served by the federal Central Valley Project (CVP) by 2013. Full metering is required by 2025 for customers of all other urban water suppliers with unmetered service connections.

Although water meters aid in preventing water loss, a recent study by the U.S. Environmental Protection Agency (EPA) and the Water Research Foundation (2011) shows that water meters in service lose their accuracy through use. Low flows of 1/8 gpm may go unrecorded by meters that are set to run at 1/4 gpm. Water meters often need to be recalibrated and checked. Higher accuracy standards should also be considered to capture a greater share of low flows that are indicative of leaks.

Projected Savings

The statewide average baseline water loss is estimated at 13 gpcd. This is derived as follows: Baseline losses are 0.5 maf (see “Other” in Table 3-2), divided by the 2000 population of 33,780,000, and then converted to gpcd.

Given that the estimated water loss in California is 0.5 maf, and that 40 percent of that is estimated to be economically recoverable, the calculated water savings from cost-effective water loss control (0.5 maf times 40 percent) is 200,000 af, or 5 gpcd.

Combined Demand Reductions

Combining the estimated demand reductions from each sector, as detailed in the preceding paragraphs, the State of California could theoretically reduce demand for potable water in the year 2020 by more than 2 million af (Table 3-4).

Table 3-4 Projected Savings by Sector[a]

Demand Reduction Sectors	Reduction	Projected Savings in 2020
Large landscape	3 gpcd	148,000 af
Commercial, industrial, and institutional	5 gpcd	170,000 af
Residential indoor	15 gpcd	739,000 af
Residential landscape	16 gpcd	789,000 af
Water loss control	5 gpcd	200,000 af
Total	**44 gpcd**	**2,046,000 af**

Notes:

af = acre-feet, gpcd = gallons per capita per day

[a] The figures in this table are a summary of projected savings that are detailed in preceding pages.

Alternative Water Sources — Recycled Water, Desalinated Water, Gray Water, and Rainwater

Alternative water supplies are expected to further reduce statewide demand of potable water by the year 2020.

Alternative water sources vary in water quality, level of treatment, local availability, and suitability for intended uses. Recycled water and desalinated water undergo the highest level of treatment prior to use and are discussed in detail in Chapters 12 and 10 of Volume 3.

Residential rainwater capture and gray water reuse are sources of water that can be used without the high investment in infrastructure that recycled water or desalinated water require.

Rainwater capture is discussed at length in Chapter 20, "Urban Stormwater Runoff Management," but it should be mentioned here that on-site rainwater capture, in the form of rain gardens, bioswales, pervious surfaces, and other landscape features, can reduce the amount of potable water needed for irrigation by replenishing soil moisture levels and shortening the irrigation season. A small to moderate-sized rain garden can collect thousands of gallons of water. For example, a demonstration rain garden at the Richardson Bay Audubon Center & Sanctuary in Marin County (Salmon Protection and Watershed Network 2010) can collect nearly 3,900 gallons of water in a 315-square-foot rain garden with approximately 22 inches of annual rainfall.

Although there is tremendous interest in rainwater capture with rain barrels and cisterns, California's dry summer climate brings into question the cost-effectiveness of small rain capture devices in many regions of the state. However, cisterns and other large-volume storage devices begin to become cost-effective in areas where the rainy season extends into the irrigation season or where supplied water is very expensive, unreliable, or difficult to convey. Unlike rainwater capture for irrigation, in which supply availability and demand are out of sync, rainwater capture for year-round indoor non-potable uses, such as toilet flushing, may be the most practical application. Rainwater standards are printed in the 2013 California Plumbing Code.

During the 2013 triennial code cycle, gray water standards were revised by the California Building Standards Commission (CBSC) and the Department of Housing and Community Development (HCD) and were organized in Chapter 16 of the California Plumbing Code. Gray water use will increase over time, partly due to changes in the gray water standards. The revised standards make it easier for a water user to install a gray water system; simple systems supplied by clothes washers or single fixtures do not require a building permit if certain conditions are met.

In its 2010 UWMP, the Los Angeles Department of Water and Power features a case study of alternative water use by one of its residential customers. In addition to collecting rainwater in 18 rain barrels, the customer installed a gray water system using the waste water from her clothes washer. The clothes-washer-supplied gray water system generates approximately 7,000 gallons of water per year by the family of three. By adding the shower and bathroom sink to the gray water system, the water generated for landscape irrigation could exceed 53,000 gallons of gray water per year.

The *California Single Family Home Water Use Efficiency Study* (Irvine Ranch Water District 2011) found that the annual estimated irrigation demand averages about 90,000 gallons per year at the homes studied. Based on this assumption, this family could offset nearly 60 percent of its irrigation demand by the expanded gray water system. Under the new gray water standards, a plumbing permit is not required if the plumbing is not altered and if health and safety conditions are met.

The Importance of Conservation Rate Structures

Conservation rate structures are rates set by water agencies to provide price signals to consumers and encourage water conservation. Conservation rates are also known as volumetric rates, because the customer bill reflects the volume of water used. These structures can be applied to water supply as well as wastewater (sewer) services. (See Box 3-10, “Consumption-Based Fixed Rates, City of Davis.”)

Properly constructed rates can be significant in motivating customers to save water. When determining conservation rate structures, water suppliers must also ensure revenue stability. This is done through a combination of variable and fixed revenues, which ensure that adequate funds are provided to operate and maintain the system even when water use is declining.

Some examples of conservation rate structures are listed below.

- Increasing block tier structures: The cost per unit of water increases as the consumer uses more water.
- Seasonal rates: Water rates are set higher during the summer months, when peak usage occurs.
- Water budget structures: Each residence has an inclining block rate structure designed according to the number of occupants, landscape area, local climate, and possibly other factors. The prices of the tiers increase significantly after the base usage tier has been reached.
- Water budgets with punitive tiers when budgets are exceeded: Often the revenue generated from punitive tiers is used to fund the conservation programs.

Box 3-10 Consumption-Based Fixed Rates, City of Davis

Volumetric water rate structures provide a strong conservation incentive to customers. However, changes in customers' water use can cause a water supplier's revenue to vary, making it difficult to cover fixed costs.

Beginning in January 2015, the City of Davis will begin implementing an innovative rate structure, known as "consumption-based fixed rates." This structure introduces a method that provides revenue stability for the water agency, regardless of the volume of water sold, while also providing a conservation price signal to its customers.

This unique rate structure divides the agency's fixed costs proportionally among all its customers, based on the customers' peak use the previous year. Customers who have implemented conservation measures and reduced their water use will lower the fixed charge on their bill. The agency's variable costs are covered by including a volumetric charge on customers' bills.

More information about Consumption-Based Fixed Rates can be found at http://cwee.ucdavis.edu/projects/CBFR.

Flat rates, where customers' bills do not reflect the volume of water used, are not considered conservation rates because they do not send a price signal to the consumer and do not encourage conservation. (For information on one successful conservation rate structure, see Box 3-11.)

Conservation Rate Structures for Wastewater Services

Although roughly 90 percent of California households served by a public water supplier pay for drinking water through a volumetric rate, about 70 percent of such California households pay for sewer service through a flat, non-volumetric charge. And sewer charges can be significant: In some jurisdictions sewer charges can be equal to, or greater than, water charges. By billing sewer service at a flat rate, the price signal rewarding water efficiency is being cut in half for a majority of California households.

Water efficiency can reduce future infrastructure requirements for sewer service, and volumetric pricing for sewer service is encouraged by the EPA, the Water Environment Federation, and the CUWCC.

Installation of new hardware is generally not required in order to begin volumetric billing for wastewater, but where water and sewer are provided by different agencies, interagency cooperation is needed, and billing software modifications are likely (Chesnutt et al. 1994). Volumetric wastewater pricing requires access to metered water consumption records and the ability to generate a customer bill. Sewer agencies currently billing fixed charges on a combined water-wastewater bill would have the fewest implementation constraints. A sewer agency whose service area cuts across multiple water agency service area boundaries would face more implementation challenges.

A 2011 report (A&N Services Inc. 2011) presented a roughly 4-percent reduction in residential water use, with a 10-percent sewer service rate increase.

Box 3-11 Successful Conservation Rate Structure: Irvine Ranch Water District

The rate structure at the Irvine Ranch Water District (IRWD) signals customers when they are exceeding their water budget and signals the IRWD about which customers are in need of attention.

The IRWD sets water budgets for each customer based on a variety of factors, such as the size of a landscape area, the weather, the number of residents, or the industrial or commercial business types. When a customer exceeds his or her water budget, the price per unit of water becomes more expensive. By taking these factors into consideration, the IRWD is able to customize the water budget for each customer and ensure a fair allocation.

The IRWD also charges a monthly fixed charge based on meter size. The fixed charge covers all operating costs and related water-use efficiency programs. The IRWD operates with a stable revenue stream despite variability in the volume of water sold.

Potential Benefits

Urban Water Use Efficiency

Using water efficiently yields multiple benefits, including:

- Increased reliability of water supplies.
- Increased capacity to meet the growing water demand of California's increasing population.
- Delayed capital costs for new infrastructure to treat and deliver water.
- Reduced contaminated irrigation runoff to surface waters (refer to Box 3-12).
- Reduced volume of wastewater, thus reducing capital costs and ongoing treatment costs.
- Increased availability of water for surface or groundwater storage.
- Reduced water-related energy demands and associated greenhouse gas (GHG) emissions.

Climate Change

Urban water suppliers and water users may be particularly vulnerable to changes in climate because they require highly reliable water supplies and because demands for water tend to grow over time with population. While some agricultural water users may be able to temporarily reduce water use by fallowing land or changing cropping patterns, urban water uses tend to have much less flexibility. Urban water use efficiency provides a key strategy for addressing these vulnerabilities.

Key impacts of climate change that relate to urban water supplies include:

- Warming temperatures, increasing water usage, particularly for outdoor irrigation.
- Decreasing snowfall, reducing the natural water storage found in the Sierra Nevada snowpack.
- Precipitation shifting from snow to rain, requiring a change in water supply management.

Box 3-12 Reducing Irrigation Runoff Helps Local Waterways

Improving irrigation efficiency will prevent irrigation runoff, saving both water and energy and preventing the contamination of receiving waters by landscape pesticides, fertilizers, pet wastes, and sediment.

Sampling of the water quality in urban streams throughout California has found the universal presence of common landscape pesticides, such as diazinon, fipronil, chlorpyrifos, bifenthrin, among others. When excess irrigation water is applied, these pesticides, as well as herbicides, fertilizers, other nutrients, and pathogenic organisms, are washed into the stormwater system and local watersheds. These contaminants are toxic to aquatic organisms.

Dry-season irrigation runoff can be prevented by irrigation system maintenance, proper irrigation scheduling, and landscape design. Irrigation scheduling should be appropriate for the site conditions, when factoring in slope, soil type, and the ability of the soil to absorb the water. Incorporation of rain gardens and vegetated swales into a landscape design will also retain runoff from irrigation and rainwater, reducing negative impacts on local waterways.

- Rising sea levels:
  - Threatening water supply infrastructure in coastal communities.
  - Increasing seawater intrusion into coastal freshwater aquifers.
  - Reducing water exports from the Delta.
- Increasing frequency of floods, droughts, and wildfires damaging watersheds that provide water to urban communities.

To help address these climate-related challenges, State and federal agencies have developed several programs that provide guidance and information to urban water suppliers. In 2011, the DWR, the EPA, the U.S. Army Corps of Engineers, and the Resources Legacy Fund cooperatively developed *Climate Change Handbook for Regional Water Planning* (online at http://www.water.ca.gov/climatechange/CCHandbook.cfm), which provides a comprehensive resource for regional water managers but includes information that will be useful to urban water managers as well. Even more focused on urban water providers is the U.S. EPA's Climate Ready Water Utilities program (online at http://www.epa.gov/infrastructure/watersecurity/climate.index.cfm), which provides guidance and tools specifically for water utilities to incorporate climate change into their planning and operations.

Adaptation

Water conservation and water use efficiency are considered primary climate change adaptation strategies — those that should be undertaken first because they are generally lower-cost and provide multiple benefits. By implementing practices that make the most of available water supplies, practices that reduce waste and increase efficiency, the urban water use sector will be better equipped to adapt to potential reductions in water supply.

Mitigation

Supplying and treating water for urban use requires a high amount of energy, which in turn contributes to greenhouse gas emissions and climate change. Reducing the amount of water used in the urban setting reduces the energy used, thus mitigating impacts to climate change. Urban water use efficiency is both a mitigation measure and an adaptation measure for climate change. Box 3-13 highlights the connection between urban water use, energy, and greenhouse gases.

Potential Costs

Increasing the supply of water has the same effect on water availability as decreasing the demand for water (through increased efficiency). However, historically reliable methods for increasing supply, such as building new dams for surface storage, or increasing water exports from the Delta, are less certain as California moves into the future. Many water suppliers are turning to other strategies, such as improving efficiency, to meet increasing demand. And as the costs for increasing water supply go up, even the more expensive conservation strategies may become economically viable in the future.

Table 3-5 shows some examples of costs for water use efficiency practices. These costs will vary from supplier to supplier, but they are provided here as an illustration of what can be reasonably expected.

It is conservatively estimated that a well-implemented set of water conservation programs would cost a water supplier an average of $333-$500 per acre-foot (Alliance for Water Efficiency 2008). (For the relative costs of six alternative water solutions, including conservation, using the San Diego area as an example, refer to Box 3-14.)

There are other important water conservation programs that cannot be quantified in terms of cost per acre-foot of water saved. These include designating and supporting a water conservation coordinator, implementing education and outreach programs, using water conservation rate structures, and developing and implementing a water waste prohibition ordinance.

Major Implementation Issues

Reduced Water Agency Revenue for Water Conservation

Because of the economic downturn, many water agencies have reduced their staff and other expenditures for water conservation. This reduction comes at a difficult time, when water agencies will need to increase, or at least maintain, the level of conservation in their districts in order to meet the 20-percent reduction by 2020.

Rate Structures and Water Agency Revenue

Providing customers with correct price signals to use water efficiently is not a simple task. The appropriate signals may vary from agency to agency and from community to community. And if the price structure is not set up correctly, the resulting water conservation can negatively

Table 3-5 Sample Costs of Water Use Efficiency to Water Suppliers per Acre-Foot of Water Saved

Program Types	Sample Costs per Acre-foot
Residential programs[a, b, c, d, e]	Toilet rebates: $158-$475/af Residential audits: $236-$1,474/af Clothes washer rebates: $154-$480/af
Landscape programs[a, b, d, e]	Landscape audits: $58-$896/af Equipment rebates: $15-$181/af Turf removal: $274-$717/af Water budgets: $10-$59/af
Commercial, industrial, and institutional (CII) programs[b, c, f, g]	Toilet rebates: $242-$1,018/af Urinal replacement: $320-$583/af Pre-rinse spray valves: $78/af
Utility operations programs [d, h]	System audits/leak detection: $203-$658/af

Notes:

af = acre-foot

[a] Source: City of Paso Robles 2010

[b] Source: Los Angeles Department of Water and Power 2010

[c] Source: California Urban Water Conservation Council 2004, 2005a, 2006, 2007a

[d] Source: Marin Municipal Water District 2010

[e] Source: City of Sacramento 2010

[f] Source: East Bay Municipal Utilities District [date unknown]

[g] Source: Alliance for Water Efficiency 2012

[h] Source: California Urban Water Conservation Council 2007b

affect the amount of revenue collected by a water supplier. The less water customers use, the less revenue the water supplier receives, which creates a disincentive for the water agency to encourage conservation. Also, because of seasonal variation in water use, some price structures may increase variability and fluctuation of water utility revenues.

This problem poses a hardship on the utility's ability to meet its revenue requirements and can undermine the financial viability of their systems and the ability to meet service needs and infrastructure maintenance.

The process for changing rate structures can also be challenging in and of itself. Regulations impose certain limitations, public support can be difficult to gain, and water board elections may influence the willingness of board members to agree to rate changes.

Box 3-13 Climate Change and Water Use Efficiency: The Energy-Water Nexus

California's energy and water resources are entwined. Energy is used to transport, pump, heat, cool, treat, and recycle water. And water is used to generate hydroelectricity and to cool power plants.

According to the report *California's Water-Energy Relationship* (California Energy Commission 2005), water-related energy use consumes about 19 percent of California's electricity, 88 billion gallons of diesel fuel, and 30 percent of non-power-plant natural gas, which together equate to about 12 percent of total statewide energy use. Urban and industrial water use, including conveyance, treatment, distribution, and end uses, account for about 11 percent of statewide energy use (the other 1 percent being related to agricultural water use).

When water is used efficiently, there is a corresponding savings in energy. Also, because most energy production creates greenhouse gases that contribute to climate change, water use efficiency is a method for mitigating climate change.

In 2004, California Urban Water Conservation Council members who implemented the council's best management practices reported a savings of 27 billion gallons of water. This significant water savings also saved more than 234 million kilowatt-hours of electricity and an estimated $200 million in energy costs.

Lack of Public Awareness Regarding Landscape Water Use

Most homeowners are not aware that the majority of their water use takes place in the landscape, nor are they aware that much of that irrigation water is used inefficiently. In the 2007 *Statewide Market Survey: Landscape Water Use Efficiency* (California Urban Water Conservation Council 2007c), the researchers found that most respondents either had no idea how much water they used in their landscapes, or they believed their water use was below the statewide average. Coupled with the tendency to leave irrigation controllers on the default setting year round and a lack of irrigation system maintenance, a statewide education campaign is needed to educate water users and increase awareness of meaningful actions that will save water in landscapes.

Landscape Area Measurement for Water Budgets

Knowing the area of a landscape is critical to developing a water budget for the site. A water budget, in turn, will assist in determining whether the landscape is being watered efficiently.

Many water suppliers have not determined the extent of landscape area in their service area. Impediments to measuring or estimating landscape area include the high cost of physically measuring the site or purchasing satellite imagery, a lack of expertise in utilizing available satellite data, linking the parcels with customer data, segregating areas served by multiple meters, and assessing the density of vegetated canopies.

Inconsistent Implementation of the Model Water Efficient Landscape Ordinance

By the end of 2010, 333 local land use agencies had reported on the status of adoption of water efficient landscape ordinances. However, it is not known how consistently local agencies enforce water efficient landscape ordinances. Local agencies are challenged by the complexity of

Box 3-14 San Diego: Comparing Water Source Options

A 2010 study (Equinox Center 2010) comparing the marginal costs of six alternative water solutions for San Diego concluded that conservation was the most favorable and least costly option.

Table A Cost per Acre-Foot by Water Source

Water source	Cost per acre-foot
Imported water	$875-$975
Surface water	$400-$800
Groundwater	$375-$1,100
Desalinated water	$1,800-$2,800
Recycled water	$1,200-$2,600
Conservation	$150-$1,000

These costs were determined for the San Diego area and would vary for each individual water agency.

landscape and irrigation design requirements and a lack of staff to review and inspect landscape. The common disconnect between water suppliers and land use authorities further complicates the issue.

Data on Industrial Water Use Are Limited

The last survey published by DWR to obtain valid information on industrial water use (Bulletin 124-3) was conducted in 1979. This information is out of date, but no current data exist. The survey determined rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.

Water Loss

The amount of water lost due to leakage in the distribution system of the State's water suppliers is not well known. This is largely due to the fact that not all water suppliers perform regular water loss audits. If water audits are not conducted, it is difficult for a water agency to know the extent of its losses and unlikely that the agency will implement practices to reduce these losses.

Lack of a Standardized Efficiency Measure for California Urban Water Suppliers

One of the limitations to the development of the 20x2020 Plan goal was the lack of an effective measure of the level of water use efficiency in a supplier's service area. The gpcd is useful to track changes in water use in individual water agencies over time, but due to differences in landscape area, climate, and CII water use it is not useful as measure of efficiency. The lack of a standard measure of supplier efficiency is one reason that four different methods for setting a 2020 water use target were provided in the SB X7-7 legislation.

Recommendations

1. **Assist Utilities in Developing Sustainable Conservation Rate Structures** — DWR, in partnership with the CUWCC, the U.S. Bureau of Reclamation, the California Public Utilities Commission, the Association of California Water Agencies (ACWA), the California Water Association, and water agencies should lead an investigation to analyze and evaluate the effectiveness of rate structures in conserving water and meeting water agency revenue requirements. DWR should disseminate the findings and recommendations from the study, as well as guidance to water agencies, throughout the state by way of regional workshops and a detailed page on the DWR Web site.

2. **Expand the Save Our Water Campaign** — DWR, in coordination with ACWA, the CUWCC, water suppliers, local stakeholders, and irrigation manufacturers, should expand the statewide Save Our Water campaign. Initially, the landscape portion of the campaign should focus on cost-effective ways to improve irrigation system function and irrigation controller programming.

3. **Assist Water Agencies in Landscape Area Measurement and Water Budgets** — DWR, in coordination with the CUWCC, should assist water suppliers in finding easy and inexpensive ways to obtain landscape area data for parcels in their service areas and offer workshops that highlight successful programs. As a priority, water agencies should measure the landscape area for sites with dedicated meters first, because their landscape water use is known. A comparison of water use and water budget will determine if the landscape is being over-watered. Water agencies can then target the sites that are over-irrigating, a cost-effective method for reducing landscape irrigation demand.

4. **Increase Landscape Water Management Skills** — Water use efficiency is most easily achieved on landscapes with properly designed and installed irrigation systems and managed with water budgets. To make this possible, the Contractors State License Board should increase the emphasis and testing requirements in the C-27 Landscape Contractor's exam in the subject areas of irrigation design and installation and water budgeting to ensure landscape professionals have the needed skills. DWR, water suppliers, and the landscape industry should increase opportunities to improve water management skills of non-English-speaking workers and workers that do not hold a contractor's license.

5. **Update the Model Water Efficient Landscape Ordinance** — DWR should work with local agencies, local water suppliers, and the landscape industry to identify and remove barriers to implementation of the MWELO. The MWELO should be updated periodically based on new findings, innovation, and technological improvements.

6. **Encourage Innovation in Irrigation Equipment Design That Increases Durability, Reliability, and Ease of Use** — The irrigation manufacturing industry should work with the landscape industry, universities, and other industries to develop irrigation equipment, sensors, and controllers that are more durable and easier to install, maintain, and program.

7. **Update the Survey of Industrial Water Use** — Because the last published survey on industrial water use in California was conducted in 1979, and updated data are needed by local agencies and the State in order to better manage industrial water use, DWR

should update the survey of industrial water use, Bulletin 124-3. The survey should provide information on the rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.

8. **Require Water Audits in 2015 Urban Water Management Plans** — To reduce water loss in water distribution systems, the Legislature should revise the Urban Water Management Planning Act to require water suppliers to complete the AWWA auditing program and report their water audit, water balance, and performance indicator in their 2015 UWMPs. Signatories to the CUWCC MOU are already required to perform this audit annually. Water audit data reported to the CUWCC provided valuable information on the extent of water losses that can be economically recovered by the water agencies. More on the AWWA auditing program can be found at http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx.

9. **Develop a Standardized Efficiency Measure for California Urban Water Suppliers** — Through a public process, DWR should develop a standardized water use efficiency measure for California urban water suppliers. The measure would be used to determine efficient water use for urban water suppliers and would account for differences in irrigated landscape area, climate, population, and CII water use. The single standardized measure for supplier water use efficiency would better permit customers, utilities, and State officials to evaluate the efficiencies of California urban water suppliers across the state.

10. **Investigate Gray Water Use in New Residential Applications** — In cooperation with water suppliers and developers, DWR should conduct a pilot study of gray water installation in new homes. The study should evaluate gray water use in landscapes and the feasibility of installing gray water systems in new homes.

Other Related Resource Management Strategies

Chapters within this volume that relate to urban water use efficiency are listed below.

- Chapter 8, “Water Transfers.”
- Chapter 9, “Conjunctive Management and Groundwater.”
- Chapter 10, “Desalination — Brackish and Sea Water.”
- Chapter 12, “Municipal Recycled Water.”
- Chapter 15, “Drinking Water Treatment and Distribution.”
- Chapter 17, “Matching Water Quality to Use.”
- Chapter 20, “Urban Stormwater Runoff Management.”
- Chapter 24, “Land Use Planning and Management.”
- Chapter 25, “Recharge Area Protection.”
- Chapter 28, “Economic Incentives — Loans, Grants, and Water Pricing.”
- Chapter 29, “Outreach and Engagement.”

References

References Cited

20x2020 Agency Team on Water Conservation. 2010. *20x2020 Water Conservation Plan*. CA. Prepared by: California Department of Water Resources, State Water Resources Control Board, California Bay-Delta Authority, California Energy Commission, California Department of Public Health, California Public Utilities Commission, and California Air Resources Board, with assistance from California Urban Water Conservation Council and U.S. Bureau of Reclamation. Viewed online at: http://www.water.ca.gov/wateruseefficiency/sb7/docs/20x2020plan.pdf. Accessed: Feb. 15, 2013.

A&N Technical Services Inc. 2011. *Volumetric Pricing for Sanitary Sewer Service in the State of California*.

Alliance for Water Efficiency. 2008. *Transforming Water: Water Efficiency as Stimulus and Long-Term Investment*.

———. 2012. *Commercial Dishwashing Introduction*. Viewed online at: http://www.AllianceforWaterEfficiency.org/commercial_dishwash_intro.

American Water Works Association. 2009. *M36: Water Audits and Loss Control Programs*. Third Edition. Denver (CO).

American Water Works Association Research Foundation. 1997. *Residential End Uses of Water*.

California Department of Corrections and Rehabilitation. 2009. "California Prisons Reduce Water Consumption by 21 Percent Through Comprehensive Drought Response Plan." Sacramento (CA): California Department of Corrections. [Press release dated April 3, 2009.] Viewed online at: http://www.cdcr.ca.gov/News/Press_Release_Archive/2009_Press_Releases/April_03.html. Accessed: Feb. 15, 2013.

California Department of Water Resources. 2008. *White Paper: Evapotranspiration Adjustment Factor*. [Draft.] 18 pp. Viewed online at: http://www.water.ca.gov/wateruseefficiency/docs/etWhitePaper.pdf. Accessed: May 21, 2013.

_____. 2009. *California Water Plan Update 2009*. Bulletin 160-09. Volumes 2 and 5. Sacramento (CA): California Department of Water Resources. Viewed online at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm.

———. 2011. *Methodologies for Calculating Baseline and Compliance Urban Per Capita Water Use*.

———. 2012. *2010 Urban Water Management Plans. A Report to the Legislature*.

———. 2014. *Commercial, Institutional and Industrial Task Force Water Use Best Management Practices Report to the Legislature*. Sacramento (CA). Volumes 1 and 2.

California Energy Commission. 2005. *California's Water-Energy Relationship*.

California Landscape Contractors Association. 2003. *Urban CII Landscape Water Use and Efficiency in California*. Prepared by J Whitcomb, Ph.D.

———. 2012. Water Management Certification Program. Viewed online at: http://www.clca.us/water-pro/about-the-program-for-professionals.html. Accessed: Nov. 1, 2012.

California Urban Water Conservation Council. 2004. *Reports on Potential Best Management Practices*.

———. 2005a. *Reports on Potential Best Management Practices*.

———. 2005b. *Water Smart Landscapes for California, AB 2717 Landscape Task Force Findings, Recommendations, & Actions*.

———. 2006. *Reports on Potential Best Management Practices*.

———. 2007a. *Reports on Potential Best Management Practices*.

———. 2007b. *Draft Revision BMP Costs and Savings Study*.

———. 2007c. *Statewide Market Survey: Landscape Water Use Efficiency*. Prepared by: Institute of Applied Research and Water Resources Institute, at California State University, San Bernardino.

———. 2009. *Memorandum of Understanding Regarding Urban Water Conservation in California*. [Revised.]

———. 2010. *Interaction Among AB 715 (Laird), SB 407 (Padilla 2009), and CAL Green Building Standards: Assessing for Provisions of Water Use Efficiency Regulations*.

Chesnutt T, Bamezai A, WM Hanemann. 1994. *Revenue instability induced by conservation rate structures: an empirical investigation of coping strategies*.

City of Paso Robles. 2010. *Urban Water Management Plan 2010*. Appendix B. Paso Robles (CA).

City of Sacramento. 2010. *Urban Water Management Plan 2010*. Sacramento (CA).

East Bay Municipal Utilities District. [Date unknown.] *Pre-Rinse Spray Nozzle Program*. Viewed online at: http://www.ebmud.com/sites/default/files/pdfs/Pre-Rinse-Nozzle-Spray.pdf. Accessed: July 2012.

Equinox Center. 2010. *San Diego's Water Sources: Assessing the Options*.

Hanak E and Davis M. 2006. "Lawns and Water Demand in California." California Economic Policy 2(2). Public Policy Institute of California.

Irvine Ranch Water District. 2001. *Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine "ET Controller" Study*.

———. 2011. *California Single Family Home Water Use Efficiency Study*. Prepared by: DeOreo W, Mayer P, Martien L, Hayden M, Funk A, Kramer-Duffield M, Davis R, Henderson J, Gleick P, and Heberger M.

Los Angeles Department of Water and Power. 2010. *Urban Water Management Plan 2010*. Los Angeles (CA).

Marin Municipal Water District. 2010. *Urban Water Management Plan 2010*.

Mitchell, David L. and Thomas W. Chesnutt. *Evaluation of East Bay Municipal Utility District's Pilot of WaterSmart Home Water Reports, Prepared for the California Water Foundation and East Bay Municipal Utility District, December 2013*.

Municipal Water District of Orange County and Irvine Ranch Water District. 2004. *The Residential Runoff Reduction Study*.

Pacific Institute. 2003. *Waste Not, Want Not: The Potential for Urban Water Conservation in California*. Oakland (CA).

Salmon Protection and Watershed Network. 2010. *10,000 Rain Gardens Project. A report to the Marin Municipal Water District*.

Southern California Edison. 2009. *Secondary Research for Water Leak Detection Program and Water System Loss Control Study*. San Francisco (CA).

U.S. Environmental Protection Agency. 2008. *Water and Energy: Leveraging Voluntary Programs to Save Both Water and Energy*. Prepared by ICF International.

U.S. Environmental Protection Agency and the Water Research Foundation. 2011. *Accuracy of In-Service Water Meters at Low and High Flow Rates*.

East Bay Municipal Utility District and Aquacraft. 2004. *National Multiple Family Submetering and Allocation Billing Program Study*. Prepared by Mayer P, Towler E, DeOreo W, Caldwell E, Miller T, Osann E, Brown E, Bickel P, and Fisher S. Prepared for: U.S. Environmental Protection Agency, National Apartment Association, National Multi-Housing Council, City of Austin, City of Phoenix, City of Portland, City of Tucson, Denver Water Department, East Bay Municipal Utility District, San Antonio Water System, San Diego County Water Authority, Seattle Public Utilities, and Southern Nevada Water Authority.

Additional References

A & N Technical Service Inc. 2011. *Revenue Effects of Conservation Programs: The Case of Lost Revenue.*

Alliance for Water Efficiency. 2012. Alliance for Water Efficiency Web site. Viewed online at: http://www.allianceforwaterefficiency.org.

American Water Works Association. [Date unknown.] *Buried No Longer: Confronting America's Water Infrastructure Challenge.*

———. 2000. *Commercial and Institutional End Uses of Water.*

———. 2008. *Water budgets and rate structures: Innovative management tools.*

Brown C. 2007. *The Business Case for Water Conservation in Texas.*

California Urban Water Conservation Council. 1997. *Designing, Evaluating, and Implementing Conservation Rate Structures.*

Coachella Valley Water District. 2010. *Urban Water Management Plan 2010.*

Delta Vision Blue Ribbon Task Force. 2008. *Delta Vision Strategic Plan*. Strategy 4.1 October 2008.

Department of Agricultural and Resource Economics and Policy. 1993. *Revenue Instability Induced by Conservation Rate Structures: An Empirical Investigation of Coping Strategies*. Division of Agriculture and Natural Resources. Berkeley (CA): University of California, Berkeley.

East Bay Municipal Utilities District. 2009. *Conservation Evaluation.*

Eastern Municipal Water District. 2010. *Urban Water Management Plan 2010.*

Los Angeles County Economic Development Corp. 2008. *Where Will We Get Our Water? Assessing Southern California's Future Water Strategies.*

Maddaus L and Mayer P. 2001. *Splash or Sprinkle? Comparing the Water Use of Swimming Pools and Irrigated Landscapes.*

Metropolitan Water District of Southern California. 2010. *Integrated Water Resources Plan*. Technical Appendix, 2010 Update, Appendix A 7-1.

Metropolitan Water District of Southern California and East Bay Municipal Utility District. 2009. *Evaluation of California Weather-Based "Smart" Irrigation Controller Programs*. Prepared by: Mayer P, DeOreo W, Hayden M, Davis R, Caldwell E, Miller T, and Bickel P.

Municipality of Red Lake. 2007. *Water Meter Feasibility Study*. Ontario (Canada). Prepared by: Keewatin-Aski Ltd. Consulting Engineers and Architect.

Natural Resources Defense Council. 2004. *Energy Down The Drain: The Hidden Costs of California's Water Supply.*

Southern California Water Committee. 2012. *Stormwater Capture: Opportunities to Increase Water Supplies in Southern California.*

Personal Communications

Brown L. Water efficiency administrator, City of Roseville, Roseville (CA); via J Sbaffi, water efficiency staff, City of Roseville, Roseville (CA). Oct. 26, 2012 — e-mail communication with Saare-Edmonds J, staff land and water use scientist, California Department of Water Resources, Sacramento (CA).

Granger W. Water conservation manager, Otay Water District. Oct. 19, 2012 — telephone conversation with Saare-Edmonds J, staff land and water use scientist, California Department of Water Resources, Sacramento (CA).

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 4

Flood Management

Sacramento, CA. The Pocket-Greenhaven community is bordered by I-5 and a semi-circular bend in the Sacramento River on the south, west, and north, and is crossed by a large canal system. Levees protecting houses in "The Pocket" have been determined by the Sacramento Area Flood Control Agency to be in need of major repairs, to retain their 100-year flood protection.

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Chapter 4. Flood Management

This resource management strategy (RMS) for flood management is unique to the other strategies in the *California Water Plan Update 2013* (Update 2013) in that it contains multiple approaches within a single RMS. Flood management is complex and still relatively new to the California Water Plan (CWP). For Update 2013, this flood management RMS provides local and regional water managers a broader perspective of the flood management tools that are available and their interrelationships within one chapter. In future CWP updates and as flood management becomes more integrated into the CWP, more than one RMS for flood management could be developed.

This flood management RMS has been subdivided into four approaches:

- Nonstructural.
- Restoration of natural floodplain functions.
- Structural.
- Flood emergency management.

The following sections will discuss flood management in general terms followed by specific subsections related to the four approaches identified above, as necessary.

Flood Management in California

Floods are naturally occurring phenomena in California. Flooding varies according to the diversity of landscape features, climate, and human manipulation of the landscape. Flooding occurs in all regions of California at different times of the year and in different forms. Examples range from tsunamis in coastal areas to alluvial fan flooding at the base of hillsides, and from fast-moving flash floods in desert regions to slow-rise deep flooding in valleys. Flooding can have positive natural impacts, such as keeping erosion and sedimentation in natural equilibrium, replenishing soils, recharging groundwater, filtering impurities, and supporting a variety of riverine and coastal floodplain habitats for some of California's most sensitive species. However, when floods occur where people live and work, they can result in tragic losses of lives and can have devastating economic impacts by damaging critical infrastructure and vital public facilities, taking valuable agricultural land out of production, and endangering California's water supply system.

In traditional flood management, the overarching purpose is to separate flood waters from people and property that could be harmed. In contrast, integrated water management (IWM) seeks a balance between exposure of people and property to flooding, the quality and functioning of ecosystems, the reliability of water supply and water quality, and economic stability that includes both economic and cultural considerations. This shift changes the focus of flood management from a local to a systemwide context.

One benefit of using IWM is that it encourages a systemwide perspective to solving flood issues as well as an increased understanding of the cause and effect of different management actions. This moves solutions beyond just reducing flood risk resulting from the 100-year flood event to meet the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) requirements to an integrated approach that reduces flood risk and also supports other objectives over a multitude of flood events. Box 4-1 provides the definition of a 500-year and a 100-year flood event.

Traditional flood management approaches inadvertently allowed development in floodplains, putting people and property at risk. An IWM approach is balanced and leads to addressing a wide variety of needs. For example, projects are assessed based on the following attributes:

- Potential velocities and timing of flood flows as well as resources that could be disturbed or damaged by those velocities and timings.
- Depth and duration of floodwaters both during the event and after the event.
- Ecosystem processes that could be either enhanced or diminished by projected flows.
- Stability of floodways including potential for scour, erosion, sediment transport, and deposition.
- Opportunities for community and private access and use of lands dedicated to the flood path.
- Alternative or combined uses of the lands that make up the flood path.
- Risks to the community should a flood occur, and recovery capabilities following a flood.
- Water supply implications from the flood management system and operating conditions before, during, and after flood events.

Flood management includes policies and practices related to educating the public, preparing for mitigating damages, responding to and recovering from flooding that creates risk for people and valued resources, as well as protecting the natural and beneficial functions of floodplains to the maximum extent practicable. Traditional approaches to flood management consisted of developing single-purpose flood infrastructure projects, like a dam or a levee, which has resulted in an extensive network of flood infrastructure around the state, including the following:

- More than 20,000 miles of levees.
- More than 1,500 dams.
- More than 1,000 debris basins.
- Many other facilities, including pump stations, monitoring facilities, bypasses, and weirs (California Department of Water Resources 2013).

While this infrastructure has reduced the chance of flooding and avoided damage to lives and property, it has altered and confined natural watercourses. These alterations lead to unintended consequences, such as loss of ecological function and redirection of flood risks upstream or downstream of projects. Additionally, these traditional approaches have encouraged urban and agricultural development within floodplains, which has placed people and property at risk of flooding, as well as degrading wildlife habitat. In 2007, legislation was passed in California to enhance statewide understanding of flooding and address flood-related issues. This legislation is summarized in more detail in Chapter 24, "Land Use Planning and Management," in this volume.

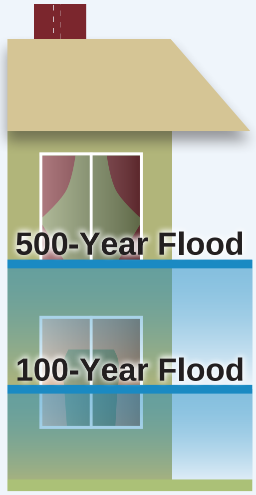
Even with its existing infrastructure, California is at significant risk due to flooding. Further development in flood-prone areas, population growth, and climate change will lead to an increased risk of flooding in the future for people and property. While flood infrastructure can reduce the intensity and frequency of flooding, it cannot completely eliminate the flood risk (i.e., residual flood risk will remain). *California's Flood Future Report: Recommendations for Managing the State's Flood Risk* (aka Flood Future Report) (California Department of Water

Box 4-1 **Definition of a 500-Year and 100-Year Flood Event**

Two flood event levels are commonly used for insurance and planning purposes. These levels indicate a percentage of probability and severity. It does not mean a flood only happens every 100 or 500 years.

- **500-Year Flood** is a shorthand expression for a flood that has a 1 in 500 probability of occurring in any given year. This may also be expressed as the 0.2-percent annual chance flood.
- **100-Year Flood** has a 1 in 100 (or 1 percent) probability of occurring in any given year.

Figure A. 500-Year Flood and 100-Year Flood



Slow rise flooding example

Resources 2013), a companion report to the CWP, characterized the potential for flood exposure in California. More than 7 million people and $580 billion in assets (crops, buildings, and public infrastructure) currently are exposed in the 500-year floodplains in California. A 500-Year Flood has a 1-in-500, or 0.2 percent, probability of occurring in any given year. A detailed description of flood risks in California can be found in the Flood Future Report available at http://www.water.ca.gov/sfmp/ (California Department of Water Resources 2013).

Today, flood management is evolving from narrowly focused traditional approaches toward an IWM approach. The flood management emphasis has shifted to this more integrated approach that involves a mix of multiple measures, including structural and nonstructural approaches. This more integrated approach enhances the ability of undeveloped floodplains and other open spaces to behave more naturally and absorb, store, and slowly release floodwaters during small and medium events. Flood management as part of an IWM approach considers land and water resources on a watershed scale, employing both structural and nonstructural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding, and recognizing the benefits to ecosystems from periodic flooding. Flood management utilizes best management practices, which are methods or techniques that are used in a variety of circumstances and fields, from stormwater management to land use planning, to yield superior results. The application of flood management approaches within the context of an IWM approach extends the range of strategies that could be employed beyond the traditional strategy. Additionally, the strategies that could be implemented to manage flood risk within a hydrologic region or watershed will vary depending on the physical attributes of the area, the presence of undeveloped floodplains, the type of flood hazards (e.g., riverine, alluvial fan, coastal), and the areal extent of flooding.

Although the primary purpose of flood management is public safety (i.e., reduce flood risk and reduce the impacts of flooding on lives and property), approaches to flood management can serve

Box 4-2 Flood Management as Part of an Integrated Water Management Approach

IWM is an approach that combines specific flood management, water supply, and ecosystem actions to deliver multiple benefits. An IWM approach uses a collection of tools, plans, and actions to achieve efficient and sustainable solutions for the beneficial uses of water. An IWM approach reinforces the interrelation of different water management components — such as water supply reliability, flood management, and environmental stewardship — with the understanding that changes in the management of one component will affect the others. This approach applied to flood management looks at the benefits of flooding to natural systems. IWM acknowledges the importance and function of flooding as a natural part of the ecosystem and helps people to learn to live with and better understand the benefits of flooding. This approach promotes system flexibility and resiliency to accommodate changing conditions such as regional preferences, ecosystem needs, climate change, flood or drought events or financing capabilities.

An IWM approach requires unprecedented alignment and cooperation among public agencies, tribal entities, land owners, interest-based groups, and other stakeholders. It is not a one-time activity but rather an ongoing process. Also, this approach relies on blending knowledge from a variety of disciplines including engineering, planning, economics, environmental science, public policy, and public information.

An IWM approach represents the future of flood management in California with the goal to improve public safety, foster environmental stewardship, and support economic stability.

many purposes. Flood management is a key component of an IWM approach. Box 4-2 provides a description of flood management as part of an integrated water management approach.

Flood Governance — Policies and Institutions in California

Traditional flood management resulted in a complex network of agencies with overlapping responsibilities. There are more than 1,300 agencies with some aspect of flood management responsibility in California. These responsibilities include planning, administering, financing, and/or maintaining flood management facilities and emergency response programs. Each agency has unique objectives, authorities, roles, responsibilities, and jurisdictions. Agencies include:

- Local, State, federal, and tribal entities (defined as federally recognized tribes and tribal communities).
- Cities, counties, community service areas and districts.
- Drainage and storm drainage districts.
- Flood control districts.
- Irrigation districts.
- Levee protection districts.
- Joint power authorities.
- Public works districts.
- Public utilities districts.
- Reclamation districts.
- Resource conservation districts.
- Sanitation or sewer districts.

- Special districts.
- Water agencies and departments.
- Water conservation districts.

Almost all communities in California have some measure of responsibility for floodplain management, including adopting National Flood Insurance Rate Maps, conforming to the International Building Code, and enforcing building and land use restrictions.

A number of laws were enacted in 2007 regarding flood risk and land use planning. These laws encourage a comprehensive approach to improving flood management by addressing system deficiencies, improving flood risk information, and encouraging links between land use planning and flood management. Many of the requirements established by these laws are applicable only within the Central Valley.

Below is a summary of the legislation.

- **Senate Bill (SB) 5 (2008) Flood Management** requires DWR and the Central Valley Flood Protection Board (CVFPB) to prepare and adopt a Central Valley Flood Protection Plan (CVFPP) by 2012.
- **Assembly Bill (AB) 156 (2007) Flood Control** provides DWR and the CVFPB with specific authorization that would enhance information regarding the status of flood protection in the Central Valley.
- **AB 70 (2007) Flood Liability** provides that a city or county might be responsible for its reasonable share of property damage caused by a flood if the State liability for property damage has increased due to approval of new development after January 1, 2008.
- **AB 162 (2007) General Plans** requires cities and counties statewide to amend the land use, conservation, safety, and housing elements of their respective general plan to address new flood-related matters.

The DWR FloodSAFE initiative created in 2006 consolidated and coordinated DWR's programs for flood management. Two major milestone reports under the FloodSAFE initiative include the 2012 Central Valley Flood Protection Plan (CVFPP) and the Flood Future Report. The CVFPP, which was adopted in June 2012, proposed a systemwide investment approach for sustainable, integrated flood management in areas currently protected by facilities of the State Plan of Flood Control (SPFC). The Flood Future Report identifies flood management issues statewide and presents recommendations to help address the statewide issues.

Flood Management

Flood management includes a wide range of management actions, which can be grouped into four general approaches: Nonstructural Approaches, Restoration of Natural Floodplain Functions, Structural Approaches, and Emergency Management. These approaches and the management actions within them serve as a toolkit of potential actions that local, State, and federal agencies can use to address flood-related issues and advance IWM.

These actions range from policy or institutional changes to operational and physical changes to flood infrastructure. Such actions are not specific recommendations for implementation; rather, they serve as a suite of generic management tools that can be used individually or combined

Box 4-3 Case Study Number 1 of Flood Management as Part of an IWM Approach

An example of a flood related IWM project is the Lower Carmel River Floodplain Restoration and Flood Control Project. The project area is located at a dynamic interface between marine and freshwater systems and serves as a refuge for sensitive species. The agencies involved in this project are the Big Sur Land Trust, Monterey County Water Resources Agency, Monterey County Public Works Department, and California State Parks. This project consists of components that:

- Improve hydrologic functions by reconnecting floodplains through levee setback or removal and land restoration.
- Integrate storage and filtration basins into restored floodplains to increase flood flow retention, promote sediment and nutrient removal, and increase groundwater recharge.
- Conduct geotechnical engineering analyses and hydraulic modeling needed to support design of flood control improvements.
- Modify placement and/or size of existing levees and/or floodwalls, add new levees or floodwalls, construct new bypasses, and restore channel form and function to improve flood protection.
- Develop local flood management plan updates.
- Establish and preserve agricultural operations adjacent to, but hydrologically disconnected from the floodplains.

Project benefits include reduced damage to residences and commercial businesses as well as local and state infrastructure, improved connectivity between the main channel and overbank areas to reduce flooding hazards, installation of a protective buffer against sea level changes, and restored riparian and wetland habitat within the historical floodplain.

for specific application situations. A variety of management actions can be bundled together as part of a single flood management project (see Box 4-3 and Box 4-4, “Case Study of Flood Management as Part of an IWM Approach”). Management actions also can be integrated with other resource management strategies under other objectives (e.g., water supply, water quality, ecosystem restoration, and recreation) to create multi-benefit projects.

Several management actions within flood management are considered to be crosscutting (i.e., they would be a part of all resource management strategies). These crosscutting actions are permitting, policy and regulations, and finance and revenue. Volume 1, *The Strategic Plan*, Chapter 7, “Finance Planning Framework,” of Update 2013 provides more details on these potential crosscutting actions, and Table 4-1 describes how these actions relate to improved flood management.

Nonstructural Approaches

Nonstructural approaches to flood management include land use planning and floodplain management.

Land Use Planning

Land use planning employs policies, ordinances, and regulations to limit development in flood-prone areas and encourages land uses that are compatible with floodplain functions. This can

Box 4-4 Case Study Number 2 of Flood Management as Part of an IWM Approach

An example of a flood related IWM project is the flood management, habitat restoration and recharge project on the San Diego River. The project is located in Lakeside in San Diego County and is within a 580-acre area known as the Upper San Diego River Improvement Project. Improvements to the San Diego River and adjacent lands are focused on flood management, environmental habitat restoration, recreation, and water supply. This project consists of components that:

- Improve flood management and water quality as a result of restoration efforts designed to increase the wetlands, improve circulation in the pond, and improve sediment transport.
- Acquire ownership or land tenure on property for preservation or restoration purposes.
- Restore riparian habitat types for several threatened and endangered species.
- Restore the channel including work to improve flood management, restore natural meanders, and lower the 100-year flood level by widening the floodway.
- Implement low-impact development techniques including the use of bioswales to capture and treat urban runoff and improve water quality.
- Capture flood flows for habitat (wetland) enhancement and for groundwater recharge.

Benefits of the project include:

- Reduced flood levels.
- Prevention of urban development in a floodplain, currently subject to development pressure.
- Improved sediment balance.
- Protection of downstream bridges and water pipeline.
- Improved water quality via constructed wetlands to treat urban runoff.
- Increased water supply through groundwater recharge of the aquifer.
- Increased recreation and public access opportunities including camping areas, trails, and a boardwalk in the pond with access for the disabled.

include policies and regulations that restrict or prohibit development within floodplains, restrict size and placement of structures, prevent new development from providing adverse flood impacts to existing structures, encourage reduction of impervious areas, require floodproofing of buildings, and encourage long-term restoration of streams and floodplains.

Floodplain Management

Floodplain management generally refers to nonstructural actions in floodplains to reduce flood damages and losses. Floodplain management includes:

- **Floodplain mapping and risk assessment.** Floodplain mapping and risk assessment serve a crucial role in identifying properties that are at a high risk of flooding. Communities, State government, and the private sector require accurate, detailed maps to prepare risk assessments, guide development, prepare plans for community economic growth and infrastructure, utilize the natural and beneficial function of floodplains, and protect private and public investments. Development of necessary technical information includes

Table 4-1 Crosscutting Management Actions and Their Relationship to Flood Management

Management Action	Description
Permitting	Regional and programmatic permitting methods can provide faster and better delivery of flood management activities including operations, maintenance, repair, habitat enhancement and restoration, and minor infrastructure improvement or construction projects. Regional and programmatic permitting methods can be used to manage permitting needs collectively for multiple projects, over longer planning horizons, while consolidating mitigation and conservation efforts into larger, more viable conservation areas. This can accelerate permitting of flood system projects and lower per-unit costs versus project-by-project mitigation. Regional and programmatic permitting methods include regional Habitat Conservation Plans, Natural Community Conservation Plans, programmatic Endangered Species Act Section 7 consultations, and Regional General Permits.
Policy and regulations	Policies and regulations that clarify flood management roles and responsibilities for local, regional, state, and federal agencies can help improve coordination across the large number of agencies and entities involved in flood management. Multiple jurisdictional and regional partnerships can be encouraged for flood planning and flood management activities including permitting, financing, operation and maintenance, repair, and restoration.
Finance and revenue	Several finance and revenue strategies can increase the ability to fund flood management projects. Aligning flood management projects with other existing or planned projects (such as roads or highways) leverages funding from different agencies and jurisdictions to help accomplish objectives. Consolidating projects on a regional or watershed level can also improve cost effectiveness and financial feasibility by pooling resources.

topographic data, hydrology, and hydraulics of streams and rivers, delineation of areas subject to inundation, assessment of properties at risk, and calculation of probabilities of various levels of loss from floods.

- **Land acquisitions and easements.** Land acquisitions and easements can be used to restore or preserve natural floodplain lands and to reduce the damages from flooding by preventing urban development. Land acquisition involves acquiring full fee title ownership of lands from a willing buyer and seller. Easements provide limited-use rights to property owned by others. Flood easements, for example, are purchased from a landowner in exchange for perpetual rights to flood the property periodically when necessary or to prohibit planting certain crops that would impede flood flows. Conservation easements can be used to protect agricultural or wildlife habitat lands from urban development. Both land acquisitions and easements generally involve cooperation with willing landowners. Although acquisition of lands or easements can be expensive, they can reduce the need for structural flood improvements that would otherwise be needed to reduce flood risk. Maintaining agricultural uses and/or adding recreational opportunities where appropriate provide long-term economic benefits to communities and the state.
- **Building codes and floodproofing.** Building codes and floodproofing include specific measures that reduce flood damage and preserve egress routes during high-water events.

Building codes are not uniform; they vary across the state based on a variety of factors. Example codes could require floodproofing measures that increase the resilience of buildings through structural changes, elevation, or relocation and the use of flood resistant materials.

- **Retreat.** Retreat is the permanent relocation, abandonment, or demolition of buildings and other structures. Retreat can be used in a variety of settings from floodplains to coastal areas. In coastal regions, this action would allow the shoreline to advance inward and unimpeded in areas subject to high coastal flooding risks, high erosion rates, or future sea level rise. Integrating recreation uses into retreat areas along the shoreline provides economic uses for these buffer lands.
- **Flood insurance.** Flood insurance is provided by the federal government via the NFIP to communities that adopt and enforce an approved floodplain management ordinance to reduce future flood risk. The NFIP enables property owners in participating communities to purchase subsidized insurance as a protection against flood losses. If a community participates in the voluntary Community Rating System and implements certain floodplain management activities, the flood insurance premium rates are discounted to reflect the reduced flood risks.
- **Flood risk awareness (information and education).** Flood risk awareness is critical because it encourages prudent floodplain management. Flood hazard information is the prerequisite for a sound education in understanding potential flood risks. If the public and decision-makers understand the potential risks, they can make decisions to reduce risk, increase personal safety, and expedite recovery after floods. Effective risk awareness programs are critical to building support for funding initiatives and to building a connection to the watershed.

Restoration of Natural Floodplain Functions

This approach recognizes that periodic flooding of undeveloped lands adjacent to rivers and streams is a natural function and can be a preferred alternative to restricting flood flows to an existing channel. The intent of natural floodplain function restoration is to preserve and/or restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters, to enhance the ecosystem, and to protect flora and fauna communities. Natural floodplain function conservation and restoration actions can include both structural and nonstructural measures. To permit seasonal inundation of undeveloped floodplains, some structural improvements (e.g., weirs) might be needed to constrain flooding within a defined area along with nonstructural measures to limit development and permitted uses within those areas subject to periodic inundation. Actions that support natural floodplain and ecosystem functions include the following:

- **Promoting natural hydrologic, geomorphic, and ecological processes.** Human activities, including infrastructure such as dams, levees, channel stabilization, and bank protection, have modified natural hydrological processes by changing the extent, frequency, and duration of natural floodplain inundation. These changes disrupt natural geomorphic processes, such as sediment erosion, transport, and deposition, which normally cause channels to migrate, split, and rejoin downstream. These natural geomorphic processes are important drivers that create diverse riverine, riparian, and floodplain habitat to support fish and wildlife, and provide natural storage during flood events. Restoration of these processes might be achieved through setting back levees, restoring channel alignment, removing unnatural hard points within channels, restoring flow of sediment that is trapped behind dams, or purchasing lands or easements that are subject to inundation.

- **Protecting and restoring quantity, quality, and connectivity of native floodplain habitats.** In some areas, native habitats and their associated floodplain have been lost, fragmented, and degraded. Lack of linear continuity of riverine, riparian habitats, or wildlife corridors, impacts the movement of wildlife species among habitat patches and results in a lack of diversity, population complexity, and viability. This can lead to native fish and wildlife becoming rare, threatened, or endangered. Creation or enhancement of floodplain habitats can be accomplished through setting back levees and expanding channels or bypasses, or through removal of infrastructure that prevents flood flows from entering floodplains. Coastal wetlands have been severely reduced, resulting in a loss of habitat for freshwater, terrestrial, and marine plant species. Restoration of these habitats could provide a buffer against storm surges and sea level rise.
- **Invasive species reduction.** Invasive species can reduce the effectiveness of flood management facilities by decreasing channel capacity, increasing rate of sedimentation, and increasing maintenance costs. Reductions in the incidence of invasive species can be achieved by defining and prioritizing invasive species of concern, mapping their occurrence using BMPs for control of invasive species, and using native species for restoration projects.

Structural Approaches

Structural approaches to flood management include flood infrastructure, reservoir and floodplain storage and operations, and operations and maintenance (O&M). When local entities are a partner on any federal project, the sponsor has to agree to operation, maintenance, repair, rehabilitation, and replacement (OMRR&R), which goes beyond the requirements of O&M.

Flood Infrastructure

Flood infrastructure varies significantly based on the type of flooding. Flood infrastructure can include:

- **Levees and floodwalls.** Levees and floodwalls are designed to confine flood flows by containing waters of a stream or lake. Levees are an earthen or rock berm constructed parallel to a stream or shore or around a lake to reduce risk from all types of flooding. Levees could be placed close to stream edges, or farther back (e.g., a setback levee). Ring levees could be constructed around a protected area, isolating the area from potential floodwaters.
- **Channels and bypasses.** Channels and bypasses convey floodwaters to reduce the risk of slow-rise, flash, and debris-flow flooding. Channels can be modified by deepening and excavating the channel to increase its capacity, or lining the streambed and/or banks with concrete, riprap, or other materials to increase drainage efficiency. Channel modifications can result in increased erosion downstream, degradation of adjacent wildlife habitat, and often require extensive permitting. Bypasses are structural features that divert a portion of flood flows onto adjacent lands or into underground culverts to provide additional flow-through capacity and/or to store the flows temporarily and slowly release the stored water.
- **Retention and detention basins.** Retention and detention basins are used to collect stormwater runoff and slowly release it at a controlled rate so that downstream areas are not flooded or eroded. A detention basin eventually drains all of its water and remains dry between storms. Retention basins generally have a permanent pool of water and may improve water quality by settling sediments and attached pollutants.

- **Culverts and pipes.** Culverts and pipes are closed conduits used to drain stormwater runoff. Culverts are used to convey streamflow through a road embankment or some other type of flow obstruction. Culverts and pipes allow stormwater to drain underground instead of through open channels and bypasses.
- **Coastal armoring structures, shoreline stabilization, and streambank stabilization.** Coastal armoring structures and shoreline stabilization reduce risk to low-lying coastal areas from flooding. Coastal armoring structures are typically massive concrete or earthen structures that keep elevated water levels from flooding interior lowlands and prevent soil from sliding seaward. Shoreline stabilization reduces the amount of wave energy reaching a shore or restricts the loss of beach material to reduce shoreline erosion rates. Types of shoreline stabilization include breakwaters, groins, and natural and artificial reefs. Streambank stabilization protects the banks of streams from erosion by installing riprap, matting, vegetation, or other materials to reduce erosion.
- **Debris mitigation structures.** When debris and alluvial flooding occur, Sabo dams, debris fences, and debris basins separate large debris material from debris flows, or they contain debris flows above a protected area. These structures require regular maintenance to periodically remove and dispose of debris after a flood. Deflection berms or training berms can be used to deflect a debris flow or debris flood away from a development area, allowing debris to be deposited in an area where it would cause minimal damage.

Reservoir and Floodplain Storage and Operations

- **Reservoir and floodplain storage.** These provide an opportunity to regulate flood flows by reducing the magnitude of flood peaks occurring downstream. Many reservoirs are multipurpose and serve a variety of functions including water supply, irrigation, habitat, and flood control. Reservoirs collect and store water behind a dam and release it after a storm event. Floodplain storage occurs when peak flows in a river are diverted to adjacent offstream areas. Floodplain storage can occur naturally when floodwaters overtop a bank and flow into adjacent lands, or storage can be engineered using weirs, berms, or bypasses to direct flows onto adjacent lands.
- **Storage operations.** This optimizes the magnitude and timing of reservoir releases. Storage operations can reduce downstream flooding by optimizing the magnitude or timing of reservoir releases, or through greater coordination of storage operations. Coordination can take the form of formal agreements among separate jurisdictions to revise reservoir release operations based on advanced weather and hydrology forecasts, or it can simply involve participation in coordination meetings during flood emergencies.

Operations and Maintenance

O&M is a crucial component of flood management. O&M activities can include inspection, vegetation management, sediment removal, management of encroachments and penetrations, repair or rehabilitation of structures, or erosion repairs. Because many flood facilities constructed in the early to mid-20th century are near or have exceeded the end of their expected service lives, adequate maintenance is critical for these facilities to continue functioning properly.

Flood Emergency Management

Flood emergency management includes the following activities:

- **Flood preparedness.** Flood preparedness includes the development of plans and procedures on how to respond to a flood in advance of a flood emergency including preparing emergency response plans, training local response personnel, designating evacuation procedures, conducting exercises to assess readiness, and developing emergency response agreements that address issues of liability and responsibility. Preparing for floods can also include modifying or restricting new development in floodplains, removing existing structures that are the most at risk, and restoring natural floodplains.
- **Emergency response.** Emergency response is the aggregate of all those actions taken by responsible parties at the time of a flood emergency. Early warning of flood events through flood forecasting allows timely notification of responsible authorities so that plans for evacuation of people and property can be implemented. Emergency response includes flood fighting, emergency evacuation, and sheltering. Response begins with, and might be confined to, affected local agencies or operational areas (e.g., counties). Depending upon the intensity of the event and the resources of local responders, response from regional, State, and federal agencies might be required.
- **Post-flood recovery.** Flood recovery programs and actions include restoring utility services and public facilities, repairing flood facilities, draining flooded areas, removing debris, and assisting individuals, businesses, and communities to return to normal. Recovery planning could include development of long-term floodplain reconstruction strategies to determine if reconstruction would be allowed in flood-prone areas, or if any existing structures could be removed feasibly. Such planning should review what building standards would be required, how the permit process for planned reconstruction could be improved, funding sources to remove existing structures, natural habitat restoration, and how natural floodplains and ecosystem functions could be incorporated.

Connections to Other Resource Management Strategies

An IWM approach relies on the application of multiple strategies. In addition to the flood-specific strategies, other water resource management strategies included in the Update 2013 have the potential to provide flood management benefits and may be incorporated as an element of an IWM approach.

Resource management strategies that share important synergies with flood management are described briefly below.

- **Land use planning and management.** One of the most effective ways to reduce the vulnerability to potential flooding is through careful land use planning that is fully informed by applicable flood information and flood management practices. Land use policies that encourage locating new development outside floodplains can reduce flood risks. Land use policies that encourage compact development and low-impact development can reduce flood volumes and peaks. In addition, nonstructural approaches to flood management can reduce flood risk to both existing and future development.
- **Sediment management.** Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of a floodplain, the depth and composition of soils, the quality of river habitats, and the type and density of vegetation. Disruption of the dynamics of natural sediment transport can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying

capacity of natural channels through increased sedimentation. Sediment is a major component of alluvial fan and debris-flow flooding.

- **Watershed management.** Watersheds are an appropriate organizing unit for managing floodplains. Restoring, sustaining, and enhancing watershed functions are key goals of flood management in the context of IWM.
- **Urban stormwater runoff management.** Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways along with the timing and extent of flooding. Impervious surfaces increase runoff volumes and velocities, which result in streambank erosion and potential flooding problems downstream. Urban runoff can pick up a variety of pollutants from the ground before it enters streams, rivers, and coastal waters. However, watershed approaches to urban runoff management can capture, treat, and use urban runoff for beneficial uses in a manner that mimics a natural hydrologic cycle.
- **Agricultural land stewardship.** Due to flat topography and rich soils caused by historical flood deposits, floodplains are often ideal for agricultural uses. Agricultural runoff can carry pollutants, such as fertilizers, into the water system. However, responsible stewardship of agricultural lands can prevent urban development within floodplains, constraining farming and ranching practices to those areas that are compatible with floodplain management. Innovative funding mechanisms like flood easements can be used to compensate farmers who allow their fields to be flooded during extreme events.
- **Forest management.** Forestry practices can influence not only sediment transport from upland streams, but also the timing and magnitude of peak flows. The high amount of surface roughness in forested floodplains reduces floodwater velocities, spreads flows across a larger area of the floodplain, and attenuates downstream flows. Catastrophic wildfires can increase peak flows and reduce surface water infiltration, which can cause erosion and debris flooding. Forest management to reduce catastrophic wildfires is an important action to minimize flood damages.

Resource management strategies that are also management actions directly contributing to flood management include the following:

- **Conveyance.** Many streams and channels are used to support both flood flow conveyance and water supply conveyance. Improvements to regional water supply conveyance systems could enhance the potential for flood flow conveyance, and vice versa.
- **Surface storage.** Most of California’s major surface water reservoirs are managed for multiple purposes including water supply, hydropower, water quality, recreation, and ecosystem needs as well as flood management. Increasing local and regional surface storage has the potential to provide greater water management flexibility for capturing runoff and controlling flood flows.
- **System reoperation.** The primary goal of forecast-coordinated and forecast-based operations is to improve downstream flood protection while improving, or at least not degrading, water supply, environmental, or recreational uses through better hydrologic forecasting and coordinated reservoir operations.
- **Outreach and engagement.** Regular outreach is needed to inform the public regarding flooding, flood risks, floodproofing, and impacts of climate change, as well as to explain what households, businesses, and communities can do to reduce or mitigate risk to acceptable levels. Outreach is also needed to inform the public regarding natural beneficial functions of floodplains.

Resource management strategies that could directly benefit from natural functions of flooding include the following strategies:

- **Ecosystem restoration.** Floodplain environments are dynamic in nature and are highly productive biological communities, given their proximity to water and the presence of fertile soils and nutrients. California native riparian and aquatic animal and plant communities are adapted to conditions of seasonal flooding. Many other terrestrial plants and animals use riparian areas for forage and movement across the landscape. The principal opportunities for improvement in both flood management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains.
- **Pollution prevention.** Floodplains that function well improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion and sedimentation of streams, and moderating temperature fluctuations.
- **Water-dependent recreation.** Protecting and enhancing public access to rivers, lakes, and beaches increases public safety, fosters environmental stewardship, and increases economic sustainability of flood management projects. Flood management infrastructure must be designed to protect public trust uses such as navigation and recreational access to the state's waterways and beaches. Flood protection facilities, natural floodplains, and restored areas can improve recreational access to waterways by providing opportunities for integrating suitable recreation facilities.
- **Recharge area protection, conjunctive management, and groundwater storage.** Diversions of flood flows for groundwater infiltration can reduce downstream flooding and improve water supply by storing groundwater as well as providing water for conjunctive use. The generally flat topography of natural floodplains and the permeable nature of alluvial soils promote infiltration into the subsurface for storage in soils and aquifers.

Potential Benefits

Primary benefits of flood management are derived from the potential to reduce risks to lives and property from flood events and increase flood resilience, which reduces social and economic disruption and flood recovery costs. Flood management also provides beneficial opportunities for water supply, environmental management, water quality, recreation, hydropower, and navigation. Potential benefit categories are discussed briefly in the following subsections. Table 4-2 provides a summary of potential benefits and costs of the specific flood management strategies and management actions.

Flood Risk Reduction Benefits

The importance of flood risk reduction to promote public safety and economic stability cannot be understated. More than seven million people and $580 billion in assets (crops, buildings, and public infrastructure) are currently exposed in 500-year floodplains in California (California Department of Water Resources 2013). Many areas in California lack even basic protection from a 100-year flood. Flood management approaches decrease this risk by decreasing the probability of flooding and the consequences from flooding using a wide variety of actions. Flood infrastructure, operations, and maintenance can reduce the frequency, extent, and depth of flooding. Floodplain management and land use planning, building resiliency into the system along with emergency preparedness, response, and recovery, further reduce residual risks that

Table 4-2 Benefits and Costs of Management Actions

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs[a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Non-Structural Approaches								
Land use planning	Addresses all types of flooding. Reduces risk by reducing what is flooded. No reduction in residual risk.	X	X	X	X			Low initial costs. No significant change to annual costs.
Floodplain management Floodplain mapping and risk assessments	Addresses all types of flooding. Could reduce flood risk if risk assessment leads to land use decisions that are consistent with floodplain mapping data.							Low initial costs. Low to medium annual costs.
Land acquisitions and easements	Addresses all types of flooding. Reduces risk by reducing what is flooded. No redirected hydraulic impacts or reduction in residual risk.	X	X	X	X			High initial costs based on location, extent, or type of easement. Costs include real estate acquisitions, relocations, mitigation, engineering, and permitting. Annual costs vary.
Building codes and flood proofing	Addresses all types of flooding. Reduces what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk.							Low initial costs for building code changes and costs for implementation could be recovered through additional fees. Medium to high initial costs for flood proofing depending on number of structures.
Synonymous retreat	Addresses coastal flooding by reducing what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk.		X	X				Medium to high initial costs depending on type of retreat, location, extent, type of structure, real estate acquisitions, mitigation, and permitting.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs[a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Flood insurance	Addresses all types of flooding. Improves the recovery of people and property from harmful flooding. Reduces residual risk.							Low to medium initial costs. Low annual costs.
Flood risk awareness – information and education	Addresses all types of flooding. Does not directly reduce flood risk, but reduces what might be flooded if it leads to land use decisions that are consistent with floodplain function. Reduces residual risk.							Low initial costs. Low to medium annual costs depending on extent of training and how flood information is disseminated.
Natural floodplain function restoration Natural hydrologic, geomorphic, and ecological processes	Addresses all types of flooding. Can reduce peak flood flows and decrease the frequency, extent, and depth of flooding. No change in residual risk.	X	X	X	X			Medium to high initial costs based on size of project, real estate acquisitions, relocations, permitting, design, construction, mitigation, and loss of property taxes. Annual O&M costs could increase during establishment period, but would be reduced over long term.
Quantity, quality, and connectivity of native floodplain habitats	Does not directly reduce flood risk. Can provide mitigation opportunities for habitat losses elsewhere for flood management. No changes in residual risk.	X	X	X	X			Highly variable initial costs depending on type of effort, real estate acquisitions, relocations, permitting, design, construction, and potential loss of property taxes. Annual costs could increase short term, but would decrease long term.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs[a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Invasive species	Addresses all types of flooding. Reduces the probability, extent, and depth of flooding by decreasing channel capacity and increasing rate of sedimentation.		X	X				Medium initial costs with potential costs related to permitting, maintenance, mapping, and technical evaluation on how to control invasive species. Annual maintenance costs would increase slightly.
Structural Approaches								
Flood infrastructure Levees and floodwalls	Addresses all types of flooding by reducing the frequency of flooding. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind levees, residual risk would increase.	[b]	[b]	X				High initial costs depending on location, number of levees or floodwalls, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Channels and bypasses	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.	X	X	X			X	High initial costs depending on location, number of channels or bypasses, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Retention and detention basins	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.	X			X			High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Culverts and pipes	Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding.							High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs[a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Coastal armoring structures, shoreline, and streambank stabilization	Addresses coastal flooding by reducing the frequency of flooding and reducing erosion rate. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind armoring structures and shoreline stabilization, residual risk would increase.		c	c				High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required.
Debris mitigation structures	Addresses debris and alluvial fan flooding by retaining debris and reducing downstream flooding. Reduces the susceptibility of people and property from harmful flooding.				X			Medium-high initial costs. High annual O&M costs for debris removal and disposal.
Reservoir and floodplain storage and operations Reservoir and floodplain storage	Addresses slow-rise and flash flooding. Reduces the probability, extent, and depth of flooding. Reduces frequency of flooding and residual risk by reducing peak flows.	X	X	X		X		Medium to very high initial costs depending on location and size of storage, real estate acquisitions, relocations, permitting/mitigation costs, complexity of facilities. Additional small annual O&M costs.
Storage operations	Addresses slow-rise and flash flooding by reducing frequency and magnitude of downstream flooding and reducing residual risk. Reduces the probability, extent, and depth of flooding. Coordinated operations can involve transfer of risk, increasing risk in one area, while decreasing risk in another.	X	X	X		X		Low-medium initial costs depending on location, extent of facilities, forecasting and hydrologic technology used. Annual costs are variable.

Management Action	Flood Risk Reduction Benefits	Potential Integrated Water Management Benefits						Costs[a]
		Water Supply	Environmental	Recreation	Water Quality	Hydropower	Navigation	
Operations and maintenance	Addresses all types of flooding. Reduces vulnerability of flood infrastructure. No change in residual risk.		X				[d]	Low initial costs. Medium to high annual costs depending on type and extent of maintenance.
Flood emergency management Flood preparedness	Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding.							Low to medium initial costs. Low annual costs.
Emergency response and flood fighting	Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding.							Low to medium initial costs. Low annual costs.
Post-flood recovery	Addresses all types of flooding. Does not directly reduce flood risk, but improves public safety in the aftermath of a disaster.							Low to medium initial costs. Low annual costs.

Notes:

[a] The costs defined in this table are in relative terms. No actual number value can be placed on the costs due to the site-specific nature of the management actions. The terms low, medium, and high are used to give a comparison between the management actions and not for budgetary or costing purposes.

[b] Setback levees

[c] Natural and artificial reefs

[d] Dredging

cannot be reduced by infrastructure alone. Limiting development in floodplains helps address the primary source of flood risk instead of merely addressing its symptoms. Without these risk-reduction measures, a major flood has the potential to catastrophically affect millions of residents, homes, businesses, and agricultural lands; cause critical infrastructure to go out of service for long periods of time; and isolate or close off vital services.

Integrated Water Management Benefits

An IWM approach is a crosscutting benefit that bundles management actions based on systemwide needs. Flood management as part of an integrated approach can leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management. There are several cost advantages of an IWM approach due to improved delivery and implementation of flood management. Improved agency interaction through an IWM approach is at the core of implementing these advantages because a diverse set of stakeholders must coordinate, cooperate, and collaborate to develop successful IWM projects. Improved agency interaction also facilitates effective planning, agency alignment, and identification of investment priorities and funding. A key benefit of agency alignment for flood management is reduced permitting and mitigation process costs as well as improving governance and policy.

Agency alignment at all levels (local, State, and federal agencies, as well as tribal entities) also enables completion of statewide planning that helps identify governance and policy needs required to develop statewide investment priorities. Setting statewide investment priorities encourages development of integrated projects and increases the pool of available funding, making funding more reliable. Local, State, and federal agencies and tribal entities are beginning to structure their flood management programs to support multiple-benefit projects. These multiple-benefit projects have access to different or new funding sources. Partnering with other agencies can increase flexibility for pursuing diverse funding sources to overcome grant caps and varied eligibility requirements. Coordination across geographic and agency boundaries can help agencies pool and leverage their funding to make the best use of limited human and financial resources.

Water Supply Benefits

An integrated approach to flood management would maximize the beneficial uses of water to improve water supply reliability, stormwater management, and groundwater recharge. An IWM approach to flood management would increase water supply reliability by improving the operational flexibility of multipurpose infrastructure, such as channels and bypasses, that are used for water supply and floodwater conveyance, and multipurpose reservoirs to store floodwaters that are used later for water supply. The restoration of natural floodplain functions by reconnecting streams to their historical floodplains, setting back levees, creating floodplain storage, and acquiring easements would encourage natural groundwater recharge by providing an expansive area where floodwaters would slow in velocity, disperse over a broader area, and infiltrate into the ground.

Environmental Benefits

An integrated approach to flood management would enhance ecosystems by restoring the natural hydrologic, geomorphic, and ecologic processes and by improving the quantity, quality, and connectivity of riverine and coastal habitats. These actions result in healthier, self-sustaining ecosystems that provide breeding and feeding grounds for a wide variety of aquatic and terrestrial species. Such actions also help maintain the diversity of plants and animals by aiding in the recovery of endangered and threatened species and controlling invasive species. These actions also increase ecosystem resiliency to uncertain changing conditions such as climate change. Integrating ecosystem conservation and restoration with flood risk-reduction projects is an essential component of flood management that can increase effectiveness, sustainability, and public support. Restoration of natural floodplain functions to attenuate peak flows would include benefits to natural watershed.

Water Quality Benefits

Restoration of natural floodplain functions as part of a flood management strategy would improve water quality by filtering nutrients and impurities from runoff, which reduces levels of pathogens and toxic substances. Restored natural floodplain functions would help process organic wastes, control erosion and sedimentation by stabilizing banks, and moderate temperature fluctuations by planting trees to provide shade. Infrastructure, such as debris mitigation structures, can improve water quality by reducing the amount of sediment from debris flooding.

Recreation Benefits

Integration of flood management and recreation can increase the number and quality of recreational areas and parks for water-oriented sports, boating, swimming, hiking, and camping. Floodplain management through land use planning and ecosystem restoration can support recreational activities by providing areas of active- and passive-use recreation in floodplains and flood greenways, increasing open space, and increasing scenic value. Even in urban areas, establishing greenways as part of flood management projects and replacing concrete channels with more natural creek environments can satisfy recreation demand. Recreation provides communities with economic and public health benefits while supporting the economic, environmental, and social sustainability of flood management projects.

Hydropower Benefits

California's major surface water reservoirs that are intended for flood management generate hydropower or are hydraulically connected to reservoirs that generate hydropower. Optimizing storage operations provides more water management flexibility to achieve multiple benefits, including hydropower generation.

Navigation Benefits

Several channels and bypasses in California that are subject to flooding provide navigation benefits when used for interstate commerce. Channel dredging operations to increase channel capacity can also provide navigation benefits.

Potential Costs

Since Update 2009, DWR has worked to identify the costs of improving flood management on a statewide basis. Included in this effort are the CVFPP, the Flood Future Report, and regional flood management through integrated regional water management (IRWM) plans. Collectively, these efforts identified the immediate need for more than $50 billion to complete flood management improvements and projects. These flood management projects include maintenance projects and other identified actions. The Flood Future Report also indicated the need for substantial additional funding to complete flood risk assessments throughout the state, and to conduct flood management improvements based on those assessments. Therefore, the total estimated capital investment needed for flood management projects could easily top $100 billion (California Department of Water Resources 2013). These estimates do not include the broader regional economic impacts or ripple effects of flooding, such as the costs resulting from rerouting traffic and closing businesses, and from compromised services of water and wastewater treatment plants, as well as critical facilities such as hospitals. These losses of function have a wider impact that can range from regional to statewide, nationwide, or even international. For example, if flood damages disrupted the delivery of water for a significant amount of time, the economic impacts would be substantial, with the effects reaching far beyond California. Specifically, if water supply were disrupted in the Delta, impacts would affect not only agricultural production, but also commercial businesses in the San Francisco Bay Area and Southern California.

The costs of different management actions vary significantly. For example, developing a new reservoir can cost billions of dollars, but some policy and regulatory management actions can be implemented for minimal investments of time and money. IWM projects can sometimes cost more in advance to implement. However, thoughtful planning can leverage different funding streams and provide multiple benefits over the project's useful life, sometimes reducing overall project costs. In addition to the initial costs for an action, provisions must be made for long-term operations and maintenance (O&M). Costs for implementing a single management action can also vary widely based on quantity, location, real estate costs, permitting and mitigation costs, and other factors. Therefore, potential costs for flood management actions are summarized qualitatively in Table 4-2. Initial and annual costs for each management action were characterized with a low, medium, or high value, which represents the relative cost of the management action compared to other flood management actions.

Nonstructural measures, such as land use planning and floodplain management, are some of the most cost-effective strategies for reducing flood risk over the short and long term. It is more economical to invest in information and education efforts that help keep people and property out of floodplains than to invest in flood infrastructure. Constructing flood infrastructure requires significant up-front capital investment and long-term funding for operations and maintenance.

Multiple benefit projects often have higher initial costs than narrowly focused projects, which can sometimes be a barrier to their implementation. However, an IWM project can achieve economies of scale while meeting multiple resource management goals with less cost and a smaller footprint. An integrated approach can also leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management.

Higher initial and short-term costs of IWM projects can be offset sometimes by benefits that accrue time. For example, setting back a levee to reconnect the channel with the floodplain and promoting natural floodplain functions can have higher initial costs than a fix-in-place levee improvement. However, incorporating the setback levee can decrease project delays as well as reduce regulatory compliance, long-term operations, maintenance, and repair costs. Setback levees can also provide long-term benefits to water supply and the environment by increasing groundwater infiltration and providing habitat restoration opportunities.

Climate Change Considerations and Implications

Climate change will have a significant impact on the timing and magnitude of precipitation and runoff and contribute to a rise in sea levels. Increased air temperatures will result in more precipitation falling as rain rather than snow, contributing to increases in winter runoff. While future precipitation is somewhat uncertain, greater flood magnitudes are anticipated due to more frequent atmospheric river storms and other extreme weather events (Dettinger 2011). In addition, rising sea levels could increase the potential for high tides and storm surges to inundate low-lying coastal areas. Warmer temperatures and changes in soil moisture are expected to contribute to more frequent and intense wildfires. Areas damaged by these wildfires would have a greater potential for flooding associated with accelerated runoff and debris flows. Such changes could affect the magnitude and frequency of flood events, although specific effects would be difficult to predict reliably.

Understanding the specific effects of climate change is a significant data gap. For example, much of the current analysis of climate and water impacts considers how changes in various mean conditions (e.g., mean temperatures, average precipitation patterns, mean sea level) will affect water resources, particularly California's water supply. Although many water resource factors are affected by such average conditions, some of the most important impacts, including flooding, will result not from changes in averages, but from changes in local extreme precipitation and runoff events over short periods (California Department of Water Resources 2006). These extremes are difficult to predict because climate projections from global climate models have difficulty representing regional- and local-scale precipitation patterns and processes that drive extreme events over short time steps (e.g., hours or days). Without this information, flood planners and emergency managers have a difficult task making informed decisions about the impacts and risks of climate change.

Adaptation

The impacts of climate change can be addressed through adaptation and mitigation measures. Anticipated changes in runoff, frequency and magnitude of flood events, and sea level rise present serious challenges to flood management. However, many of the approaches presented in the flood management actions, such as setback levees, reservoir operations, floodplain management, land acquisition/easements, retreat, and restoring ecosystem functions, can assist in providing more flexibility and resiliency in adapting to a changing climate. For example, levee setbacks and bypasses can provide greater protection from anticipated changes in the timing and magnitude of precipitation and runoff, as well as changes in storm intensities that are expected by improving flow capacity.

Incorporating climate change considerations into land use and emergency management planning decisions can also play a key role in flood management. For example, decisions to avoid developing in areas particularly vulnerable to sea level rise or retreating from them would greatly reduce the risk of flooding and/or the need for new or larger levees, seawalls, coastal armoring, or other flood infrastructure.

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Structural approaches to flood risk management are often the most energy-intensive actions that cause increased greenhouse gas emissions from the building and maintenance of infrastructure. In contrast, nonstructural approaches, such as land use planning and floodplain management, require less energy and emit fewer greenhouse gas emissions. Floodplain restoration can also aid in mitigating climate change through carbon sequestration in soil and vegetation or riparian restoration.

Major Implementation Issues

Major issues and challenges to implementing flood management as part of an IWM approach were identified in the Flood Future Report, based upon interviews with more than 140 local, State, and federal agencies, and tribal entities, with varying levels of flood management responsibilities in each county. Additional issues have been identified by land use and environmental planners, and others with flood management responsibility. Together, these issues represent the following primary barriers related to implementation of flood management in the context of IWM:

- Issue 1: Inadequate and unstable funding and incentives.
- Issue 2: Inadequate data/information and inconsistent tools.
- Issue 3: Inadequate public and policy-maker awareness of flood risk.
- Issue 4: Complex and fragmented governance structure impeding agency alignment and systems approach (California Department of Water Resources 2013).

Issue 1: Inadequate and Unstable Funding and Incentives

Current funding for flood management is inadequate and unreliable because it is dependent upon agency user fees, assessments, bond funding, and earmarking. Flood management program funding has been cyclical, often increasing following a flood disaster, then gradually decreasing as other priorities garner the attention of residents and policy-makers. Local funding is linked to city and county revenue and is affected by changes in the state's economy. State funding has been heavily dependent on bond funds, and to some extent the fluctuations of the General Fund. Funding of flood management for local agencies is hampered by Propositions 13 and 218, which restrict an agency's ability to increase property assessments. Funding from assessments or impact fees can have limitations on where the funds can be spent geographically. For example, upstream infrastructure that decreases downstream risk could not be funded in a flood management assessment district because the infrastructure is not within the district's geographic boundary. Flood management budgets are especially susceptible to reductions in dry years or economic downturns. State bond funding will be depleted by 2017, and the federal spending on flood management is uncertain, but is unlikely to continue at the same levels as in the past.

Funding for flood management, as well as funding for an IWM approach, is inadequate to meet current needs. Funding sources and incentives have changed over time. In addition, agencies involved in flood management do not have clear and strong incentives from State and federal governments to implement regional/systemwide planning and multi-benefit solutions. Financial incentives provided to local agencies traditionally have not distinguished between supporting narrow-purpose projects implemented by a single agency and multi-benefit projects implemented on a regional scale. Providing adequate incentives for an IWM approach to flood management is important because it requires investments of time, energy, and staff resources for the required coordination to achieve long-term benefits.

Also, new regulations place additional requirements on projects. For example, the California Water Code Sections 12840-12842 stipulate that "recreational development should be among the purposes of all federal flood control and watershed protection projects." This regulation requires broad-based public funding of recreational opportunities associated with many types of flood control projects. As with the Davis-Dolwig Act, the State has struggled to establish a funding strategy to provide for planning, construction, operation, and maintenance of these facilities to "achieve the full utilization of such projects for recreational purposes."

Issue 2: Inadequate Data/Information and Inconsistent Tools

Improved quantity, quality, and accessibility of data are needed in large areas of the state to close data gaps related to flood risk, floodplain mapping, hydrologic data, flood infrastructure integrity, ecosystem mapping, flood forecasting, flood readiness, and climate change.

Inadequate and outdated hydrologic and mapping data hinder assessments of flood risk across the state. Accurate and detailed mapping is needed to guide development, prepare plans for community economic growth and infrastructure, utilize natural and beneficial functions of floodplains, and protect private and public investments. The condition of aging infrastructure is sometimes not fully understood and can be expensive to assess. Funding is often inadequate to meet current data, assessment, and mapping needs.

A need also exists to increase the quality of environmental information and tools for informing flood management and conservation activities. Even in cases where data and information are available, variable conditions, such as climate change, add new uncertainties to existing data sets. Although much information is available online about flood management including data, case studies, budget information, funding sources, climate change, and other planning tools, many data repositories have differing levels of accessibility, ease of use, and metadata requirements. Although these data exist, the sources are difficult to locate and access and data may be inconsistent.

Other major data gaps exist that inhibit a consistent methodology to assess flood risk and measure project benefits. Different methods are used across the state to assess flood risk, which yields inconsistent results. The methods include those used by the U.S. Army Corps of Engineers (USACE), FEMA, and local agencies. Each of these methods were developed to reach unique objectives that required different levels of complexity. For example, FEMA uses an approach that has traditionally focused on hazards associated with 100-year and 500-year flood events, in contrast to USACE approach that assesses and describes risk in terms of expected annual damage (EAD). Many of the benefits that are reaped using an IWM approach cannot be quantified monetarily, which hampers assessing and comparing different integrated solutions. It is especially difficult to assign a value to ecosystem restoration benefits. No set methodology exists to measure such benefits, resulting in an under-valuation of the benefits of IWM.

Issue 3: Inadequate Public and Policy-Maker Awareness and Understanding of Flood Risk

Policy-makers and the public have varying levels of understanding about risks and consequences of flooding. Lack of awareness and understanding can increase risks to people and property and make it difficult to achieve sustainable, long-term planning and investment that supports flood management. Currently, many California residents and policy-makers are primarily aware of risk of flooding based on the need to purchase flood insurance under FEMA's NFIP. This program and the use the of terms 100-year and 500-year floods, leads many people to mistakenly believe that protection from a 100-year flood means that their home will not be flooded for 100 years. Actually, a 500-year flood has a 1-in-500 probability of occurring in any given year (0.2 percent annual chance) and a 100-year flood has a 1-in-100 probability of occurring in any given year (1 percent annual chance). These flood event levels indicate a percentage of probability and severity, but they do not mean that such a flood would happen only once every 100 or 500 years. Policy-makers need updated data, including maps, to help make better decisions. Also, residents and policy-makers rely on the infallibility of flood infrastructure, including levees, and are often unaware of consequences that occur outside floodplains (e.g., economic impacts, loss of critical services).

Another barrier to understanding is that flood risk is a dynamic and complex topic because it is impacted by changes in hydrology (including climate change uncertainties), reliability of the data used to assess flood hazards, reliability of flood management structures, and changes in the consequences of a flood event. Changes in any of these factors can greatly change a community's flood risk over time.

In addition, major floods are infrequent, they occur many years apart, and this results in the public underestimating flood risk. Policy-makers responsible for land use decisions need updated information and data from the State and FEMA in order to make better decisions that avoid putting people and assets at risk. This lack of awareness makes it difficult to achieve sustainable, long-term planning and investment that support flood management and even more difficult to gain public understanding of flood risks.

Issue 4: Complex and Fragmented Governance Structure Impeding Agency Alignment and Systems Approach

Responsibilities for flood management are currently fragmented across numerous local, State, and federal agencies and tribal entities. Flood management is often complicated by the large number of agencies and entities involved, and by their complex jurisdictional roles and responsibilities. More than 1,300 agencies have some aspect of flood management responsibility in California. Each of these agencies has unique objectives, authorities, roles, responsibilities, and jurisdictions. The fragmentation of flood management responsibilities results in poor agency alignment. Overlapping jurisdictions and conflicting missions and priorities across various local, State, and federal agencies and tribal entities involved in flood management can lead to inconsistent policies, regulations, enforcement, and practices. Coordinating activities within this fragmented jurisdictional landscape can be challenging, particularly for local entities. There is a strong need for improved agency alignment through coordination of policies and guidance across multiple agencies at all levels – local, State, federal, and tribal.

The complex and fragmented governance structure in California hinders and sometimes precludes agency alignment. Agency alignment is cooperation and collaboration toward a common IWM approach. There are agency coordination issues that are both intragency and interagency, as well as coordination with regulatory and resource agencies. Improper agency alignment results in projects that are narrowly focused, miss opportunities for integration and funding maximization, and projects that have unintended negative impacts on downstream or upstream communities and natural environments. Most flood management agencies in California understand the benefits of an IWM approach, but might not have the authority or resources to participate in projects that are regional or systemwide in scale.

Another consequence of improper agency alignment is inconsistent regulatory requirements, permitting processes, and enforcement practices. Unclear, conflicting, or mutually exclusive regulatory objectives or requirements can increase costs and time needed for regulatory review. Lack of consistent standards for mitigation requirements can impede project development and implementation. This can result in conflicts between competing project objectives.

Agency alignment is essential for establishing clear roles and responsibilities related to emergency preparedness, response, and recovery. This lack of alignment, as well as concerns about funding and cost reimbursement, can result in confusion or inaction during a flood emergency.

Recommendations

Recommendations to facilitate implementation of flood management initiatives have been developed in response to the four major issues identified above. These recommendations are organized by the need to:

- Pursue stable funding and create incentives.
- Develop and disseminate adequate data and tools.
- Improve public and policy-maker awareness and understanding of flood risk.
- Strengthen agency alignment.

Pursue Stable Funding and Create Incentives

1. **Federal and State agencies should link funding to using an IWM approach by 2017.** Providing incentives for an IWM approach with State and federal funds will encourage local agencies to implement higher-value, multi-benefit projects when developing options for flood management. This effort could include providing incentives to all agencies and tribal interests for regional- or systemwide-scale flood management planning that encompasses conservation and restoration, including riverine, floodplains, and other ecosystem functions. Performing planning at this broader scale for flood management enables a more holistic approach to water and ecosystem management. Future flood management planning and actions should proceed utilizing an IWM approach. Flood management planning based on IWM leads to better projects, reduces the need for more costly structural solutions, and

promotes multiple societal benefits, including public safety, environmental stewardship, and economic stability.

2. **Local, State, and federal agencies should work together to develop a roundtable to assess the applicability of all potential funding sources, propose new funding options, and identify needed changes to legislation by 2020.** The roundtable initially would review existing funding sources identified in the online resource catalog of flood management funding created by State and federal agencies, review other funding mechanisms, and make recommendations. The roundtable should also propose changes or alterations to local funding restrictions by pursuing exemptions to existing statutes for public safety. For example, changes to current laws (e.g., Proposition 218) could include reclassification of flood management agencies as exempted public safety utilities. The roundtable also could pursue establishment of regional assessment districts.

3. **By 2017, State and federal agencies should expand processes for developing, funding, and implementing flood management projects with an IWM approach in each region.** The use of IWM would promote and encourage incorporation of project components that achieve a broader range of objectives. Also, this would result in development of a common terminology for State and federal programs to help grantors and grant recipients understand IWM processes.

4. **By 2020, DWR should add compliance with best management practices and other statuary requirements for land use as a criterion for making flood management funding decisions as applicable to agency authorities.** Land use policies that keep new development out of floodplains and encourage compact, low-impact development can reduce costs of flood management projects.

5. **By 2017, working with the California Emergency Management Agency (CalEMA) and other State agencies, DWR should provide grant funding for increased coordination among flood responders, facility managers, planners, tribal entities, and representatives of State and federal resource agencies to improve flood emergency preparedness.** Coordination before a flood event improves emergency preparedness by identifying and reinforcing areas of expertise, available resources, and agreement about plans.

6. **State and federal agencies should establish more stable sources of funding to assist local and regional collaboration, including IRWM.**

7. **By 2020, the State should develop broad-based public funding to support recreational facility planning, construction, and O&M in flood protection projects as required by California Water Code Sections 12840-12842.**

Develop and Disseminate Adequate Data and Tools

8. **DWR should ensure that guidelines, tools, and technical assistance for an IWM approach include best management practices for flood management by 2017.** Improved guidelines and technical assistance would provide tools and incentives for local implementation.

9. **DWR should provide technical assistance to local flood management agencies that encourage an IWM approach.** Improved guidelines and technical assistance would provide tools and incentives for local implementation.

10. **Local, State, and federal agencies should work together to develop methodologies and data to perform regional risk assessments across the state by 2020.** These efforts will provide flood management agencies at all levels with the data and tools necessary to establish and achieve appropriate levels of flood protection. Goals should be based on the number of lives and value of property at risk, degree of urbanization, number of critical facilities, type of flood, and level of acceptable risk for the region.

11. **DWR, academic institutions, USACE, U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) should build on studies currently underway to develop a climate change report by 2017.** The report would focus on climate change and its impacts on flood hydrology, concentrating on local extreme events instead of average precipitation and temperature changes. Such a report would be valuable because it would provide additional localized information to the State and would address water and flood-related issues that will be affected by climate change, understanding that flooding is impacted more by extreme events and that potential future impacts might be more severe.

12. **By 2017, DWR should catalog, provide, and promote online information and resources about flood risk, grants, and other related topics in a comprehensive statewide database.** DWR should develop a comprehensive statewide database on flood management that builds on and enhances existing efforts. The database should be accessible to flood management agencies and tribal entities. The database should include:

    A. Natural floodplain resources.

    B. Land use and watershed boundaries.

    C. Updated flood hazard areas.

    D. Floodplain mapping.

    E. Risk maps.

    F. Flood awareness information.

    G. Hydrologic, geomorphic, and climate change data and information.

    H. Relevant ecosystem information.

    I. Other relevant information.

    Easy access to data, case studies, budget information, and planning tools will improve local agency capabilities to identify opportunities for collaboration and integration. Additionally, online information resources should lead to an increase in the public's overall flood risk awareness.

13. **DWR should update the Flood Future Report by 2017 and every five years thereafter.** The update should cover:

    A. Risk assessment information.

    B. Regional planning efforts including prioritized projects.

    C. Flood readiness.

    D. Flood awareness initiatives.

    E. Land use decision-making.

    F. Agency alignment efforts in the context of IWM.

G. Flood-related funding needs.

H. Discussion of revisions to the recommendations to improve flood management.

14. **With input for local agencies, State and federal agencies should develop a methodology, including indicators and metrics, for evaluating regional or systemwide benefits by 2017.** The methodology should quantify benefits, such as ecosystem restoration, recreation and open space, water supply, groundwater recharge, sustainability, and community/social benefits.

15. **By 2017, local, State, and federal agencies should identify data and forecasting needs, including cost estimates, for emergency management.** Accurate and timely forecasts for flood events can increase warning time, save lives, and reduce property damage. Additional data will help improve the readiness and response to floods. Providing data and tools to improve system operations will improve overall management of natural and human-made flood systems.

16. **By 2017, DWR should release the next update of the Central Valley Flood Protection Plan.** Updates to the CVFPP will be prepared by DWR and its partner agencies (including USACE, the Central Valley Flood Protection Board, and local agencies) every five years, following adoption of the first CVFPP by the Central Valley Flood Protection Board in 2012.

Improve Public and Policy-Maker Awareness and Understanding of Flood Risk

17. **By 2017, DWR should develop and disseminate educational outreach materials targeted for local governments and the public that clearly explain flood risks and measures that can reduce these risks.** Materials should include explanations of urban levels of flood protection, the limited role of FEMA 100-year floodplain maps, the role of the 2007 flood legislation, and types of actions for flood risk-reduction actions that are available to communities (nonstructural, natural floodplain function restoration, structural approaches, and emergency management).

18. **By 2017, DWR, in collaboration with local governments and organizations that represent flood management and land use professionals, should be developing land use planning principles and criteria that will help local planning agencies and decision-makers in conducting prudent land use planning.** These principles should be promoted as best management practices to increase prudent land use planning. These principles should promote preservation of existing floodplains and restoration of natural floodplain functions, where feasible. The planning principles should recognize unique differences of rural, suburban, and urban California. These best management practices should include definition of the philosophy to “minimize adverse environmental impact” for project planning.

19. **By 2017, local, State, and federal agencies and tribal entities should establish processes to leverage existing flood management awareness initiatives, data, and share outreach programs tools, templates, and other resource materials to local agencies.**

Strengthen Agency Alignment

20. **Local, State, and federal agencies should pursue a regional permitting process to avoid limitations of compensatory mitigation, allow more landscape restoration opportunities, and facilitate more efficient permitting processes for project execution.**

21. **By 2017, local, State, and federal agencies should develop a plan to conduct regular flood emergency preparedness and response exercises statewide and increase participation among public agencies at all levels in flood fight training.** Regular training, tabletop drills, and participation in training and functional exercises are a necessary part of disaster preparedness.

22. **By 2015, local, State, and federal agencies should work together to identify regional flood planning areas.** Flood management planning areas are needed throughout the state with boundaries that are systemwide, watershed-based where feasible, and consistent with existing federal and State agency boundaries, including existing IRWM funding areas and existing CWP planning areas. By organizing regional planning areas hydrologically, these areas would be better able to address issues that impact a united group of stakeholders. Also, such areas would enable the complex array of flood management agencies to begin working together to resolve common issues on a regional basis.

23. **By 2020, State and federal agencies should realign existing internal processes to support regional groups that undertake regional flood planning by addressing statutes that impede this realignment.** State and federal agencies can modify internal agency processes and programs that would assist local agencies in expediting project delivery and promoting multi-benefit projects. This effort should include the development of common terminology for State and federal programs, which would help agencies communicate the various aspects and benefits of multiple-objective projects, as well as remove the statutes that impede agency alignment.

24. **By 2017, resource agencies should collaborate to develop a permitting guidebook that includes a description of relevant permits, permit applications, and permitting guidance.** The guidance would include a description of the types of permits that are required for flood management projects and guidelines for when such permits are needed, explicit lists of what information permitting agencies require to issue these permits, and explanations of how and when to coordinate with regulatory agencies for project-specific and regional permitting approaches.

25. **By 2017, when issuing permits for flood facility maintenance or improvement projects, resource agencies should give priority to those projects where immediate action is needed and to those projects that provide the greatest long-term benefits to protect lives, property, and sensitive habitats.** Resource agencies should jointly develop regulatory guidance for issuing regional permits for flood control/stormwater conveyance maintenance or improvement activities, including consistent mitigation requirements for such projects. Resource agencies should develop guidance for expedited processes and/or appropriate exemptions, based on the California Environmental Quality Act, for emergency flood management activities and for flood control facility improvement projects that have minor wetland impacts.

References

References Cited

California Department of Water Resources. 2006. *Progress on Incorporating Climate Change into Management of California's Water Resources*. Sacramento (CA): California Department of Water Resources. Technical Memorandum Report. 339 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/DWRClimateChangeJuly06.pdf.

California Department of Water Resources, U.S. Army Corps of Engineers. 2013. *California's Flood Future: Recommendations for Managing the State's Flood Risk*. Sacramento (CA): Public Draft. 148 pp. Viewed online at: http://www.water.ca.gov/sfmp/resources/PRD_FFR_4-3-13MainRPT.pdf.

Dettinger M. 2011. "Climate change, atmospheric rivers, and floods in California – A multimodel analysis of storm frequency and magnitude changes." Journal of the American Water Resources Association. Volume 47, Issue 3. Pp. 514-523.

Additional References

Federal Emergency Management Agency. 2010. *Floodplain Management Requirements, A Study Guide and Desk Reference for Local Officials, Unit 1: Floods and Floodplain Management*. Washington (DC): Federal Emergency Management Agency. 32 pp. Viewed online at: http://www.fema.gov/library/ assets/documents/6417?id=2165. Accessed: July 12, 2012.

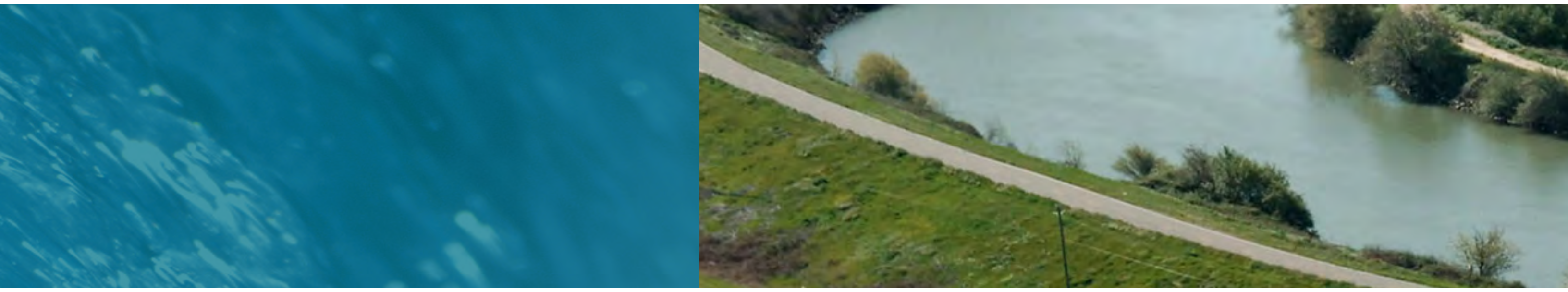
———. 2012. National Flood Insurance Program, Definitions. Washington (DC): Federal Emergency Management Agency. [Web site.] Viewed online at: http://www.fema.gov/national-flood-insurance-program/definitions. Accessed: July 6, 2012.

Kelley Robert E. 1998. *Battling the Inland Sea*. Berkeley (CA): University of California Press. 420 pp.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 5

Conveyance — Delta



Miner's Slough, Sacramento-San Joaquin Delta. In the area near Ryer Island, levees along Miner's Slough protect the surrounding agricultural land and the island from flooding, the potential for which has increased due to subsidence of the surrounding land to a level lower than the waterway.

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The Delta — A Brief Overview

The Sacramento-San Joaquin Delta (Delta) is the confluence point of the Sacramento and San Joaquin rivers as water is naturally conveyed westward from upstream water basins to the bays connected to the Pacific Ocean (Figure 5-1). In its natural state, the Delta was a vast marsh and floodplain dissected by meandering channels and sloughs. Even in today's highly altered environment, the Delta remains a critical ecosystem and dynamic habitat that is home to hundreds of aquatic and terrestrial species, including many species endemic to the area and a number that are designated as threatened or endangered by the federal Endangered Species Act (ESA) and California Endangered Species Act (CESA).

The Delta is also a centerpiece of California's water system. The conveyance of water through the Delta supplies water for more than 25 million Californians. The water conveyed through the Delta also supports farms and ranches stretching from the north Delta to California-Mexico border, which collectively produce nearly half of the nation's domestically grown fresh produce and supports a $27 billion agricultural industry. In addition to being a key agricultural region itself and recreational destination, the Delta supports extensive infrastructure of statewide importance, such as aqueducts, natural gas pipelines, electricity transmission lines, railroads, shipping channels, and highways.

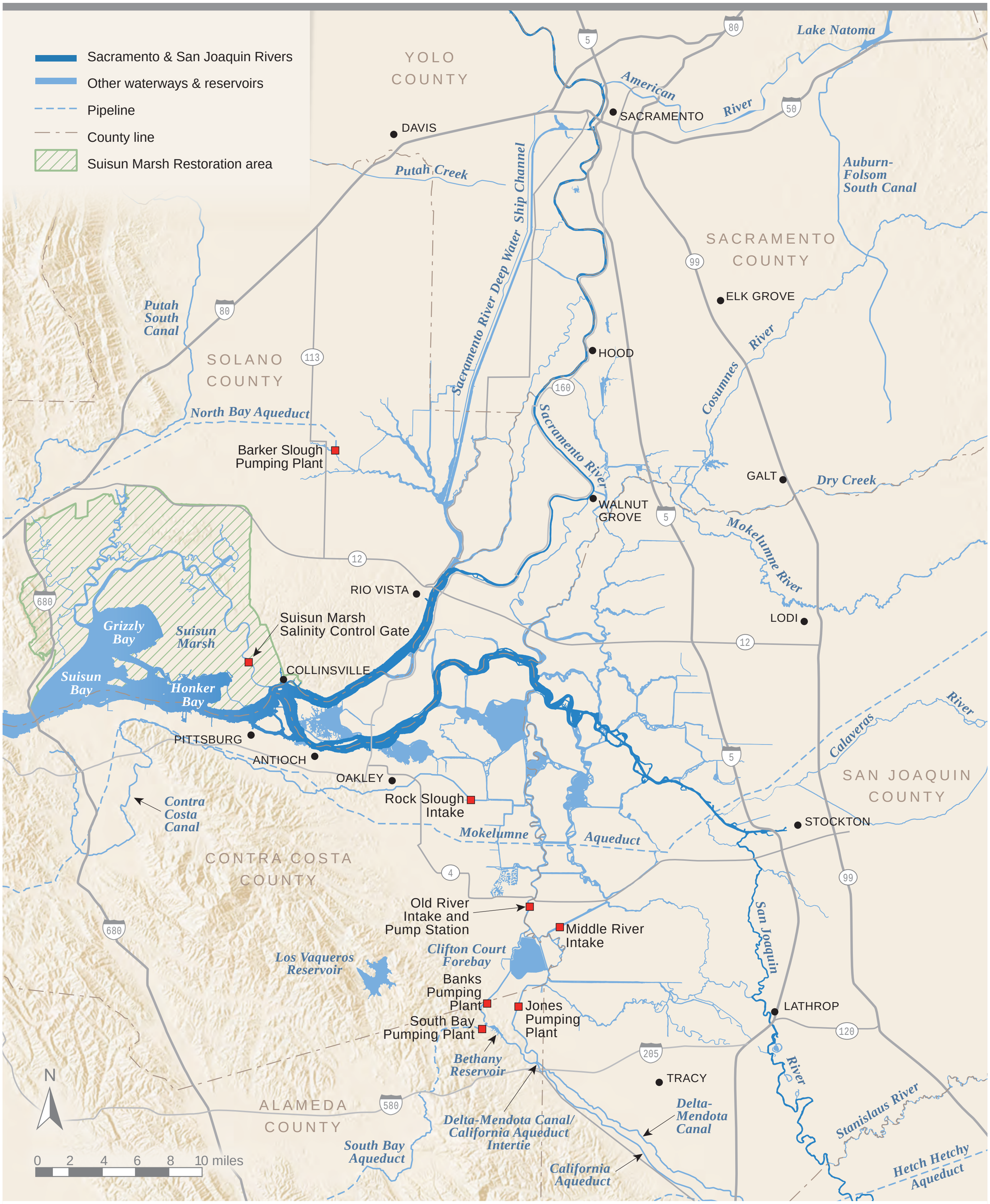
Infrastructure Changes to Delta Conveyance — A Brief History

Concerted efforts to control and redirect the flow of water through the Delta began as early as the 1850s. Early water supply diversion projects included the construction of the network of levees that facilitated the conveyance of water for agriculture and human consumption uses. The straightening, widening, and dredging of channels similarly increased shipping access to the Central Valley and improved downstream water conveyance for flood control.

California's post-World War II growth resulted in the planning and construction of two large-scale water projects with an emphasis on conveying water to develop and sustain California's agricultural economy and urban growth. The Central Valley Project (CVP), which was initiated in 1933 and is operated and maintained by the U.S. Bureau of Reclamation (USBR), is comprised of 20 dams and reservoirs with a combined storage capacity of more than 11 million acre-feet (maf), 11 power plants, and more than 500 miles of major canals and aqueducts. The CVP provides sufficient water to irrigate one-third of California's agricultural land and to meet the municipal and industrial needs of close to 1 million households annually.

The State Water Project (SWP), which was initially authorized by voters in 1960 and is operated and maintained by the California Department of Water Resources (DWR), is a complex system comprised of 20 pumping plants, five hydroelectric power plants, 34 storage reservoirs and lakes with combined storage capacity of approximately 5.8 maf, and approximately 700 miles of pipelines and canals. The SWP provides water for more than 20 million Californians, about 660,000 acres of irrigated farmland, and distributes water under contract to 29 urban and agricultural water suppliers (SWP contractors).

Figure 5-1 Sacramento-San Joaquin Delta



The Delta is a critical component of both water projects, which rely on the Delta conveyance system to provide water at their diversion facilities in the south Delta for use in the San Francisco Bay Area, the Central Valley, and Southern California. Other agencies and facilities, such as the Contra Costa Water District, the East Bay Municipal Utility District, the City of Stockton, and the Folsom South Canal also rely on the Delta as a source of supply or as a transportation corridor for their water supply facilities.

Current Diversion and Future Impacts on the Delta Ecosystem — A Brief Overview

Once a vast marsh and floodplain dissected by meandering channels and sloughs, the Delta provided a dynamic habitat for a rich diversity of fish, wildlife, and plants. The Delta of today has been altered by the construction of levees and reservoirs and dredged waterways to support farming and urban development, as well as to provide flood protection on lands that historically supported marshes and floodplains. The water flow in the Delta is also affected by the movement of water for operations of the SWP and CVP. Many other factors have compounded the alteration of the Delta and include:

- Introduction of invasive non-native fish, wildlife, and plant species.
- Barriers to fish migration.
- Changes in Delta water quality constituents.
- Turbidity and toxicity from both natural and human sources.
- Unscreened power plant and agricultural diversion.
- Illegal fish harvesting.
- Improper fish hatchery management practices.

The Delta's future will be affected by increasing land subsidence, heightened seismic risk, and possible effects of climate change that include rising temperatures, changes in runoff timing, sea level rise, and changes in storm timing, intensity, and frequency.

In this highly altered environment, several native and non-native fish species have declined to the lowest population numbers in their recorded histories. In response, federal regulatory actions to protect threatened and endangered fish species have limited through-Delta conveyance and have made water supplies increasingly variable.

The Bay Delta Conservation Plan (BDCP) — Achieving the Coequal Goals of Ecosystem Restoration and Water Supply Reliability

Brief History and Purpose of the BDCP

During the past several decades, the increasing demand for the Delta's resources has escalated the conflict between the needs of water users and the efforts to sustain the estuary's aquatic ecosystem and support the protection of State and federally threatened or endangered fish. These conflicts have led to a crisis regarding the ability to protect Delta fisheries, maintain water quality, and meet the needs of both in-Delta and export area agricultural and municipal water users. This situation has resulted in the need to address these competing beneficial uses and sustainability concerns.

The Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act) mandates developing a comprehensive Delta management plan (Delta Plan) with the coequal goals of (1) protecting, restoring, and enhancing the Delta ecosystem, and (2) providing a more reliable water supply for California. The proposed Bay Delta Conservation Plan (BDCP) is anticipated to be the 50-year comprehensive conservation strategy component of the Delta Plan.

The Delta Reform Act establishes the framework to achieve the coequal goals of providing a more reliable water supply and restoring and enhancing the Delta ecosystem. The coequal goals will be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta. The Delta Reform Act creates the Delta Stewardship Council, ensures the California Department of Fish and Wildlife and the State Water Resources Control Board identify the water supply needs of the Delta estuary for use in determining the appropriate water diversion amounts associated with the BDCP, establishes the Sacramento-San Joaquin Delta Conservancy to implement ecosystem restoration activities within the Delta, restructures the current Delta Protection Commission, and appropriates funding from Proposition 84.

The Delta Stewardship Council adopted the Delta Plan, which furthers the coequal goals of Delta restoration and water supply reliability, which includes determining the consistency of the BDCP with coequal goals.

The BDCP is being developed in compliance with the federal ESA, the CESA, and the Natural Community Conservation Planning Act (NCCPA). The BDCP's comprehensive conservation plan is also undergoing intensive environmental review in the form of both a State Environmental Impact Report (EIR) and a federal Environmental Impact Statement (EIS). The EIR and EIS will evaluate the conservation plan's impact on all aspects of the environment and will identify alternatives and mitigation actions.

Delta Ecosystem Restoration and Protection — The Conservation Plan

The federal and State ESAs presently regulate the operational impacts of the SWP and CVP on a species-by-species basis. The BDCP is a joint habitat conservation plan (HCP) and Natural Community Conservation Plan (NCCP) that seeks to improve the health of the Delta's ecological system using a comprehensive conservation strategy to address the collective impacts associated with the SWP, CVP, and certain existing and anticipated future actions within the area covered by the BDCP. The BDCP takes into account multiple stressors on the ecosystem, the needs of multiple species, and the diverse natural communities that support them, including species listed under the federal and State ESAs as threatened, endangered, or candidates for listing, inclusive of habitat, if any, designated for these species.

The BDCP aims to enhance the Delta's ecosystem processes and function, including seasonal floodplain habitat, intertidal and associated subtidal habitat, hydrologic conditions, and salinity within the Delta estuary including a reduction in the direct loss of fish and other aquatic organisms. Specific problems to be addressed include the reconnection of floodplains, the development of new tidal marsh habitat, the restoration of river banks to a more natural state, invasive species control, decreasing water toxicity levels, and modifying water operations to include attributes of more natural seasonal flow patterns.

An overriding goal of the BDCP is to contribute to the recovery of at-risk species in the Delta. The BDCP seeks to accomplish this goal by identifying specific conservation and management actions, or conservation measures, to improve habitat conditions within the Delta's natural communities. The overall BDCP conservation strategy includes 22 conservation measures that are designed to achieve biological goals and objectives specific to 11 conservation zones comprising the Delta.

BDCP — Taking Conveyance a New Direction

Central to the BDCP is the proposal to develop an improved conveyance system. Specifically, the BDCP proposes the creation of dual water conveyance delivery system comprised of the existing (through-Delta) conveyance and a new conveyance system that will route water through an isolated facility conveyance system to be exported via the SWP and CVP. As proposed, the North Delta Diversion would become the primary diversion point and would be subject to water delivery operation rules. The new facility would help meet the coequal goals of the Delta Plan by providing for a more reliable supply of water while simultaneously maintaining sufficient bypass flows for State and federally listed species of concern.

Water Supply Reliability

There are many factors that influence water supply reliability. The distribution of precipitation and water demand in California is unbalanced because most of the state's precipitation falls in the north and a substantial amount of the state's water demand is south and west of the Delta. This includes irrigation water for southern Central Valley agriculture, and municipal and industrial uses in Southern California and the Bay Area. Additionally, federal- and State-mandated regulatory actions to protect threatened and endangered species in the Delta have further limited the levels of through-Delta water conveyance, which makes available water supplies even more unreliable.

To compound these challenges further, the Delta is not a static ecological system and fundamental changes are certain to occur. The anticipated effects of climate change indicate elevated sea levels, altered annual and inter-annual hydrological cycles, changed salinity, and water temperature regimes in and around the Delta, and accelerated shifts in species composition and distribution. These changes further add to the difficulty of resolving the increasingly intensifying conflict between the ecological needs of at-risk Delta species and natural communities and the need to provide adequate and reliable water supplies for people, communities, agriculture, and industry. Anticipating, preparing for, and adapting to these changes are key underlying drivers associated with implementation of the proposed BDCP.

Existing Delta conveyance does not provide long-term reliability to meet current and projected needs. Conveyance through the Delta during drought is especially challenging considering the various demands from agriculture, municipalities, and environmental regulations. To improve through-Delta conveyance water supply reliability, provide greater operational flexibility, and improve ecosystem function, improvements to existing facilities should be made. These improvements include updating aging infrastructure, increasing existing capacities, adding redundancy to the system, constructing additional facilities, and restoration of habitat may be needed.

The major issues pertaining to reliability of water supply transferred through the Delta include the following items:

- The health of the Delta ecosystem is paramount considering water-related activities within the Delta. Continuing declines in some native species populations migrating through or living in the Delta, such as salmon and delta smelt, highlight the increasing influence of the Delta ecosystem on water supply reliability. Any activity proposed for Delta conveyance will need to consider the restoration and preservation of native habitat.
- The integrity of more than 385 miles of Project levees (State Plan of Flood Control facilities) and over 730 miles of non-Project levees (neither State Plan of Flood Control facilities nor other State-federal flood protection facilities) throughout the Delta is continually tested by such elements as storm events creating floods and seawater surges, island subsidence, natural levee erosion, poor quality peat soils used to build the original levees, seismic activity, burrowing animals, and sea level rise. (For a discussion of Project and non-Project levees, see *Delta Levees Special Flood Control Projects,* at http://www.water.ca.gov/floodsafe/fessro/docs/special_guidelines2014.pdf.)
- Maintaining optimal water quality within the Delta for both drinking water and for native species habitat is paramount. Control of water quality in a tidal estuary with seasonal and yearly fluctuating hydrology will require well-understood and adaptive strategies. As water quality requirements can vary, and at times conflict among users, the challenge will be to agree upon the implementation strategy.
- Maintenance of in-Delta projects for beneficial uses such as recreational boating and swimming, sport fishing, shipping, and agriculture, industrial, and drinking water supply will be an ongoing management challenge as political and fiscal climates evolve and resources for competing priorities become scarcer.

Potential Benefits

Implementation of the proposed dual conveyance will enhance the operational flexibility. The use of an alternative conveyance strategy will also allow for the restoration of a more natural flow from east to west toward the Pacific Ocean.

Key beneficial effects of the BDCP:

- Improve south Delta flows.
- Protect and restore more than 100,000 acres of natural communities to promote improved ecosystem function.
- Increased climate change adaptation in the Plan Area.
- Reduce other stressors such as stranding, invasive aquatic species, localized predation, and low dissolved oxygen.

Net beneficial effects on fish species:

- Increase suitable habitat such as restored tidal and channel margin habitat.

- Increase food sources and availability from restored habitat.
- Decreased entrainment.
- Reduced entry into interior Delta.
- Reduced predation.
- Reduced illegal harvest.

Potential Costs

Dual Conveyance — Implementation Costs and Funding Sources

A detailed discussion of the estimated costs associated with the implementation of the BDCP over the proposed 50-year term of the conservation plan is in Chapter 8 of the proposed BDCP at http://baydeltaconservationplan.com/.

Major Implementation Issues

While conservation plans like the BDCP are meant to be beneficial to the environment, specific actions in the plan can have an impact on natural and human environments. These impacts must be evaluated and actions identified to mitigate them. State and federal environmental laws require a review of potential impacts of the BDCP before it is approved and implemented.

The BDCP Environmental Impact Report/Environmental Impact Statement (EIR/EIS) was prepared in compliance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA).

The term "mitigation," as used in the EIR/EIS, refers to measures used to reduce environmental impacts after considering all of the environmental commitments described for each resource. The BDCP EIR/EIS was released for a 120-day public review on December 13, 2013.

Climate Change

Northern California is expected to experience changes to the physical environment as a result of climate change. It is expected that climate change will result in more precipitation falling as rain rather than snow, leading to reduced snowpack, earlier snowmelt, and reduced river flows and reservoir storage in summer, causing changes to the seasonal timing of flows in rivers. Air temperatures will continue to rise, which will increase water temperatures. Accelerated rates of relative sea level rise will increase the intrusion of seawater into the upper estuary and when combined with an increase in coastal storms, storm surge, and river runoff will increase shoreline flooding and erosion. Sea level rise will continue to threaten infrastructure, increase flooding at the mouths of rivers, place additional stress on levees in the Delta, and will intensify the difficulty of managing the Delta as the heart of the state's water supply system.

Adaptation

Both the increase in winter runoff and more intense storm events that are anticipated with climate change may require larger conveyance capacity and reservoir storage to manage water successfully for flood risk reduction and water supply reliability. Delta conveyance improvements can provide additional resiliency for minimizing these impacts while providing more flexibility in managing water supplies and reducing flood risk, while achieving the coequal goals. Expected climate change adaptation benefits of Delta conveyance improvements include:

- Enhanced ecosystem services through restoration of wetlands, floodplains, and riparian habitats will restore ecosystem services that benefit humans as well as ecosystems.
- Increased protection of upland habitat and structures from flooding and storm surges due to sea level rise.
- Improved floodplain connections to rivers to restore the ability of floodplains to absorb flood flows and to provide a water reservoir to help aquatic species withstand droughts.
- Increased resilience to invasive species from creation of seasonally inundated floodplains by increasing numbers and health of native species and excluding invasive species.
- Increased habitat variability helping to support species diversity by providing a mosaic of habitats that can be used by different species that have evolved to use specific habitats.
- Increased habitat complexity from wetland restoration, which will include networks of channels within marshes that are used by fish for foraging, refuge, and movement in and out of the marsh.
- Increased habitat patch size and connectivity through the protection and restoration of a variety of natural communities. Increasing patch size will tend to increase population sizes of native species, which provides more resiliency against a changing climate.
- Additional flexibility in managing water supplies under more frequent dry conditions and periods of prolonged drought.

Mitigation

Despite the overall positive benefits of the BDCP Conservation Strategies, implementation will result in some negative impacts. For example, there are tradeoffs between BDCP environmental benefits with its negative impacts on greenhouse gas (GHG) emissions from construction as well as potential indirect project effects from growth and development. As stated in the EIR/EIS, BDCP will develop a GHG Mitigation Program prior to the commencement of any construction or other physical activities associated with water facilities and operations that would generate GHG emissions. The GHG Mitigation Program will consist of feasible options that, taken together, will reduce construction-related GHG emissions to net zero (i.e., emissions will be reduced to the maximum extent feasible and any remaining emissions from the project will be offset elsewhere by emissions reductions of equal amount). The BDCP proponents will determine the nature and form of the components of the GHG Mitigation Program after consultation with the various local air control agencies.

As a part of ongoing operations of the Delta conveyance, improving conveyance system efficiency could reduce energy use in pumping plants, power supply, and water diversion, which contributes to GHG reduction for climate change mitigation. Furthermore, promoting water conservation, efficiency, and sustainable use will also reduce energy use for GHG reduction that is beneficial for climate change mitigation.

Recommendations

As one of California's most invaluable natural resources, the Delta has been stretched to the breaking point. The Delta ecosystem is in steep decline, which jeopardizes the native fish and wildlife species, threatens reliable water supplies for millions of Californians, and puts the state's broader economy at serious risk. To reach the coequal goals necessary to successfully improved Delta conveyance, the following recommendations include:

1. Legally acknowledge the coequal status of restoring the Delta ecosystem and creating a more reliable water supply for California.
2. Recognize and enhance the unique cultural, recreational, and agricultural values of the Delta as an evolving place.
3. Restore the Delta ecosystem as the heart of a healthy estuary.
4. Promote water conservation, efficiency, and sustainable use.
5. Build facilities to improve the existing water conveyance system and expand statewide storage, and operate both to achieve the coequal goal.
6. Reduce risks to people, property, and state interests in the Delta by effective emergency preparedness, appropriate land uses, and strategic levee investments.
7. The California Urban Water Management Planning Act requires urban water suppliers to adopt water management plans every five years and submit to DWR. In these plans, urban water suppliers must assess whether their current and planned water supplies will be enough to meet the water demands during the next 20 years. DWR is required to review local water management plans and report on the status of these plans.
8. The Water Conservation Act of 2009 includes distinct requirements related to both urban and agricultural water use. DWR is required to report on progress toward meeting urban per-capita water use goals.
9. Through its Agricultural Water Management Planning and Implementation Program, DWR helps water districts develop agricultural water management plans and implement cost-effective efficient water management practices.
10. DWR will participate in workshops and technical discussions about managing for extreme drought and floods.

References

References Cited

None.

Additional References

CALFED Bay-Delta Program. 2007. *Draft CALFED End of Stage 1 Staff Report.* Sacramento (CA): Bay-Delta Authority. 27 pp. Viewed online at: http://www.calwater.ca.gov/content/Library/EndofStage/Draft_EOStage_1_11-8-07.pdf.

———. 2008. *Final Draft CALFED Bay-Delta Program Conveyance Program Plan – Year 9.* Sacramento (CA): Bay-Delta Authority. 18 pp. Viewed online at: http://calwater.ca.gov/content/Documents/library/ProgramPlans/2008/Conveyance_Program_Plan_Year_9.pdf.

CALFED Bay-Delta Science Program. 2008. *State of the Bay-Delta Science.* Sacramento (CA): Bay-Delta Authority. 186 pp. Viewed online at: http://www.science.calwater.ca.gov/pdf/publications/sbds/sbds_final_update_122408.pdf.

California Department of Water Resources. 2007. *Delta Conveyance Improvement Studies Summary Report. Franks Tract, Through-Delta Facility, and Delta Cross Channel Reoperation Projects.* Sacramento (CA): California Department of Water Resources. Bay-Delta Office, Delta Conveyance Branch. 51 pp. Viewed online at: http://www.water.ca.gov/frankstract/docs/Delta_Conveyance_Summary_Report_121007.pdf.

———. 2007. *Value Planning Study Final Report. Through Delta Facility*. Sacramento (CA): California Department of Water Resources. Bay-Delta Office, Delta Conveyance Branch. 167 pp. Viewed online at: http://baydeltaoffice.water.ca.gov/ndelta/TDF/documents/Through%20Delta%20Facility%20Final%20VE%20Report.pdf.

———. 2007. *Draft Summary Report. Phase 1: Risk Analysis*. Delta Risk Management Strategy (DRMS). Sacramento (CA): California Department of Water Resources. 50 pp. Viewed online at: http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/phase1_information.cfm.

———. 2008. *An Initial Assessment of Dual Delta Water Conveyance.* Final Draft. Sacramento (CA): Prepared for the Delta Vision Blue Ribbon Task Force by the California Department of Water Resources. 40 pp. Viewed online at: http://www.deltavision.ca.gov/BlueRibbonTaskForce/April2008/Handouts/Item_5d_Report.pdf.

———. 2009. *California Water Plan Update 2009*. Volume 2, Chapter 4: Conveyance. Sacramento (CA): California Department of Water Resources. 18 pp. Viewed online at: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2c04_deltaconvey_cwp2009.pdf.

———. 2012. Central Valley Flood Management Planning (CVFMP) Program. Sacramento (CA): California Department of Water Resources [Web site]. Viewed online.at http://www.water.ca.gov/cvfmp/2012cvfpp.cfm

California Natural Resources Agency. 2009. *Bay Delta Conservation Plan EIR/EIS. Chapter 3: Conservation Strategy*. Sacramento (CA): California Natural Resources Agency. Viewed online at: http://baydeltaconservationplan.com/Library/Library_EnvironmentalReview.aspx#EIREISDraftChaptersForReview. Accessed: Dec., 2009.

———. 2010. Bay Delta Conservation Plan. Highlights of the Bay Delta Conservation Plan. December 2010. Sacramento (CA): California Natural Resources Agency. 92 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Highlights_of_the_BDCP_FINAL_03-17-11.sflb.ashx.

———. 2012. Bay Delta Conservation Plan 2011 Accomplishments. Sacramento (CA): California Natural Resources Agency. 8 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_2011_Accomplishments_Brochure.sflb.ashx.

———. 2012. Bay Delta Conservation Plan EIR/EIS. Chapter 1: Introduction. Administrative Draft. Sacramento (CA): California Natural Resources Agency. 29 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/EIR-EIS_Chapter_1_-_Introduction_2-29-12.sflb.ashx.

———. 2012. Bay Delta Conservation Plan EIR/EIS. Chapter 2: Project Objectives and Purpose and Need. Administrative Draft. Sacramento (CA): California Natural Resources Agency. 7 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/EIR-EIS_Chapter_2_-_Project_Objectives_and_Purpose_and_Need_2-29-12.sflb.ashx.

———. 2012. Bay Delta Conservation Plan EIR/EIS. Chapter 3: Description of Alternatives. Administrative Draft. Sacramento (CA): California Natural Resources Agency. 133 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/EIR-EIS_Chapter_3_-_Description_of_Alternatives_2-29-12.sflb.ashx.

———. 2012. Bay Delta Conservation Plan. Chapter 1: Introduction. Administrative Draft. Sacramento (CA): California Natural Resources Agency. 49 pp. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Chapter_1_-_Introduction_2-29-12.sflb.ashx.

———. 2012. Bay Delta Conservation Plan. Chapter 2: Existing Ecological Conditions. Administrative Draft. Sacramento (CA): California Natural Resources Agency. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Chapter_2_-_Existing_Ecological_Conditions_2-29-12.sflb.ashx.

———. 2012. Bay Delta Conservation Plan. Chapter 8: Implementation Costs and Funding Sources. Administrative Draft. Sacramento (CA): California Natural Resources Agency. Viewed online at: http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/BDCP_Chapter_8_-_Implementation_Costs_and_Funding_Sources_2-29-12.sflb.ashx.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 6

Conveyance — Regional/Local

Alameda County. This intertie project connects the Delta-Mendota Canal and the California Aqueduct via a new pipeline and pumping plant to restore the Delta-Mendota Canal conveyance to 4,600 cubic feet per second to achieve multiple benefits.

Contents

Chapter 6. Conveyance — Regional/Local

Conveyance provides for the movement of water, geographically connecting the supply to the demand. Conveyance infrastructure includes natural watercourses as well as human-made facilities like canals, pipelines, and flood bypasses. Examples of natural watercourses include streams, rivers, floodplains, and groundwater aquifers. Conveyance facilities range in size from small, local, end-user distribution systems to the large systems that move water to and from distant areas. Conveyance facilities also require associated infrastructure such as pumping plants, diversion structures, fish ladders, and fish screens. Regional and local water supply conveyance is discussed in this chapter. For a discussion of flood conveyance systems and integrated flood management, see Chapter 4, "Flood Management," of this volume.

Conveyance in California

Most of California's precipitation occurs in Northern California, and most of the demand is in Southern California. Delivering the supply to meet the demand requires some of the largest water conveyance systems in the nation. An extensive system of regional and interregional conveyance facilities in the state moves water from a source location to an area where it is used and conveys excess flood flows safely to protect existing resources.

Sacramento-San Joaquin Delta Conveyance

The Sacramento-San Joaquin Delta (Delta), located at the confluence of the Sacramento and San Joaquin rivers, is a critical element of both regional and interregional conveyance systems. The Delta's waterways are interconnected natural streams, sloughs, and constructed canals. The Delta waterways serve as a hub to move water from the drainage basins of the Sacramento and San Joaquin rivers to bays eventually leading out to the Pacific Ocean. The Delta is heavily relied upon to convey water for in-Delta diversions as well as exports for use in the San Francisco Bay area, the San Joaquin Valley, Central Coast, and Southern California. A more thorough discussion of Delta conveyance issues is in Chapter 5 of this volume.

Interregional Conveyance

California has an extensive system of conveyance facilities that move water throughout the state by a combination of natural waterways and constructed facilities. The two largest interregional conveyance projects in California are the State Water Project (SWP) and the federal Central Valley Project (CVP). Both the SWP and the CVP use natural rivers such as the Sacramento, San Joaquin, and Feather as well as the Delta for conveyance. In addition, they rely upon entirely human-made conveyances such as the California Aqueduct, the Delta-Mendota Canal, the Friant-Kern Canal, and the Madera Canal. These natural and human-made conveyances deliver water to a broad array of agricultural water agencies in Northern California and the San Joaquin Valley as well as urban water agencies in the Sacramento Valley, San Francisco Bay area, Central Coast, and Southern California. For a map that shows the extensive conveyance systems throughout the state, see Chapter 7, Figure 7-1, "Location of Local, State, and Federal Water Projects."

Local agencies have also developed a number of interregional conveyance systems. For example, the East Bay Municipal Utility District and the San Francisco Public Utilities Commission have developed major conveyance systems that transport water from Sierra Nevada rivers directly to their service areas. The Los Angeles Department of Water and Power developed and operates the Los Angeles Aqueduct to convey water from the Owens Valley to Los Angeles. A major Southern California water source continues to be Colorado River water which is diverted and distributed via the All-American Canal, the Coachella Canal, the Palo Verde Canal, and Metropolitan Water District's Colorado River Aqueduct. Each of these conveyance systems is a major distributor of California's water supplies and plays a key role in maintaining California's overall water supply reliability.

Regional Conveyance

At the local level, water is distributed from locally developed sources to the end users located within the same watershed or river system. Existing regional, multi-agency conveyance projects exist in all urban regions of California, particularly the San Francisco Bay area and the Southern California regions surrounding the Los Angeles and San Diego areas. These systems often include emergency interconnects between various agencies, which can be used in events such as earthquakes and fires to transport water when the normal pipelines are inadequate to meet emergency needs or when one delivery system has been taken out of service.

Conveyance systems are necessary to achieve benefits from virtually every other facet of local and regional water management such as desalination, recycling, and water transfers as well as both surface and groundwater storage. Water supplies are of no use without an extensive network of interregional conveyance systems to distribute imported or locally produced water to the end users for immediate use or to storage for future use.

Potential Benefits

Regional and interregional conveyance facilities can provide benefits to flood management, consumptive and non-consumptive environmental uses, water quality improvement, recreation, operational flexibility, groundwater basin conjunctive uses, and both urban and agricultural water management.

The main benefits of conveyance to the urban, agricultural, and environmental water-use sectors are in maintaining or increasing water supply reliability, protecting water quality, augmenting current water supplies, and providing water system operational flexibility. Improvements in system conveyance capacity can be achieved by locating and widening bottlenecks that constrict the movement of water. For example, improved conveyance capacity can increase the amount of available surplus water or exchange water that can be transported for immediate use or stored in a local conjunctive use project, which will enhance the capabilities of groundwater recharge. See Chapter 9 of this volume for a comprehensive discussion of various types of conjunctive water use projects and concepts in California. For the environmental sector, benefits from improved conveyance capacity can be integrated into project design in order to support stream restoration goals such as improved in-stream flows, appropriate water temperatures for fish, channel maintenance, and water quality for aquatic and riparian habitat.

In some cases, improving the reliability of existing water supplies can be just as valuable as increasing overall supply. A system is unreliable when it cannot provide the water when and where it is needed. Conveyance capacity improvements can enhance reliability without augmenting supplies by increasing operational flexibility to move water between storage locations and points of use. For example, water agencies in the Los Angeles, San Diego, and the San Francisco Bay regions have been constructing alternative pipeline transmission facilities between reservoirs in different locations to provide system flexibility and prevent stranded service areas in an earthquake emergency.

Other types of benefits from improved conveyance include:

- Facilitating the movement of water for storage and ultimately to the end users. In order for water to be developed from new groundwater conjunctive use or off-stream surface storage, diversion facilities must have adequate conveyance capacity to fill the storage. Also, facilities must then be in place to convey the water releases from storage to the users at the right times and flow rates.
- Improving water quality by transporting more river water when water quality conditions are high (minimal turbidity and contaminants) and reducing water diversions when water quality is poor.
- Enabling diversions of more water during high river flows with less competitive use periods, and consequently reducing the pressure to divert water during low flow, highly competitive use periods. Given the high-intensity, short duration characteristics of California's hydrology, improved conveyance capacities combined with adequate surface water or groundwater storage make beneficial diversions possible for metered release later in the year. This concept is sometimes referred to as the gulp and sip strategy.
- Providing the operational flexibility to divert and move water at times that are less harmful to fisheries.

Other specific benefits of conveyance improvements are listed below.

- Enlarged and enhanced conveyance systems can increase flood control capability with higher and more controlled flow through the river basins, while increased surface storage retention ponds will decrease the magnitude of peak storm event outflows.
- Conveyance management practices such as spreading basins that slow overland storm event outflows can increase retention and thereby enhance groundwater recharge processes that have been hindered by sprawling impervious surfaces characteristic of urbanization.
- Effective incorporation of best management practices for storm water runoff, storm water retention basins, and grassy swales, for example, can reduce peak flows, contribute to groundwater recharge, and filter out non-point-source pollutants such as sediments and heavy metals. This, in turn, decreases the burdens on management for system conveyance, flood control, and water quality. Reducing peak discharge from heavy precipitation events in particular will decrease the demand on the conveyance system.
- Increases in resiliency to extreme events by employing interconnected conveyance systems can provide some redundancy to ensure continuation of services during a long-term drought or following a catastrophic event such as an earthquake.
- Reductions in operating costs results from enlarged conveyance capacity that allows pumping of water at optimal times to decrease the energy requirements at peak California energy demand periods.

- Improvements to instream and riparian habitat. Enlarged streams and channels for flood passage can incorporate habitat improvements that are designed with varying hydrology (including climate change) and operations.

Potential Costs

Potential conveyance costs vary significantly and can include both facility and operating costs which can be a significant portion of the costs in a water management system. These costs generally depend on how far the water needs to be conveyed, timing, and topography (for example, pumping vs. gravity flow). It costs less to convey water from DWR's Oroville Dam to the Delta via gravity flow through largely natural systems than to convey water from the Delta to Southern California through a constructed conveyance system with canals and pumps. With additional conveyance capacity, flexible management strategies can help control costs, for example, by moving water during off-peak energy demand periods when power costs are lower. Below are examples of significant conveyance projects and their costs.

- In 2010, the Contra Costa Water District (CCWD) finished construction of a screened intake on Victoria Canal in the Delta that would relocate some of CCWD's diversions to obtain better source water quality and shift diversions from a then unscreened Rock Slough intake. The total project cost, including planning, design and construction, was just less than $100 million.
- In 2011, the U.S. Bureau of Reclamation constructed a fish screen at Rock Slough which allows more use of the intake during high-flow, good water quality conditions rather than the more expensive CCWD Old and Middle River diversions. Water from the Delta is diverted at Rock Slough for the Contra Costa Canal which is CCWD's major water supply and delivery system. Rock Slough was one of the largest unscreened Delta diversions. Cost of the fish screen structure was about $26 million.
- The Freeport Regional Water Project (FRWP) was completed in 2010 settling a 40-year debate over East Bay Municipal Utility District's (EBMUD's) federal contract for American River water rights. The project is a cooperative effort between the Sacramento County Water Authority (SCWA) and EBMUD to supply surface water from the Sacramento River to customers in central Sacramento County and the East Bay in Alameda and Contra Costa County. SCWA and EBMUD share a screened intake capacity of 185 million gallons per day (mgd). SCWA will receive 85 mgd. EBMUD will receive 100 mgd in dry years to supply its customers in the San Francisco Bay area. The intake, fish screen, pumps, canals, and 17-mile pipeline connecting to EBMUD's Mokelumne Aqueducts cost approximately $1 billion.
- The CVP/SWP intertie project connects the Delta-Mendota Canal and the California Aqueduct via a new pipeline and pumping plant to restore the Delta-Mendota Canal conveyance to 4,600 cubic feet per second (cfs) which improves CVP water deliveries to south of Delta contractors, provides capability to more frequently fill CVP San Luis earlier in the water year, allows for maintenance and repair activities, and provides the flexibility to respond to CVP and SWP emergency water operations. The project went online in the spring of 2012 at a cost of $20 million.
- In an effort to increase water delivery flexibility, the Cross Valley Canal (CVC) was constructed in 1975 to deliver State Water Project (SWP) water from the California Aqueduct to urban Bakersfield. The delivered water is then used for agricultural, municipal, and water recharge purposes. The Kern County Water Agency contracted with various water districts for CVC construction and operation. The first 17 miles of its 21.5-mile length are concrete-lined to minimize water losses while the remaining section is unlined to facilitate ongoing

percolation (recharge) to the aquifer. In 2005, the CVC Expansion Project began in an effort to increase the ability to accept imported water from the SWP. This represents incredible infrastructure, with the CVC connecting to the California Aqueduct, local groundwater banking projects, Kern County Water Agency's Henry C. Garnett Water Purification Plant, and the Friant-Kern Canal. The expansion was completed in January 2012 at a cost of approximately $78 million.

- The Red Bluff Fish Passage Project was completed in the winter of 2012 and consists of a screened replacement intake on the Sacramento River for the Tehama-Colusa and Corning canals. The screens replace the operation of the Red Bluff Diversion Dam, which was an impediment to several salmonid species and green sturgeon recently listed under the Endangered Species Act. The screened pumping plant improves fish passage conditions while ensuring continued water deliveries to 150,000 acres of high-value cropland. New project features include construction of a flat-plate fish screen, intake channel, 2,500 cfs capacity pumping plant, access bridge, and discharge conduit to divert water from the Sacramento River into the Tehama-Colusa and Corning canals. These new features maintain and ensure conveyance capacity into the future. This joint project between the U.S. Bureau of Reclamation and the Tehama-Colusa Canal Authority cost approximately $190 million.

Major Implementation Issues

Managing California's water conveyance systems requires persistent efforts to address chronic issues, such as maintenance of an aging infrastructure, while simultaneously addressing new issues, such as direct and cumulative impacts to fish, wildlife, and environmental habitat (refer to Chapter 8, "Water Transfers," under the heading "Recommendations for Water Transfers" for more information). Along natural waterways and rivers, significant issues involve flooding impacts to adjacent lands and levee maintenance.

Maintenance

It is essential, at a minimum, to maintain the current level of conveyance capacity for both natural and constructed facilities. Substantial reinvestment will be required just to maintain the current level of benefits due to aging infrastructure and diminishing conveyance capacity in natural watercourses. Diminishing conveyance capacity is also a problem for flood management facilities such as bypasses that, over time, fill with silt, debris, and plant growth that reduce the effectiveness for passing floodwaters. The cost of maintenance is likely to become more significant over time due to the increasingly higher costs and the increasing ecosystem and population demands.

Science and Planning

Water managers, planners, and biologists continue to identify and understand the relationships among hydrodynamics, flow timing, species response, water temperature, geomorphology, water quality, environmental responses, global climate change, and other conveyance-related considerations so that they can optimally plan, develop, operate, and maintain natural and constructed conveyance infrastructure. The Bay Delta Conservation Plan and the Delta Stewardship Council's Delta Plan processes have been studying these factors to develop plans to improve the operation of the state's conveyance systems with a balanced approach to meet the needs of its people and the environment. In addition to the Delta, these studies include regions where export demands must be met, flood control improvements are needed, water quality improvements are being sought, and in-stream fisheries and their habitat must be protected and restored.

The U.S. Army Corps of Engineers' Long-Term Management Strategy outlines dredging and levee maintenance work needed to maintain conveyance in the Delta. DWR's Delta Risk Management Strategy seeks to establish Delta levee standards in order to increase through-Delta water supply reliability by decreasing the chance of levee failures and subsequent conveyance impacts.

Regulatory Compliance

Operation of conveyance facilities must comply with various laws, regulatory processes and statutes such as the Public Trust Doctrine, Area of Origin statutes, California Environmental Quality Act (CEQA), National Environmental Policy Act (NEPA), the Clean Water Act, and the Endangered Species Act. Proposed new conveyance projects must comply with the above regulations, especially the required CEQA and NEPA environmental evaluation and disclosure requirements.

Emergency Water Supply Reliability

Existing conveyance facilities do not provide long-term reliability to meet current and projected needs. To meet needs under changing conditions, improvements such as updating aging infrastructure, upgrading existing capacities, and constructing additional facilities must be made.

Greater interconnections are needed to help improve water supply reliability. Each water system has its own water supply reliability level based largely on storage and conveyance systems, hydrology, and the demand schedule timing and magnitude. Operational flexibility, particularly during emergency conditions, is a primary benefit of greater water system interconnections, as demonstrated during previous droughts.

Area of Origin Interests

Interregional movement of water is sometimes opposed by the water users or agencies located in the watershed where the water supply originates. Area of origin interests, like interests in the export areas, need to augment local supplies to meet growing demands. Downstream water users could derive multiple benefits (water quality, water quantity, flood control) from investing in projects and programs in the upper watersheds from which their water originates.

Ultimately, it is important for all interests to strike a balance that provides for the needs of all of California.

Climate Change

Climate models project that average temperatures are expected to continue to rise several degrees by the end of this century. With warmer temperatures, the state can expect more precipitation to fall as rain instead of snow leading to a reduction in snowpack, which serves as a natural form of storage. In the past decade we have seen a gradual shift in snowpack and runoff timing in California, where runoff is occurring earlier in the year than expected. Although climate temperature models have a higher degree of certainty, it isn't fully understood how total precipitation will be affected by climate change. Climate precipitation models project little change in precipitation in California before 2050; projections after 2050 suggest even more uncertainty with either more or less precipitation; however, projections estimate that flood magnitudes will increase by the end of the century. Additionally, with global temperature rise, corresponding sea level rise is projected to impact low-lying areas in the Delta.

Mitigation

Energy intensity for regional/local conveyance ranges from low to high depending on whether water is distributed with the infrastructure system using extensive energy. For example, some local conveyance uses gravity to distribute water, which may have the benefit of using very low energy or perhaps generating electricity. Improving conveyance system efficiency will have benefits for climate change mitigation. Local conveyance management strategies discussed in this chapter provide new opportunities to reduce energy use and greenhouse gas emissions:

1. Improving conveyance system efficiency by (a) upgrading the aging infrastructure to reduce water leakage and related loss will improve infrastructure and energy efficiency to reduce energy uses and related greenhouse gas emissions; and (b) increasing existing capacities, or adding new conveyance facilities, could increase capacities of local water supplies, thereby reducing the need for more energy-intensive water supplies, especially in Southern California. However, there could be tradeoffs in energy usage with increasing existing capacities, or adding new conveyance facilities at specific locations, if water is then distributed using energy intensive pumping without using gravity.

2. Upgrading aging water distribution systems to improve energy efficiency and water quality by eliminating sources of pollution from degraded pipelines to save energy from water treatment, could also provide greenhouse gas (GHG) mitigation benefits by reducing energy use.

3. Promoting development of more extensive interconnections among water resources systems also enhances efficiency of conveyance systems with possible energy efficiency, which could have GHG mitigation potential.

4. Ensuring adequate resources, establishing performance metrics, and creating energy efficiency measures could provide energy reduction and GHG mitigation potential for local conveyance systems.

Adaptation

Anticipated effects of climate change including changes in flow timing, altered precipitation patterns, and increased flooding have the potential to dramatically impact existing conveyance. Infrastructure improvements and efficiency enhancements will not only benefit present-day operation and resilience of the systems but will also reduce vulnerabilities to prepare for an uncertain hydrologic future.

Development of adaptation strategies to a changing climate is dependent upon identifying conveyance system vulnerabilities. Vulnerabilities mentioned in this chapter include aging facilities and lack of resilience and redundancy to respond to natural disasters such as earthquakes and floods. Changing climate and hydrology have the potential to intensify existing vulnerabilities, for example, increased magnitude or changes in timing of peak flood flows.

Potential dual-purpose or no-regrets strategies outlined in this chapter should be considered by planners to address both existing and climate induced vulnerabilities:

- Improving infrastructure and increasing capacity for enhanced flood control capability and beneficial water transfer.
- Management practices that enhance groundwater recharge and quantify conveyance efficiency.
- More interconnections between conveyance systems for future operational flexibility and redundancy.

Recommendations

The following recommendations apply to federal, State, and local water agencies:

1. Improve conveyance systems. This could take the form of improving the aging infrastructure, increasing existing capacities, or adding new conveyance facilities. New conveyance could increase opportunities for further conjunctive water use in areas with depleted groundwater. Installation of state-of-the-art fish screens also improves supply reliability by reducing ecosystem constraints on the water system.

2. Upgrade aging distribution systems that could provide reduced energy needs through improved efficiency and also provide improved water quality by eliminating sources of pollution from degraded pipelines.

3. Promote development of more extensive interconnections among water resources systems such as, and in addition to, the SWP/CVP aqueduct intertie or improved connectivity within the Bay Area and Southern California. It is likely that leadership and funding on this will be at the local level. Agreements should be solidified in advance to avoid critical impasses during extreme droughts or catastrophes.

4. Establish performance metrics for quantitative indicators, such as quantity of deliveries for agricultural and urban users and miles of rehabilitated conveyance facilities, and qualitative indicators, such as resiliency of conveyance to earthquakes and fewer regulatory conflicts.

5. Assure adequate resources to maintain the condition and capacity of existing constructed and natural conveyance facilities. This may include development of a strategy to maintain channel capacity in areas of the Delta and in flood management facilities. Financially support regional, interregional, and Delta conveyance improvements.

Other Resource Management Strategies

This chapter, "Conveyance — Regional/Local," is closely related to:

- Chapter 2, "Agricultural Water Use Efficiency."
- Chapter 3, "Urban Water Use Efficiency."
- Chapter 7, "System Reoperation."
- Chapter 8, "Water Transfers."
- Chapter 12, "Municipal Recycled Water."
- Chapter 13, "Surface Storage — CALFED."

This chapter, "Conveyance — Regional/Local" is also related to:

- Chapter 4, "Flood Management."
- Chapter 24, "Land Use Planning and Management."

References

References Cited

California Natural Resources Agency. 2012. "Bay-Delta Conservation Plan, Conveyance Working Group, Proposed Actions and Criteria." Sacramento (CA): California Natural Resources Agency. [Web site.] Viewed online at: http://baydeltaconservationplan.com/Home.aspx.

Contra Costa Water District.2010. "Middle River Intake and Pump Station." Project update July21, 2010. Contra Costa Water District. Concord (CA).[Web site]. Viewed online at: http://www.ccwater.com/aip.asp.

Fetcher A. 2011."Secretary Salazar Joins Dedication Ceremony for Contra Costa Water District's Rock Slough Fish Screen." Washington (DC). U.S. Department of the Interior. [News Release]. Viewed online at: http://www.doi.gov/news/pressreleases/Secretary-Salazar-Joins-Dedication-Ceremony-for-Contra-Costa-Water-Districts-Rock-Slough-Fish-Screen.cfm.

Freeport Regional Water Authority. 2012. "The Freeport Regional Water Project." Sacramento (CA). [Web site]. Viewed online at: http://www.freeportproject.org/.

U.S. Army Corps of Engineers. 2001. *Long-Term Management Strategy (LTMS) for Placement of Dredged Material in San Francisco Bay Region*. San Francisco (CA): U.S. Army Corps of Engineers. 174 pp. Viewed online at: http://www.spn.usace.army.mil/Portals/68/docs/Dredging/LMTS/entire%20LMTF.pdf.

U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Delta-Mendota Canal/California Aqueduct Intertie, April 27, 2012. Viewed online at: http://www.usbr.gov/mp/2011_accomp_rpt/major_projects/dmc/index.html

U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region. 2012 "Red Bluff Fish Passage Improvement Project." Sacramento (CA). [Web site]. Viewed online at: http://www.usbr.gov/mp/rbfish/.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 7

System Reoperation

Kern County. The Edmonston Pumping Plant, as the highest lift pumping facility in the State Water Project (SWP), plays a vital role in nearly all system reoperation projects involving the SWP. The plant's huge motor-pumping units lift water nearly 2,000 feet up and over the Tehachapi Mountains through 10 miles of tunnels.

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Chapter 7. System Reoperation

Introduction

System reoperation in the context of water resources means changing existing operation and management procedures for a water resources system consisting of supply and conveyance facilities and end user demands with the goal of increasing desired benefits from the system. System reoperation may seek to improve existing water facilities to meet existing system needs more efficiently and reliably, or it may seek to prioritize one system need over another. Although reoperation of existing facilities is generally regarded as the preferred alternative to constructing major new facilities, minor physical modifications to existing facilities may be necessary to eliminate constraints to reoperation and to meet operational goals. Changes to the water rights or regulatory framework for allocating water — for example, modifying existing water rights or creating new supply exchange agreements — may also be required.

Some systems may be very simple and include only a single surface water reservoir or groundwater basin. Other water systems may be much more complex, consisting of many facilities that form a combination of local, interregional, and interstate water sources and delivery destinations. The concept "system reoperation" applies to the system at all scales, thus reoperation can be implemented at different scales within a system, ranging from individual facilities to several integrated components.

Reoperation of existing facilities usually serves three basic purposes:

1. Addresses a specific problem(s) and/or need(s).
2. Improves efficiencies.
3. Adapts facilities to anticipated future changes (changes in water demands, legal and regulatory constraints, and key physical variables such as climate).

Background

California's statewide water system is comprised of a diverse set of local, State, and federal projects, as depicted in Figure 7-1. These projects include facilities such as dams and reservoirs, hydropower plants, canals, and water diversion structures. Many of these facilities were developed in the 20th century, and were not designed, constructed, or operated as an integrated water supply and flood management system. Over time, operations of the two largest projects, the State Water Project (SWP), operated by the State, and the Central Valley Project (CVP), operated by the federal government, have been integrated to a certain degree. The current level of integration is based on the Coordinated Operating Agreement that was initiated in the 1970s and finalized in 1986.

California's water supply and flood control systems are inextricably linked, from Trinity County in the north to Imperial County in the south, through physical interconnections and coordinated management arrangements. This reality influences water resources planning in two ways:

1. Changes in water management at any point may have consequences throughout the rest of the system.

Figure 7-1 Location of Local, State, and Federal Water Projects

2. The inherent physical interconnections in the system provide opportunities for improving water resource benefits throughout the state via systemwide optimization.

DWR's System Reoperation Study (SRS) was undertaken with these two points in mind. In recognition of these points, this SRS represents a systems analysis to understand how changes influence the system and in what ways the system can be optimized to meet reoperation goals. Current water resources problems necessitate better integration and optimization of the State's flood protection and water supply management system.

Study Authorization

The authorization and funding of the SRS were granted by the Legislature through Senate Bill X2 1 (SB X2 1) (chapter 1, statutes of 2008 – California Water Code Section 83002.5), which mandated and allocated resources for "planning and feasibility studies to identify potential options for the reoperation of the state's flood protection and water supply systems that will optimize the use of existing facilities and groundwater storage capacity." Specifically, SB X2 1 stipulated that "the studies shall incorporate appropriate climate change strategies and be designed to determine the potential to achieve the following objectives:

> (I) Integration of flood protection and water supply systems to increase water supply reliability and flood protection, improve water quality, and provide for ecosystem protection and restoration.
>
> (II) Reoperation of existing reservoirs, flood facilities, and other water facilities in conjunction with groundwater storage to improve water supply reliability, flood hazard reduction, and ecosystem protection and to reduce groundwater overdraft.
>
> (III) Promotion of more effective groundwater management and protection and greater integration of groundwater and surface water resource uses.
>
> (IV) Improvement of existing water conveyance systems to increase water supply reliability, improve water quality, expand flood protection, and protect and restore ecosystems."

To meet the legislative objectives, DWR, in coordination with willing participants, is conducting studies to identify and evaluate potential operations strategies for reoperation of the State's flood protection and water supply systems. These reoperations strategies will be assessed with respect to their ability to improve (1) water supply reliability, (2) flood hazard reduction, and (3) ecosystem protection and restoration.

Along with the three objectives, water quality, groundwater overdraft, and climate change are also mentioned in SB X2 1. Water quality affects water supply and ecosystems, and therefore is included in those discussions. Similarly, groundwater overdraft is considered as a component of water supply. Finally, because climate change increases the variability of hydrology and because such variability is expected to further stress future water supply, flood hazard management infrastructure, and aquatic ecosystems, climate change is part of each of those topical areas.

Geographic Scope

The geographic scope of this study could include the entire state; however, a close read of the authorizing language indicates a focus on systems and systemwide analyses. The legislative mandate focuses this study on the “State’s flood protection and water supply systems.” This suggests that emphasis should be given to those areas of the state where both of these systems are found. Much of the State’s flood control infrastructure is located in the Central Valley and the Central Valley is also where the greatest concentration of interconnected water supply infrastructure is located. Additionally, a significant percentage of California’s water supply originates in the northern Central Valley. Because this infrastructure has had a profound effect on aquatic ecosystems, the greatest potential for ecosystem restoration through infrastructure reoperation is also found in the Central Valley. For these reasons, the initial geographic scope for identifying system reoperation will be limited to the Central Valley.

DWR recognizes that there are several independent watersheds that contain a certain level of systemized infrastructure development. Ownership of these systems varies and opportunities for reoperation and optimization may exist provided cooperation from the owners and operators can be obtained. However, the initial focus for system reoperation is in the Central Valley due to the integration, size, and proximity of existing infrastructure, and the perceived opportunities for meeting the stated goals of the authorizing legislation. Figure 7-2 shows the location of the Central Valley and study area for the SRS.

Study Phases

Five phases were identified in the System Reoperation Plan of Study (June 2011) for carrying out the study. The primary purpose of the Plan of Study was to define the phases of the study such that it can be used as a guide to implement each phase. The study phases have been modified and updated since the Plan of Study was completed. The current study phases are described below.

Phase 1: Preliminary Reoperation Measures and Concepts

In Phase 1, the relevant existing literature, related programs, and available tools were assessed for use in subsequent phases. The planning process to formulate preliminary reoperation strategies was established and followed. This phase is important in that it established the ground rules for developing the SRS and identified preliminary reoperation measures and concepts.

Phase 2: Strategy Formulation and Refinement

In Phase 2, the preliminary reoperation measures and concepts identified from Phase 1 was refined and formulated into potential reoperation strategies. Phase 2 included input and identification of fatal flaws from technical experts, affected parties, as well as outreach and coordination with other relevant programs. Phase 2 yielded specific potential reoperation strategies determined to warrant continued consideration.

Figure 7-2 Location of Central Valley and Study Area of System Reoperation Study

Phase 3: Preliminary Assessments of Strategies

Preliminary assessments will be conducted on those strategies carried forward from Phase 2. The purpose of the preliminary assessments will be to assess the strategies ability to meet the objectives of the study, and rank the reoperation strategies relative to one another. These preliminary assessments will provide a sound basis for selecting strategies that warrant reconnaissance level assessments in Phase 4.

Phase 4: Reconnaissance Level Assessments of Strategies

Strategies carried forward from Phase 3 will be subject to a reconnaissance level assessment. The reconnaissance level assessment will be performed at a more detailed level than the preliminary assessments and will rely upon existing tools (e.g., water supply, flood, and ecosystem related models). The purpose of the reconnaissance assessments will be to evaluate and determine whether or not the selected strategies warranted further evaluation for potential recommendation for implementation, develop a relative ranking of the reoperation strategies, and identify needed funding and key steps necessary for implementation.

Phase 5 was identified in the Plan of Study as the strategy implementation phase. Strategy implementation is beyond the scope of this study and is therefore not a part of the study.

Planning Principles

In development of the SRS, DWR has adopted a set of guiding principles:

- Water supply benefits resulting from reoperation will be shared with the owners of the projects as negotiated with the owners.
- Reoperation studies of regional and local projects will be performed with the collaborative and voluntary participation of the facilities owners and operators.
- Priority for study will be reoperation opportunities that simultaneously reduce flood hazards, improve water supply reliability, and restore damaged ecosystems.

Phase 1: Preliminary Reoperation Measures and Concepts

During Phase 1, management and physical reoperation measures were identified that addressed one or more of the objectives and capitalized on existing opportunities. Measures were formulated based on a review of available reoperation literature and suggestions from knowledgeable experts. Reoperation measures were combined with other measures to create reoperation scenarios resulting in greater benefits to the water system. A conjunctive use scenario, for example, might include construction of conveyance and recharge facilities, integration of two or more reservoir project operations, and reoperation at those same reservoirs. Thus, many individual measures are not complete by themselves, but must be combined with other measures.

The measures were formulated and organized based on the system reoperation building blocks identified in the Plan of Study. During measure formulation, measures were only identified under these building block categories:

- Integrate CVP, SWP, and other local projects.

- Reoperate reservoirs.
- Integrate management of groundwater and surface water.
- Facilitate water transfers.
- Change stream flow regime/patterns.
- Expand through valley conveyance/reactive floodplains.

The preliminary reoperation measures and concepts developed in Phase 1 are shown in Box 7-1. Phase 1 was completed in July 2011.

Phase 2: Reoperation Strategy Formulation and Refinement

In Phase 2, preliminary reoperation strategies were formulated based in part on the reoperation measures and concepts identified in Phase 1 and in part from inputs from cooperators. Those strategies were further developed and screened through a process of consultations with agency experts, facility owners and operators, and experts from within and outside of the study team. The reoperation strategy candidates were formulated based on the following criteria:

- Has the potential to provide net benefits that satisfy the three study objectives of (1) flood hazard reduction, (2) improvements in water supply reliability, and (3) restoration or enhancement of natural functions in river ecosystems.
- Can be accomplished with only minor capital improvements to the water system, which are limited to those that are necessary to reoperate existing infrastructure. The exception is the isolated Delta conveyance. All of the promising reoperation strategies that have a nexus to the Delta will be evaluated with and without an isolated Delta conveyance in Phase 3.

During the summer of 2012, the study team consulted with various water management institutions and organizations whose infrastructures or water management policies would be implicated in the reoperation strategies or that have expert knowledge of system reoperation. Through this vetting process, the study team obtained input and used the information to further refine some reoperation strategies and eliminate some other strategies. The organizations that the study team consulted with during the vetting process are shown in Box 7-2.

As a result of the vetting process, some of the preliminary reoperation strategies were eliminated from further consideration due to various reasons, including unwillingness of the facility owner(s) to participate in the study, lack of sufficient operational flexibility for reoperation, or lack of sufficient benefit from reoperation. The preliminary strategies that were eliminated from further consideration after the vetting process include:

- Reoperation of Friant Dam (Lake Millerton). According to the Friant Water Authority, Lake Millerton is already operated to carryover only dead storage in many, perhaps most, years. That means there is very little additional operation flexibility that would be exploited under the reservoir reoperation in conjunction with groundwater banking options.
- Reoperation of Folsom Reservoir. Folsom Reservoir, too, has limited operational flexibility under current demands and constraints. This conclusion is based on previous vetting with the CVP Folsom operations staff. It appears that the best way to incorporate Folsom Reservoir into a reoperation scenario may be in conjunction with Shasta Reservoir reoperation.
- Reoperation of New Don Pedro Reservoir. The co-operating irrigation districts, Turlock Irrigation District and Modesto Irrigation District, are going through a FERC (Federal Energy

Box 7-1 System Reoperation Measures and Concepts

Integrate Groundwater and Surface Water Operations

- Integrate operations of reservoirs in the American River watershed with groundwater pumping operations of groundwater authorities in the Sacramento area near the American River.
- Integrate operations of reservoirs in the Sacramento River watershed with groundwater pumping operations of the San Joaquin County groundwater users.
- Integrate operations of reservoirs in the Sacramento River watershed with groundwater pumping operations of the San Joaquin River of the Tulare basin groundwater users.
- Integrate reoperation and groundwater storage operations to facilitate Bay Delta Conservation Plan solutions.
- Integrate operations of reservoirs in the San Joaquin River watershed and groundwater pumping operations of the Merced District groundwater users using in lieu recharge.
- Integrate operations of reservoirs in the San Joaquin River watershed and groundwater pumping operations of the Madera District groundwater users using active recharge.
- Integrate operations of reservoirs in the San Joaquin River watershed and groundwater pumping operations of the Merced and Turlock Districts' groundwater users.

Integrate CVP, SWP, USACE, and Local Surface Water Operations

- Integrate CVP-SWP reservoir operations.
- Integrate operations of CVP, SWP, and South-of-Delta export pumps.
- Integrate operation of CVP reservoirs and USACE reservoirs.
- Integrate CVP-SWP reservoir operations and local reservoir operations.

Reactivate Floodplains for Improved Flood Hazard Reduction

- Reoperate flood control reservoirs in the Central Valley in conjunction with reactivated downstream floodplains.

Reduce Physical Losses of Water Supply through Transfer Facilitation

- Reduction in physical losses of water supply through transfer facilitation.

Capture Flood Control Spills and Store Them in Quarries

- Divert American River flood flows into existing sand and gravel quarries in the Mather Field/Jackson Highway/Florin Road area.

Improve Reservoir Operations Using Forecasting

- Implement forecast-based operations at CVP/SWP reservoirs in the Sacramento River watershed.
- Implement forecast-based operations at locally-owned reservoirs.
- Implement forecast-based operations in the Sacramento River watershed reservoirs.
- Implement forecast-based water quality operations at CVP/SWP reservoirs.
- Implement forecast-based water supply delivery releases at CVP/SWP reservoirs.
- Implement forecast-based operations at CVP reservoirs in the San Joaquin River watershed
- Implement forecast-based operations at locally-owned reservoirs in the San Joaquin River watershed.
- Implement forecast-based operations at CVP and locally-owned reservoirs in the San Joaquin River watershed.

Box 7-2 Organizations Consulted During Phase 2

Arvin-Edison Waters Storage District

California Water Plan – Stakeholder groups

Calleguas Municipal Water District

East Bay Municipal Utility District

Friant Water Authority

Glenn-Colusa Irrigation District

Inland Empire Utilities Agency

Kern Water Bank Authority

Madera Irrigation District

Merced Irrigation District

Metropolitan Water District

Modesto Irrigation District

NOAA Fisheries

North San Joaquin Water Conservation District

Orange County Water District

Raymond Basin Management Board

RD 108

San Gabriel Basin Water Quality Authority

Semitropic-Rosamond Water Bank Authority

SWP and CVP Operators:

The Nature Conservancy

Three Valleys Municipal Water District

Turlock Irrigation District

U.S. Army Corps of Engineers

U.S. Bureau of Reclamation

Regulatory Commission) relicensing process and do not wish to collaborate with DWR to study reoperation of New Don Pedro Reservoir.

- Reoperation of Camanche and Pardee reservoirs. According to East Bay Municipal Utility District, the Camanche and Pardee reservoirs are already operating efficiently and do not have potential operational flexibility for reoperation.
- Reactivating Floodplains for Improved Flood Management and Ecosystem Restoration. This stand-alone strategy does not appear to be able to achieve the three objectives of the study. Some type of reactivating floodplains or floodplain inundation concepts may be included in the remaining strategies that will be carried forward into Phase 3.

- Mechanisms to Facilitate Conservation Water Transfers. This strategy does not appear to be able to achieve the three objectives of the study. Also, no entities were interested in pursuing this strategy during the vetting process.
- Systemwide Reoperation Strategies to Implement the Solution Strategies of the Bay Delta Conservation Plan (BDCP). BDCP analyzed the operations of the existing water system with the new Delta conveyance. The new Delta conveyance associated with BDCP will be analyzed for all reoperation strategies that have a nexus to the Delta.

The remaining reoperation strategy candidates that emerged from the vetting process and will be carried forward into Phase 3 for preliminary assessments are:

- Reoperation of Shasta Reservoir.
- Reoperation of Oroville Reservoir.
- Reoperation of New Exchequer Dam (Lake McClure).
- Integration of the SWP and CVP operations.

Basic Concept of Reservoir Reoperation for Shasta and Oroville Reservoirs

The basic concept for the reoperation of Shasta and Oroville reservoirs is to lower carryover storage levels relative to current operations to increase flood reservation by conveying additional water to either an existing or future groundwater bank located in the Sacramento Valley or south of Delta with available capacity. This reoperation would reduce flood control spills and would occur at times when excess conveyance capacity is available in the Delta. To the extent reservoirs recover fully, the banked water is a supplement to water supplies. In dry years where complete storage recovery does not occur, the reservoir would be paid back with withdrawals from the groundwater bank and delivered to CVP/SWP customers on a full cost recovery basis.

Basic Concept for Reoperation of New Exchequer Dam

The concept for reoperation of New Exchequer Dam (Lake McClure) is with reservoir payback by in lieu groundwater banking within the Merced Irrigation District and the Merced Area Groundwater Planning Initiative (MAGPI). The reoperation would enable environmental flows to be restored from the dam to the Delta to improve conditions for steelhead trout. This strategy would be developed and conducted in partnership with Merced Irrigation District and MAGPI. The environmental flow release would have to be managed through the downstream infrastructure. Releases from Lake McClure pass through a series of power plants and smaller diversions and are regulated at McSwain Reservoir. Below McSwain Reservoir, water is diverted to Merced Irrigation District at the PG&E Merced Falls Dam and is diverted further downstream at Crocker-Huffman Diversion Dam. It is possible that the surplus water dedicated to steelhead habitat enhancement in the Merced River could be diverted below the confluence with the San Joaquin River for water supply.

Operational Components

Four operational components will be included in the reoperation strategies:

- Forecast-Based Operations. The goal is to reduce flood control space in reservoirs to allow higher storages at certain times of the year based on improved inflow forecasts.
- Conjunctive Management. Conjunctive management involves the coordinated use and management of groundwater and surface water resources to maximize the water supplies to meet water management objectives. Surface water and surface storage facilities need to be operated conjunctively with groundwater supplies and groundwater storage as a single system to maximize storage and water resources objectives. The goal is to develop more integrated management of groundwater and surface water supplies. Several different operational changes are possible with increased conjunctive management including increased groundwater banking through in lieu and active recharge and more aggressive reservoir reoperations backstopped by groundwater pumping.
- System Integration. The goal is to integrate operations between multiple reservoirs or increase the degree of integration at reservoirs that are currently integrated.
- Environmental Flows. A variety of new environmental flows may be included in each strategy. Differences in the timing and magnitude of environmental flows change how those flows can be used to meet multiple project objectives. Flows under consideration include floodplain inundation flows, spring pulse flows, flows to improve water temperature, and flows coordinated with fish hatchery operations.

The Shasta Reservoir reoperation strategy may consider fish passage above Shasta Dam into the colder water environments of the Upper Sacramento and McCloud rivers as a component. Fish passage above Shasta Dam is a core element of the Salmon Recovery Plan of the National Marine Fisheries Service (NMFS). The key issue is whether fish passage would allow more flexible operations of Shasta Dam that could facilitate the reoperation concepts under consideration.

Tradeoff Analysis

A tradeoff analysis is being performed as part of Phase 2 to help define the operations of the strategies. One of the purposes of the tradeoff analysis is to identify combinations of measures that will meet all three objectives of the study. While the ultimate objective of the SRS is to achieve simultaneous and system-wide net improvements in water supply, flood control, and ecosystem protection/restoration, there may be conflicts among the competing goals in the reoperation strategies. Understanding the tradeoffs among the competing goals will help in strategy formulation as the various measures and benefit types are pursued. For example, there may be tradeoffs within ecosystem goals between environmental flow improvements above the Delta and Delta outflow, and between different species (delta smelt and salmon) or even life stages of the same species (out-migration versus over-summer holding). There are also tradeoffs between goals such as water supply and flood hazard reduction.

A tradeoff analysis will facilitate consideration of the relative priority of the system reoperation objectives. For example, an ecosystem restoration action, if implemented in the existing system, will have an effect on water supply and perhaps other restoration objectives such as temperature management. This tradeoff analysis will provide a foundation for understanding the water system effects and will inform how measures can be ultimately combined into full system reoperation strategies. In addition, the tradeoff analysis will give potential system reoperation participants, such as managers, operators, regulators, and other stakeholders a better understanding of each measure under consideration.

Some of the key tradeoffs being evaluated as part of the Phase 2 includes:

- Flexibility in temperature management operations at Shasta Dam – the ability to change releases from Shasta Dam while complying with winter run temperature requirements is a key tradeoff for evaluating conjunctive management and environmental flows at Shasta Dam.
- Temperature and flow changes associated with higher spring releases and risks of warmer temperatures in the fall.
- North of Delta water supply reliability versus systemwide water supply.
- Effects of increased stream flows in the Feather River on water supply and storage in Lake Oroville.

Phase 2 was completed at the end of 2013. The strategy formulation and refinement process is documented in the Phase 2 report (California Department of Water Resources 2014).

Next Steps

Phase 3: Preliminary Assessments of Strategies

The study team will continue to refine the reoperation strategies to change operations in ways that may result in improved system performance in terms of additional water supply, flood hazard reduction, and ecosystem protection and restoration. Those reoperation strategies that survived through the vetting process will be evaluated for potential benefits at the regional and systemwide scale during Phase 3.

The purpose of Phase 3 is to evaluate, sort, and rank strategies based on their performance in meeting the goals and objectives of the study. The strategies will be examined for acceptability, completeness, effectiveness, and efficiency. Phase 3 will include:

- Defining baseline operations.
- Evaluating system reoperation strategies:
  - Identifying existing physical and operational constraints.
  - Identifying new or modified physical facilities needed for potential system reoperation strategies.
  - Conducting hydrologic and other modeling.
  - Quantifying benefits.
- Ranking reoperation strategies based on their performance.
- Selecting reoperation strategies to be carried forward into Phase 4 for more detailed analysis.

Phase 4: Reconnaissance-Level Assessments of Strategies

In Phase 4, the strategies evaluated in Phase 3 that met the objectives of the study will be carried forward into Phase 4 for more detailed evaluations. Phase 4 will include:

- Analyzing and assessing reoperation strategies.
- Evaluating benefits.

- Evaluating costs.
- Quantifying economic benefits.
- Developing conceptual designs for facilities modifications.
- Identifying institutional challenges.
- Documenting the findings.
- Recommending strategies for potential implementation.
- Identifying funding and key steps necessary for implementation.
- Making recommendations for next steps.
- Preparing a report.

The California Water Commission has developed a document titled *Description and Screening of Potential Tools and Methods to Quantify the Public Benefits of Water Storage Projects* that provides guidance on economic methods for quantifying public benefits of water storage projects. This document may be used to as a guidance to quantify the public benefits associated with the system reoperation strategies.

Climate Change

Climate change presents a significant challenge for California water management. Recent climate change studies project a broad range of potential effects, such as increases in air temperature, changes in the timing, amount, and form of precipitation, changes in runoff timing and volume, sea level rise, increased storm extremes, greater floods, and longer droughts.

While there is much uncertainty about how climate change will affect the overall amount of precipitation in California, there is general agreement that climate change will affect both the timing and form of precipitation. Climate change studies indicate that more precipitation will fall in the form of rain instead of snow and that higher temperatures will cause earlier snowmelt. The results of these changes in precipitation form and timing will be a decrease in the overall snowpack storage, as well as earlier and greater runoff from both rainfall and earlier snowmelt.

Climate Change Adaptation

Most of California's major surface water reservoirs are managed for multiple benefits, but are primarily managed for water supply and flood protection. During the winter, when storms are common, flood protection takes priority and this drives reservoir operation decisions. For the rest of the year, when storms are uncommon, water supply, water quality, and ecosystem management drive reservoir operation decisions.

As runoff patterns shift to occurring earlier in the year, more and more runoff will arrive during the flood operations period. Much of this water will need to pass through the reservoirs to allow the reservoirs to maintain adequate flood protection space. By the time the flood protection season ends, much of the runoff will have already passed through the reservoirs and will not be available in storage for use later in the year, which is during peak water demand periods.

In addition to changes in precipitation timing and form as a result of climate change, studies indicate that sea levels may rise by as much as 55 inches at the Golden Gate Bridge by 2100. Sea level rise would increase salinity in the Delta, requiring larger volumes of fresh water to control salinity for SWP, CVP, and other Delta water user operations. Delta salinity requirements are one of the primary constraints guiding the operation of the SWP and CVP systems.

System reoperation measures that primarily use existing storage infrastructure and conveyance systems, such as conjunctive use of surface water and groundwater, could help reduce climate change impacts such as reduced snowpack, more precipitation in the form of rain, and early snow melt. For example, by moving water to groundwater banking sites in the fall, reservoir levels could be lowered further so that excess water during the winter and spring could be stored in the reservoirs. This early reservoir drawdown would increase flood storage capacity and therefore improve flood protection. In turn, the water stored in groundwater banking sites would help supplement summer water supplies and decrease the reliance on reduced snowpack runoff.

Large-scale system reoperation measures, such as conjunctive use of surface water and groundwater, provide opportunities to adapt operations to climate change with an efficient and consistent approach.

Climate Change Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas (GHG) emissions to lessen contributions to climate change. System reoperations can lead to emission reductions or emission increases, depending on the goals of the reoperation and whether climate change is considered during planning. For example, reoperating systems in a way that maximizes hydroelectric power generation would allow water managers to produce clean, renewable energy, thus reducing the need for GHG-intensive energy produced from burning of fossil fuels. However, because climate change is expected to bring larger, more intense precipitation events, reoperating the systems to provide additional flood protection benefits through the early release of water may decrease water availability during the summer months when water and electricity demands are highest, which could result in water pumping, water imports, and therefore increase the purchase of GHG-intensive energy sources. Reoperating systems that keep GHG emissions to the minimum of what is necessary to operate would be the best way to meet the needs of all parties while mitigating for climate change.

Major Implementation Issues

Physical Constraints

The capacity of existing infrastructure, such as storage and conveyance, could limit system reoperation opportunities to make water transfers, conduct conjunctive water management, and refine flood operations. Future studies should focus on eliminating infrastructure constraints in order to add flexibility to systems.

Institutional Constraints

Although there are numerous institutional arrangements that help water resource projects function together as a system, these same institutional arrangements present some very inflexible constraints that make it difficult and time-consuming to consider the reoperation potential of an entire system. Some of the relevant institutional constraints and the challenges they present are listed below.

- California's priority system for surface water rights, including area-of-origin water rights, presents complications for large-scale changes.
- Contractual obligations for water deliveries largely constrain the operations of many projects.
- Flood rule curves mandate the reservation of flood control space during the flood season. Changing rule curves would require congressional approval, which is a difficult and time-consuming process.
- Coordinated operating agreements already govern the operation of multiple projects (e.g., the agreement that governs SWP and CVP operations).
- Changes in federal project purposes require congressional approval.

Integrating Water Resource Management

California water resources management involves many tiers and players. Facilities are operated for local, regional, or nearly statewide beneficial uses. Implementing large-scale system reoperation would involve a combination of regulatory actions by local, regional, State, and federal agencies.

Planning, Design, and Implementation Costs

As mentioned earlier in this chapter, significant up-front and ongoing costs can be involved with system reoperation, as with the planning, design, and implementation of any large-scale infrastructure project.

Up-front planning and design costs might include such items as data collection, hydrologic and hydraulic model development, decision-support systems development, and environmental documentation necessary just to evaluate the benefits and impacts of proposed reoperation strategies through the feasibility study level. Tangible implementation costs would be associated with the actual removal, modification, or construction of any infrastructure.

Water management agencies might have difficulty raising needed funds for feasibility-level studies and implementation due to existing contracts or regulations that prohibit them from increasing water or energy rates. As with implementing any large-scale project, selling the project costs to those directly in line to receive benefits is a foregone necessity.

Recommendations

The following recommendations can help facilitate reoperation to meet water supply reliability, flood management, hydropower, water quality, ecosystem, and other objectives better.

1. State, federal, regional, and local agencies should collaborate on large-scale system reoperation studies to pool resources and share benefits.

2. The State and federal water operators should encourage and expand the use of forecast-based and forecast-coordinated reservoir operations.

3. The State should take the lead to establish a baseline hydrology applicable to large-scale system reoperations modeling.

4. The State should fund reoperation studies of smaller regional water purveyors through the Integrated Regional Water Management Grant Program.

5. The State should take the lead and develop an integrated water resources analytical tool to support regional and statewide system reoperation analysis that balances water supply, flood protection, water quality, and ecosystem needs. This tool would make the State a leader in large-scale integrated water management. Many local/regional agencies have their own tools for evaluating their local/regional systems. The State should support improvements to the local/regional tools and integrate them with the statewide tool.

References

References Cited

California Department of Water Resources. 2014. *Draft Phase 2 Report System Reoperation Study — Strategy Formulation and Refinement.* Sacramento (CA): 39 pp. Viewed online at: http://www.water.ca.gov/system_reop/docs/System%20Reop%20Phase%202%20Report%20-%20February%202014%20Draft.pdf.

Additional References

California Department of Water Resources. 2011. *System Reoperation Program, Phase 1 — Plan of Study*. Sacramento (CA): Prepared by HDR Engineering, ESA PWA, Natural Heritage Institute, and Newfields. 89 pp. Viewed online at: http://www.water.ca.gov/system_reop/docs/system_reop_phase1_plan_of_study_6-2011.pdf.

California Department of Water Resources and U.S. Environmental Protection Agency Region 9. 2011. *Climate Change Handbook for Regional Planning*. Sacramento (CA): Prepared by CDM under EPA Contract Number EPA099BOA002. Prepared for the U.S. Environmental Protection Agency Region 9 and the California Department of Water Resources in partnership with the U.S. Army Corps of Engineers South Pacific Division, Resources Legacy Fund, and U.S. Environmental Protection Agency Office of Research and Development. 246 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/Climate_Change_Handbook_Regional_Water_Planning.pdf.

Natural Heritage Institute. 2008. "Global Dam Reoperation." Natural Heritage Institute. San Francisco (CA): Natural Heritage Institute. [Web page.] Viewed online at: http://www.n-h-i.org/?id=42. Accessed: Oct. 30, 2009.

Yuba County Water Agency. 2008. *Forecast-Coordinated Operations of Lake Oroville and New Bullards Bar Reservoir for Managing Major Flood Events*. January 2008 update. Marysville (CA): Yuba County Water Agency. Prepared and produced by GEI Consultants Inc. [Brochure.] 8 pp.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 8

Water Transfers


California Aqueduct. Voluntary water transfers assist in supplementing water supply portfolios for areas experiencing water scarcity south of the Sacramento-San Joaquin Delta. DWR is one of several public agencies involved in approval and management of proposed water transfers, based on the agency's management of the State Water Project export facilities in the Delta.

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Chapter 8. Water Transfers

The California Water Code (CWC) defines a water transfer as a temporary or long-term change in the point of diversion, place of use, or purpose of use due to a transfer, sale, lease, or exchange of water or water rights. Temporary water transfers have a duration of one year or less (CWC Section 1725). Long-term water transfers have a duration of more than one year (CWC Section 1728).

Transfers can be between water districts that are neighboring or across the state, provided there is a means to convey or store the water. A water transfer can be a temporary or permanent sale of water or a water right by the water right holder, a lease of the right to use water from the water right holder, or a sale or lease of a contractual right to water supply. Water transfers can also take the form of long-term contracts for the purpose of improving long-term supply reliability. Generally, water is made available for transfer by five major methods:

- Transferring water from reservoir storage that would otherwise have been carried over to the following year. The expectation is that the reservoir will refill during subsequent wet seasons.
- Pumping groundwater (groundwater substitution) instead of using delivered surface water.
- Transferring previously banked groundwater either by directly pumping and transferring the banked groundwater or by pumping the banked groundwater for local use and transferring surface water that would have been used locally. (Groundwater banks consist of water that is "banked" during wet or above-average years. The water to be banked is provided by the entity that will receive the water in times of need. Although transfers or exchanges may be needed to get the water to the bank and from the bank to the water user, groundwater banks are not transfers in the typical sense. The water user stores water for future use; this is not a sale or lease of water rights. It is typical for fees to apply to the use of groundwater banks.)
- Reducing the existing consumptive use of water through crop idling or crop shifting to make water available.
- Reducing seepage to saline sinks by applying water-use efficiency measures. Water that seeps to saline groundwater is irrecoverable. Any deep percolation, whether from canal seepage or from irrigated fields that would otherwise seep to unusable groundwater, can be transferred if the seepage is prevented. Thus, deep seepage conserved from lining a canal or by switching from flood irrigation to drip can be transferred.

Water exchanges are typically water delivered by one water user to another water user, with the receiving water user returning the water at a specified time or when the conditions of the parties' agreement are met. Water exchanges can be strictly a return of water on a basis agreed upon by the participants or can include payment and the return of water. The water returned may or may not be an "even" exchange. Water can be returned on a one-for-one basis or by another arrangement (e.g., for each acre-foot [af] of water received, 2 af are returned).

Water transfers are sometimes seen as merely moving water from one beneficial use to another. However, in practice many water transfers become a form of flexible system reoperation linked to many other water management strategies, including surface water and groundwater storage, conjunctive management, conveyance efficiency, water use efficiency, water quality improvements, and planned crop shifting or crop idling for the specific purpose of transferring water. These linkages often result in increased beneficial use and reuse of water overall and are among the most valuable aspects of water transfers. Transfers also provide a flexible approach to distributing available supplies for environmental purposes.

Water Transfers in California

For a historical summary of water transfers in California, see *California Water Plan Update 2005* (California Department of Water Resources 2005).

Each year hundreds of water transfers occur in California. The majority of these transfers are between agricultural water users in the same basin (intra-basin transfers). Intra-basin transfers do not require review by other government agencies because there is no change to the permit provisions for place of use, manner of use, or point of diversion. These transfers are governed by the water rights held by the water district and are a matter of internal allocation adjustments by water district members.

Anecdotal evidence suggests that the percentage of water obtained through water transfers by agricultural buyers is increasing. Throughout the Central Valley, there has been a trend toward higher value crops replacing lower value annual crops. Some of the higher value crops include large acreage increases in permanent crops such as almonds. This trend has also occurred in the project service area of the West San Joaquin Division (westside) of the Central Valley Project (CVP). Water districts in the westside often participate in water markets to purchase supplemental water to meet water requirements of the permanent crops and account for much of the intra-basin agricultural water transfers. The westside is particularly susceptible to water shortages because many westside CVP contracts have a lower priority than other CVP contracts. Having lower priority for contract water means this region is typically the first and most severely affected by water shortages.

During 2005 and 2006, California experienced a relatively wet period, and water users had the opportunity to store some excess water in groundwater banks for future withdrawal. Many of these reserves were tapped in 2007 because of dry hydrology. In 2008, continuing dry conditions prompted the purchase of approximately 230,000 af of water from Northern California agriculture, specifically by various buyers south of the Sacramento-San Joaquin Delta (Delta).

In 2009, Governor Arnold Schwarzenegger declared drought and tasked the California Department of Water Resources (DWR) with establishing the 2009 Drought Water Bank (Water Bank) to purchase water from willing sellers, which would be sold at cost to willing buyers. The amount of water requested for purchase from the Water Bank exceeded the approximately 80,000 af purchased for the buyers of the Water Bank. Several factors came to play in 2009 that limited the availability of Water Bank supplies. One significant factor was that high rice prices meant that rice growers were not willing to sell water at the price offered by the Water Bank.

In addition, as a result of operational constraints placed by the 2008 U.S. Fish and Wildlife Service and the 2009 National Marine Fisheries Service biological opinions for the coordinated operational criteria and plan (OCAP) of the CVP and the State Water Project (SWP), about half of the water made available by the idling of rice land could not be delivered to buyers in 2009, thus increasing the cost of transfer water to buyers beyond what they could pay or were willing to pay. In addition to the water transferred through the Water Bank, about 177,000 af were purchased by DWR from long-term water transfer programs already in place before the Water Bank, including the Lower Yuba River Accord (Yuba Accord).

An additional 23,100 af of water were transferred in 2009 south of the Delta, using only SWP conveyance facilities. Another nearly 400,000 af were reallocated among the CVP users but was not transferred across the Delta.

Operations restrictions, resulting from the biological opinions, affected the Water Bank's ability to purchase water (National Marine Fisheries Service, Southwest Regional Office, 2009; U.S. Fish and Wildlife Service 2008, 2009a, 2009b) originating from certain transfer proposals due to timing constraints in the movement of transfer water through the Delta. The biological opinions have resulted in restrictions on the export of combined CVP and SWP (Project) water at certain times of the year. Pumping restrictions have essentially limited pumping transfer water from the Delta to July through September. The result is that an increased export of Project supply has been shifted to the summer months, with the consequence that in years when SWP allocations are high (greater than 60 percent of the Table A supplies [see Glossary]), there is very limited to no capacity to convey water made available for transfer from upstream of the Delta to downstream. The net result of the biological opinions is to add additional uncertainty to water transfer transactions. As such, there is no guarantee that properly developed water transfer agreements can be executed and the transfers completed.

The pumping restrictions resulting from biological opinions have significantly affected the opportunities for cropland idling and cropland shifting water transfers. Transfer water from crop idling and crop shifting becomes available beginning in May. In some situations, particularly for Sacramento River diverters, required environmental releases make it impossible to hold transfer water in the Shasta Dam's reservoir for future delivery. This causes about 40 percent of the water made available for transfer to be undeliverable to the buyer in any given year. This circumstance causes the price of the transfer water from cropland idling and shifting to nearly double from the Sacramento River diverters. The water becomes so expensive, and so much cannot be transferred due to the operational constraints, that buyers are not willing to purchase the transfer water from crop idling or shifting from those diverters. Certain Feather River diverters, however, are able to store water from rice idling made available in May and June in Oroville Reservoir, or in the associated Thermalito complex, which can then be transferred during the July-September transfer period. The net result of the impact of the biological opinions on rice land idling for water transfers is that only about 25 percent of the potential rice acreage is able to participate in water transfers, as compared with the participating rice acreage before the biological opinions.

The Environmental Water Account (EWA) was established by the CALFED record of decision signed in August 2000 (CALFED Bay-Delta Program 2000). The EWA provided for enhancing environmental conditions for at-risk fish species, above and beyond regulatory requirements, through curtailment of pumping or reservoir releases (re-operations) at CVP and SWP facilities, with no net water cost to water users downstream of the Delta. The CVP and SWP water supplies forgone as a result of the re-operations were made up from EWA assets. From 2001 to 2006, EWA operational assets averaged 82,000 af, with a range of 0 to 150,000 af in a given year. The EWA negotiated an average of 60,000 af per year — termed as Component 1 water and typically stored in New Bullards Bar Reservoir — in the Yuba Accord (Yuba County Water Agency 2009). The Yuba Accord agreement runs to 2015, with a possible extension to 2025. According to provisions of the accord, the EWA's Yuba River water (Component 1 water) is only provided when the Delta is in balanced conditions. In rare instances, which occurred in 2006 and again in 2011, the Delta was in excess conditions throughout the summer period and into the fall, and the EWA's Yuba River water was carried over to a subsequent year when it could be made available and delivered to end users. In the foreseeable future, available Yuba River water will be used to offset SWP water lost from the recent Delta biological opinions.

Oversight of Water Transfers in California

Water transfers that involve changes in point of diversion, place of use, or purpose of use to a water right most often require the approval of the State Water Resources Control Board (SWRCB). Transfers that require the use of State, regional, or a local public agency's conveyance facilities require the owner thereof to determine that the transfers will not harm any other legal user of water, will not unreasonably affect fish and wildlife, and will not unreasonably affect the overall economy of the county from which the water is transferred (CWC Section 1810[d]). Strictly speaking, economic issues are typically only required to be evaluated in water transfers that seek to use DWR's water conveyance facilities or those of other State or local agencies. However, economic impacts associated with physical changes to the environment may require analysis under the California Environmental Quality Act (CEQA).

In addition, the California Water Code (CWC) specifies the requirements for changes in water right permits subject to the oversight of the SWRCB (post-1914 appropriated water; CWC Sections 1702, 1727, and 1736) and for water rights not subject to the SWRCB (pre-1914; CWC Section 1706). The CWC also specifies that DWR and other regional and local agencies must allow use of any unused conveyance capacity to a bona fide transferor of water (CWC Section 1810 et seq.).

To assist water projects that may require the use of Project facilities to complete a transfer, DWR and the U.S. Bureau of Reclamation (Project Agencies) have developed a draft technical information document. This document provides details that will assist transferors in developing the technical information that the two agencies will need to make their determinations under the CWC. This document is revised as needed and posted on DWR's website (California Department of Water Resources and U.S. Bureau of Reclamation, Mid-Pacific Region 2012).

Additionally, as of the preparation of *California Water Plan Update 2013*, the Delta Plan was prepared by the Delta Stewardship Council, pursuant to the Delta Reform Act. As drafted, the Delta Plan would contain enforceable regulatory policies that would apply to certain proposed plans, programs, and projects of public agencies that have been classified as "covered actions," in addition to a multiplicity of non-regulatory "recommendations." Public agencies that propose to undertake covered actions would be required to certify before the Delta Stewardship Council that the action is consistent with the Delta Plan. In 2016, temporary through-Delta water transfers may require a consistency determination with the Delta Plan. This would add another level of oversight for water transfers.

As the water transfer market has matured, the buyers and Northern California sellers have begun to develop mechanisms to better respond to concerns over potential transfer effects on local water users and the environment. Water transfer proposals are generally designed to avoid injuring any legal user of water; avoid unreasonably affecting fish, wildlife, or other instream beneficial uses; and avoid unreasonably affecting the overall economy or the environment of the county from which the water is being transferred. To further ensure that sustainable transfers are being developed, continued research and study of Northern California aquifers is necessary to better understand how those aquifers can safely supply water during times of drought. The studies must be a joint effort of State, federal, and local government, as well as involve other interested parties.

Local leadership and initiative are also needed to implement water transfers. Water transfers are typically proposed by local water agencies and can benefit from local community involvement in the development of these proposals. Some counties have passed local ordinances to regulate groundwater extraction for water transfer purposes. With adequate public notice, timely disclosure of proposals, and meaningful public participation, local communities can best assess their area's water demands and supplies and determine whether there is potential for transferring water outside the local region.

Potential Benefits

For receiving areas, water transfers have the potential to improve economic stability and environmental conditions that would otherwise deteriorate with water scarcity. Sellers can use the compensation from transfers to fund beneficial activities, though there is no guarantee that benefits to the seller will benefit the source area as a whole. Compensation from most transfers involving agricultural water goes directly to the participating landowner, who may choose to reinvest in the farming business. In some cases, compensation goes to water districts, which can use the income to reduce water rates, improve facilities, or improve environmental conditions. For example, Western Canal Water District, in the northern Sacramento Valley, used proceeds from Water Bank sales to remove diversion dams and reconfigure its canals to reduce impacts on threatened spring-run salmon. Transfers by regional water agencies can provide additional resources to benefit the entire community. For example, the Yuba County Water Agency has used more than $10 million from the proceeds of water transfers over the past several years to fund needed flood control projects.

Potential Costs

The direct costs of completing a water transfer include more than just the price of water to the seller. Additional direct costs to the buyer include conveyance, storage, and treatment costs. Sale prices reflect the cost to make the water physically available for transfer and, in some cases, added monitoring or mitigation needed to protect the environment or other legal water users. The buyer typically arranges for transferred water to be conveyed to the area of use. Conveyance costs can be significant, and conveyance losses can lessen the amount of water actually delivered to the receiving area. In addition, there are also administrative costs of the conveyance agency in developing conveyance contracts, including staff time for ensuring compliance with statutory provisions regarding third-party impacts and the development of associated environmental review documents by the transfer proponents.

Another cost related to transferring water is carriage water. Carriage water is the extra water needed to carry a unit of water across the Delta to the pumping plants, while maintaining a constant salinity. For the Sacramento River, this has generally been about 20 percent of the transfer water and for the San Joaquin River, it is about 10 percent. It is worth noting, however, that in 2012 and 2013 carriage water losses for the Sacramento River were as high as 30 percent of the transfer water. Carriage water losses are usually viewed as part of the overall transaction cost associated with making a water transfer. Costs associated with carriage water losses, along with other transaction costs, are typically negotiated between buyers and sellers for a water transfer and may be reflected in the overall pricing.

Major Implementation Issues

Balanced Approach to Regulating Transfers

Some stakeholders assert that State laws and oversight of water transfers are not adequate to protect the environment, third parties, public trust resources, and broader social interests that may be affected by water transfers. This is particularly a concern for water transfers involving pre-1914 water rights, which are not subject to regulation by the SWRCB. Conversely, there is also concern that efforts to regulate water transfers more heavily may unnecessarily restrict many short-term, intraregional transfers that have multiple benefits during temporary supply shortages and that have little likelihood of direct or indirect impacts. The key issue is how to balance these concerns to allow water transfers to continue as a viable water management strategy while having mechanisms in place to minimize effects on others.

Stakeholders also have asserted that the regulatory requirements for completing water transfer agreements are burdensome. Much of the information requested by DWR and the U.S. Bureau of Reclamation from water transfer proponents is aimed at ensuring that the water being transferred is “a real water supply” (i.e., additional water made available to the hydrologic system for transfer by the supplier) and not someone else’s water. Some would contend that the present system is warranted and presents an adequate level of protection. For example, a water transfer involving pre-1914 water rights, while not subject to the review of the SWRCB, would require CEQA compliance if one of the parties were a public agency or would require the conveyance of a public agency to complete the transfer. Additionally, any project that would require the use of a public agency’s conveyance would require the agency that owns the conveyance to make certain determinations pursuant to CWC Section 1810(d) (no injury to other water users and no unreasonable impact on wildlife and the economy of the county from which the transfer originated).

In relation to these impacts, it should be noted that water is a resource fundamental to the physical and economic well-being of the local communities and areas in which it originates and is used. Although not readily apparent, far more water is appropriated in water rights permits for a given system than originally flows in the source system. This discrepancy in overappropriation of water rights can be explained by recognizing that water can be used and reused many times over. Impacts that may occur from various water management strategies are frequently hard to assess, in that most water systems are physically complex and uncertain and the uses in them are highly interdependent. For example, groundwater extraction, including that water used for water transfers involving groundwater substitution, may connect with and affect surface water flow. The extent of that impact would depend on when the extraction occurred and the magnitude of groundwater recharge by surface water replenishment. This could potentially affect water right holders with access to those surface waters. At this time, the analyses of these types of impacts are complex and replete with uncertainties. Future analytical tools may help to explain these complexities and reduce system uncertainties.

Environmental Concerns

Environmental consequences of transfers could occur in three places: the area from which water is transferred, the area through which water is conveyed, and the area to which water is transferred. Cumulative effects of short- and long-term transfers could have impacts on habitat, water quality, and wildlife caused by substituting groundwater for surface water; changing the location, timing, and quantity of surface diversions; reducing agricultural return flows to wildlife areas; or changing crop patterns through crop shifting or idling. For example, rice growing areas could have significant secondary benefits as wildlife habitat. Transfers that involve crop idling in these areas could either harm or benefit wildlife, depending on implementation. Transfers that involve increased groundwater pumping also raise concerns over groundwater overdraft and the long-term sustainability of groundwater resources. In addition, long-term water transfers that induce new urban development in the receiving area may have environmental impacts.

Using Temporary Water Transfers for Long-Term Demands

The potential for temporary water transfers to be used for long-term demands raises a couple concerns. One is that urban areas may use limited-duration transfers to accommodate additional development with water supplies that are not sustainable. Another is that agricultural users may rely on limited-duration transfers to supply permanent crops, such as orchards, that cannot be easily scaled back during droughts. Temporary water transfers are also used to supply the environment, such as refuge water, but these do not provide long-term supplies for this environmental use.

Economic Concerns

Short-term, out-of-county transfers created through extensive crop idling can reduce production and employment of both on-farm and secondary economic sectors, resulting in reduced tax revenues and increased costs for farmers who are not participating in the transfer. Extensive idling of crops that results in unemployment of low-wage laborers could be considered unfair treatment under the State's environmental justice policies (California Government Code Section 65040.12). In addition, reduced revenues could affect local governments disproportionately, with potential impacts on spending for a wide range of services provided by local government. Long-term transfers could result in similar impacts, even though the amount of fallowed land may be less. For long-term transfers, impacts on other elements of the local community (e.g., schools, businesses) may be more widespread and severe. Transfers of surface water that are replaced by increasing groundwater pumping may reduce groundwater levels and increase the pumping costs to other groundwater users, and may also contribute to groundwater overdraft.

State law generally requires that water transfers not unreasonably affect the overall economy of the county from which the water is transferred (referred to as the source area). However, there is potential for some economic disruption to source areas, depending on the source of transferred water, the amount of water transferred, and the duration of the transfer. The CWC provides for limiting the economic impacts on local communities by limiting the amount of water that can be provided by cropland idling by a water supplier to 20 percent of the water that would have been applied or stored (CWC Section 1745.05[b]), unless a hearing is conducted. While groundwater substitution still allows for a crop to be produced, cropland idling does not produce a crop, which may cause economic impacts on third parties. Although there is no evidence that recent water transfers have had long-term negative economic impacts on source areas, there is a concern that source areas could experience long-term economic impacts if transfers were to become more widespread. Water scarcity can also cause economic impacts, both where the shortage occurs and far beyond. Water transfers can help reduce water scarcity in areas receiving transfers, thereby helping to avoid job losses and secondary economic impacts in these areas.

Quantifying Uncertainties and Effects on Others

Transfers, especially those where water is moved long distances, are limited by several factors, including access to and physical capacity of conveyance systems; environmental and water quality regulations; evaporation, evapotranspiration, and seepage along the flow path; linkages between surface water and groundwater movement and use; and other factors difficult to quantify or anticipate. For example, those water users who traditionally have relied on return flows from upstream diversions as a source of supply are concerned about being affected by changes in the timing and quantity of flows resulting from water transfers or water conservation measures. Quantifying the actual water savings from crop shifting and crop idling is particularly difficult because only the consumptive use by the crop is transferable in most cases. There is a risk that estimates of the water supply benefits from the transfer to the water system (estimates of "real water") will be inaccurate and that the transfers have unintended consequences to other water users, local economies, or the environment. A key challenge is to improve methods for quantifying these uncertainties and to include adequate monitoring and assurances when implementing water transfers. Monitoring is particularly critical for transfers that obtain water from crop idling, from crop shifting, from water use efficiency measures, or by increasing groundwater use. Information may be needed on historical and current land use and water use, groundwater levels, land subsidence, water quality, environmental conditions, and surface water flows.

Need for More Integrated Management of Water Resources

In California, authority is often divided among local, State, and federal agencies for managing different aspects of groundwater and surface water resources. Several examples are listed below.

- The SWRCB has jurisdiction for appropriative water rights dating from 1914, but disputes over appropriative water rights dating before 1914 are settled by the court system.
- The SWRCB has jurisdiction over groundwater quality, but disputes over groundwater use are settled by the court system.
- County groundwater ordinances and local agency groundwater management plans often only apply to a portion of the groundwater basin, and those with overlapping boundaries of responsibility do not necessarily have consistent management objectives.

Failure to integrate water management across jurisdictions makes it problematic to develop transfers with multiple benefits; provide for sustainable use of resources; identify and protect or mitigate potential impacts on third parties; and ensure protection of the legal rights of water users, the environment, and public trust resources.

Infrastructure and Operational Limits

The ability to optimize the benefits of water transfers depends on access to and the physical capacity of existing conveyance and storage facilities. For example, when export facilities in the Delta are already pumping at full capacity, transferable water cannot be moved. This occurred in 2003, when the Metropolitan Water District of Southern California (MWD) negotiated water transfers with growers in the Sacramento Valley but was unable to move water through the Delta, where the conveyance system was flowing full, or to store the water in Lake Oroville, which filled with late spring rain. As noted previously, the implementation of the biological opinions for the OCAP has also limited the period when water can be transferred across the Delta. This has affected Project water operations such that the exporting of Project water has now shifted to the water transfer period, which reduces available capacity for transfers.

The ability to convey water is also an important aspect of water transfers between the Imperial Irrigation District and the San Diego County Water Authority, which requires access to the Colorado River Aqueduct owned and operated by the MWD.

Climate Change

Water supply reliability faces increasing challenges, including impacts caused by changing climate. Increasing air temperatures will result in more precipitation falling as rain rather than as snow. This will shift the runoff timing, with higher runoff occurring in the winter and early spring and lower runoff in the summer and fall (California Natural Resources Agency 2009). The ability to capture this water for supply will be constrained in some cases by the need for flood protection. Warmer air temperatures will also increase the demands for both urban and agricultural users. Anticipated impacts from climate change also include more intense wet and dry periods (California Natural Resources Agency 2009). Longer, more frequent droughts will put additional demands on water supplies, and larger storm events could damage conveyance infrastructure. Water transfers can provide benefits in adapting to these expected changes in climate (preparing for unavoidable changes).

Adaptation

Water transfers can help improve regional resiliency to future climate changes by providing more operational flexibility and greater water supply reliability. However, the ability to transfer water may also be affected by these changes. Rising sea levels and reduced runoff in the summer and fall will contribute to greater salinity intrusion into the Delta, further limiting the ability to transfer water south of the Delta during the period when transfers can occur. While water transfers from north to south will potentially be limited, transfers between water users within a region could be an effective strategy for meeting local demands or responding to shortages associated with longer droughts or disruptions in deliveries.

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Within the SWP, water transfers are not typically a mitigation strategy. Water transferred from north to south via pumps is energy intensive. Transferred water replaced by groundwater pumping is another source of greenhouse gas emissions. If the transferred water is not replaced, then the land dries out and is left idle, releasing any sequestered carbon in the process. Water transfers could be considered a mitigation strategy only if the transfer eliminated the need to use a more energy-intensive source of water.

Recommendations

1. Because local government and water agencies have the lead role in developing and implementing water transfers, they should:

    A. Implement monitoring programs that evaluate potential specific and cumulative impacts from transfers, provide assurances that unavoidable impacts are mitigated reasonably, and demonstrate that transfers comply with existing law.

    B. Develop groundwater management plans to guide the implementation of water transfers that increase groundwater use or that could affect groundwater quality.

    C. Evaluate and implement regional water management strategies to improve regional water supplies to meet municipal, agricultural, and environmental water demands and minimize the need to import water from other hydrologic regions.

    D. Provide for community participation when identifying and responding to conflicts caused by transfers to which they are a party.

2. State and federal agencies, in addition to implementing State and federal law, should assist with resolving potential conflicts over water transfers when local government and water agencies are unable to do so and when there are overriding State or federal concerns.

3. State and federal agencies continue to gain consensus on how best to implement water transfers. The following actions are ongoing and should be continued and improved:

    A. Preparing programmatic and site-specific CEQA and National Environmental Policy Act (NEPA) documents and other technical assistance for interregional transfers.

    B. Developing and improving current computer modeling tools with the capacity to assess impacts of groundwater substitution transfers, including the effects on groundwater basins, surface water depletion, water quality, and subsidence.

    C. Conserving, protecting, and managing fish, wildlife, native plants, and habitats necessary for ensuring biologically sustainable populations of those species, in particular by the California Department of Fish and Wildlife (formerly known as the California Department of Fish and Game) as the trustee agency responsible for, and with jurisdiction over, those resources of the State (California Fish and Game Code Section 1802).

    D. Streamlining the approval process of State and federal agencies for water transfers where approvals are required, while protecting water rights, the environment, and local economic interests.

    E. Refining current methods to identify and quantify water savings for transfers using crop idling, crop shifting, and water use efficiency measures; and assessing the impacts of riceland idling on environmental resources, while using a collaborative process to evaluate a wide range of methods.

    F. Developing, with interested parties, acceptable ways to identify, lessen, and distribute economic impacts from transfers that use crop idling and crop shifting.

    G. Providing financial assistance for local and regional groundwater management activities that promote sustainable and coordinated use of surface water and groundwater. Seeking consensus among interested parties about the role of water transfers as a water management strategy while identifying and preventing or mitigating potential impacts on other water users, third parties, the environment, and public trust resources.

H. Improving coordination and cooperation among local, State, and federal agencies with different responsibilities for surface water and groundwater management to facilitate sustainable transfers with multiple benefits, allow efficient use of agency resources, and promote easy access to information by the public.

I. Developing water transfer policies that balance the ability of agriculture to provide water for transfers on a limited periodic basis to help with temporary water scarcity so that transfers do not destabilize agricultural productivity and economic benefits.

References

References Cited

CALFED Bay-Delta Program. 2000. *Programmatic Record of Decision*. Sacramento (CA): CALFED Bay-Delta Program. (3 vol.). 82 pp. Conveyance Program. Viewed online at: http://bibpurl.oclc.org/web/752. Accessed: January 22, 2013.

California Department of Water Resources. 2005. *California Water Plan Update 2005*. Volume 2, "Resource Management Strategies"; Chapter 23, "Water Transfers." Sacramento (CA): California Department of Water Resources. Viewed online at: http://www.waterplan.water.ca.gov/previous/cwpu2005/index.cfm#vol2.

California Department of Water Resources and U.S. Bureau of Reclamation, Mid-Pacific Region. 2012. *Draft Technical Information for Water Transfers in 2012: Information to Parties Interested in Making Water Available for 2012 Water Transfers.*). Sacramento (CA): California Department of Water Resources. Viewed online at: http://www.water.ca.gov/watertransfers/docs/TechInfoDoc-WaterTransfers-2012.pdf. Accessed: Jan. 22, 2013.

California Natural Resources Agency. 2009. 2009 *California Climate Adaptation Strategy*. Viewed online at: http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF. Accessed: Jan. 22, 2013

National Marine Fisheries Service, Southwest Regional Office. 2009. "Operations, Criteria and Plan." Long Beach (CA): National Oceanographic and Atmospheric Administration's National Marine Fisheries Service, Southwest Regional Office. [Web page.] Viewed online at: http://swr.nmfs.noaa.gov/ocap.htm. Accessed: December 2009.

U.S. Fish and Wildlife Service. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. Sacramento (CA): U.S. Department of the Interior, Fish and Wildlife Service. [Memorandum 81420-2008-F-1481-5.] Viewed online at: http://www.fws.gov/sfbaydelta/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf.

———. 2009a. *Endangered Species Consultation on the Proposed 2009 Drought Water Bank for the State of California*. Sacramento (CA): U.S. Department of the Interior, Fish and Wildlife Service. 91420-2008-F-1596-1. 49 pp.

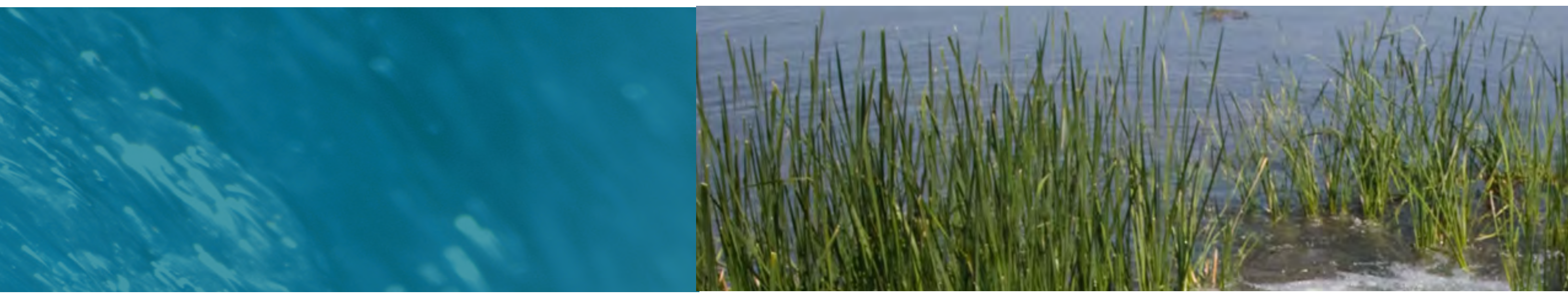
———. 2009b. "Delta Update." Sacramento (CA): U.S. Fish and Wildlife Service, Sacramento Fish & Wildlife Office. [Web page.] Viewed online at: http://www.fws.gov/sacramento/delta_update.htm. Accessed: December 2009.

Yuba County Water Agency. 2009. "Lower Yuba River Accord." Marysville (CA): Yuba County Water Agency. [Web page.] Viewed online at: http://www.ycwa.com/projects/detail/8. Accessed: December 2009.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 9

Conjunctive Management and Groundwater Storage



Yuba River. Infrastructure, such as this water discharge pipe, allow water districts and agencies to manage surface water and groundwater within the same hydrologic area as a single resource, using one source to balance the other when surface water or groundwater levels are low. This can reduce water diversions and groundwater pumping, enhance local supply, and increase the amount of water available for transfer.

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Chapter 9. Conjunctive Management and Groundwater Storage

Introduction

Conjunctive management or conjunctive use refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit. Conjunctive management thus involves the efficient use of both resources through the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin that is planned to be used later by intentionally recharging the basin when excess water supply is available, for example, during years of above-average surface water supply or through the use of recycled water. The necessity and benefit of conjunctive water management are apparent when surface water and groundwater are hydraulically connected. Well-planned conjunctive management that prevents groundwater depletion by maintaining baseflow to streams and support for ecosystem services not only increases the reliability and the overall amount of water supply in a region, but also provides other benefits such as flood management, environmental water use, and water quality improvement.

In this document, the two terms - conjunctive water management and conjunctive water use are utilized to depict the same water management strategy described above. However, there are water management practitioners who distinguish between the two or view them somewhat differently. Examples of definitions of the terms as used by other practitioners are furnished in Box 9-1.

Conjunctive management can occur at multiple areal coverages — from local to regional to statewide coverage. As the areal coverage increases, so do the difficulties of and benefits derived from implementing conjunctive management projects. Locally planned conjunctive management projects are easier to design and implement and should be an integral part of water management portfolios of local agencies. At the larger geographic scale, conjunctive management with an appropriate infrastructure and applied in a responsible manner has the potential to span multiple regions and achieve greater benefits than individual, isolated projects. In the long run, failure to integrate surface water and groundwater management across jurisdictions will make it difficult to manage water for multiple benefits and to provide for sustainable use including the ability to identify and protect or mitigate potential impacts on third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, reduce subsidence potential of aquifers, protect the environment, recognize and protect groundwater recharge and discharge areas, and safeguard natural resources under the public trust doctrine.

Project Feasibility Considerations

One of the roles and goals of California is to seek statewide water supply reliability and sustainability. Similarly, one of the roles and goals of the California Department of Water

Box 9-1 Examples of Definitions of Conjunctive Water Management and Conjunctive Water Use

Example Definition 1

"Conjunctive water use primarily changes the timing in the flow of existing water sources by shifting when and where it is stored and does not result in new sources of water. Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users to manage an immediate situation, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are not involved in conjunctive use but are reliant on the same groundwater basin.

"An alternative to conjunctive water use is conjunctive water management. The difference between the two is more than semantics. Conjunctive water management engages the principles of conjunctive water use, where surface water and groundwater are used in combination to improve water availability and reliability. But, it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies. Scientific studies are needed to support conjunctive water management. They provide important data to understand the geology of aquifer systems, how and where surface water replenishes the groundwater, and flow directions and gradients of groundwater."

Source: Dudley and Fulton 2006

Example Definition 2

"Conjunctive use and conjunctive management describe the interchangeability of ground and surface water. ... Conjunctive use, with its roots in traditional water application, denotes an opportunistic or incidental interchangeability, as when an unplanned shortfall of natural ground or surface water availability causes a user to switch back and forth between sources. Typically, surface water users switch to groundwater available naturally beneath their land when surface supplies fall short of their needs. On the other hand, conjunctive management seeks to actively manage the balance of ground and surface water availability over a period of naturally occurring wetter and drier water cycles. The objective of conjunctive management is to intercede in natural groundwater recharge processes to even out the year-to-year variations in regional water availability with potential peripheral benefits of flood management, environmental water, and water quality improvement. While conjunctive use is an inherently local concept, conjunctive management with an appropriate infrastructure has the potential to span multiple regions."

Source: St. Amant 2012

Example Definition 3

"Conjunctive use of groundwater and surface water in an irrigation setting is the process of using water from the two different sources for consumptive purposes. Conjunctive use can refer to the practice at the farm level of sourcing water from both a well and an irrigation delivery canal, or can refer to a strategic approach at the irrigation command level where surface water and groundwater inputs are centrally managed as an input to irrigation systems. Accordingly, conjunctive use can be characterized as being planned (where it is practiced as a direct result of management intention – generally with a top down approach) compared with spontaneous use (where it occurs at a grass roots level – generally with a bottom up approach).

"…the aim of conjunctive use and management is to maximize the benefits arising from the innate characteristics of surface and groundwater water use; characteristics that, through planned integration of both water sources, provide complementary and optimal productivity and water use efficiency outcomes."

Source: Evans et al. 2012

Example Definition 4

"Conjunctive use of surface water and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects of each solution and to optimise the water demand/supply balance."

Source: Food and Agriculture Organization of the United Nations 1995

Resources (DWR) is to strive for sustainable groundwater supplies throughout the state. Conjunctive management is getting increased attention as one major water resources management strategy to attain these goals, although the strategy in some form has been practiced for more than 100 years by certain agencies in California. The five project feasibility considerations of conjunctive management are:

- **Hydrogeologic feasibility.** Hydrogeologic feasibility takes into consideration the hydrogeologic constraints that must be identified.
  - Where is the recharge zone for the aquifer that is going to be pumped?
  - What is the mechanism and rate of recharge?
  - Is the recharge zone connected to the aquifer that is going to be pumped?
  - What are the soil, sub-soil, and aquifer characteristics – infiltration capacity, porosity, hydraulic conductivity, specific yield – that are important for success of conjunctive management?
- **Available groundwater storage capacity.** Available groundwater storage capacity denotes the space available to recharge the basin.
- **Water source.** Water source provides the supply of water that will be used to store water in the groundwater system. Water sources include imported water, local runoff, and treated wastewater.
- **Conveyance.** Conveyance is necessary to transport the water from water source to recharge location and to distribute water from the groundwater extraction facility to the point of demand. Conveyance systems include lined and unlined canals, pipelines, and streams.
- **Recharge and extraction and pre- and post-treatment facilities.** Recharge and extraction facilities are essential components of a conjunctive management project. Recharge includes direct spreading, injection, in-lieu recharge, and induced natural recharge. Extraction may be for direct use, pumped back to conveyance systems, and surface water exchange. Additionally, pre- and post-treatment facilities may also be necessary to meet existing water standards.

The five project feasibility considerations of conjunctive management — hydrogeologic feasibility, available groundwater storage capacity, water source, conveyance, recharge and extraction facilities, and pre- and post-treatment facilities (under certain circumstances) — are the fundamental, physical elements that are indispensable for conjunctive management to be functional. If any of these physical elements are missing, it will make conjunctive management impractical and unworkable.

Project Development Components

In practical terms, once the five project feasibility considerations are determined to be satisfactory, a set of five project development components must blend together for a specific conjunctive management project or program:

- **Groundwater planning and management.** Groundwater planning is the process to decide what needs to be accomplished to preserve the natural resource. The outcome of this planning process is a groundwater management plan. Groundwater management denotes the set of activities that direct how to implement management actions identified during the planning step as contained in the groundwater management plan. Formally speaking, groundwater management is the planned and coordinated management of a groundwater basin or portion of a groundwater basin with a goal of long-term sustainability of the resource. Groundwater management aims to improve specific aspects of the management of groundwater resources in individual basins or portions of basins across a region or throughout the state. The improvements pertain to many aspects of groundwater management, including implementing programs or projects to manage and protect groundwater, characterizing and increasing knowledge of individual groundwater basins, identifying basin management strategies or objectives, planning and conducting groundwater studies, and designing and constructing conjunctive management projects.

- **Project construction and operation.** Project construction and operation may include construction and operation of treatment facilities, conveyance facilities, or spreading basins as well as installation and operation of monitoring, production, and injection wells, and drilling of test holes.
- **Institutional structures.** As with other types of projects, conjunctive management projects must also adhere to local ordinances in addition to State and federal laws and regulations. Institutional structures include:
  - Laws.
  - Regulations and ordinances.
  - Contracts and agreements.
  - Political support.
  - Public-private partnerships.
  - Governance.
- **Funding.** Funding sources include State and federal grants and loans, State and local bonds, State and local taxes, assessments, and fees, and public-private partnerships. As with other types of projects, a conjunctive management project also has associated cost components, and financing and economics issues. As a result, available sources of funding have to be identified and secured to successfully plan, design, and implement a conjunctive management project.
- **Organizational capacity building.** Organizational capacity building is the process of equipping entities, usually public agencies, with certain skills or competences, or upgrading performance capability by providing assistance, funding, resources, and training. This is important for the continued operation and long-term success of conjunctive management projects.

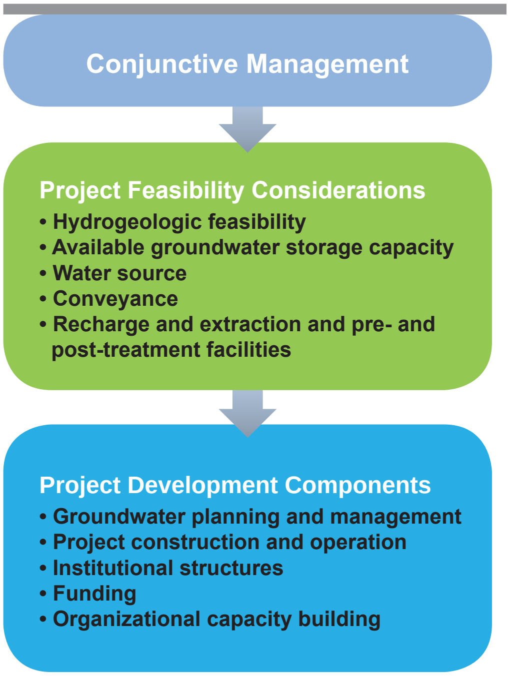
The five project development components — groundwater planning and management, project construction and operation, institutional structures, funding, and organizational capacity building — bring a conjunctive management project to fruition.

Figure 9-1 presents in a nutshell, practical considerations that need to be thought about and met before planning conjunctive management projects and important components for implementing successful conjunctive management projects.

Groundwater Storage

Understanding terms related to groundwater storage is critical to ensure the success of a conjunctive management project. Groundwater in storage or simply groundwater storage can be defined as the quantity of water found at a given time in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. Groundwater storage capacity — the maximum attainable groundwater storage — is defined as the maximum volume of usable void space that can be occupied by water in a given volume of a formation, aquifer, or groundwater basin. Available groundwater storage capacity is defined as the volume of usable physical space available at a given time to store water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface. These water-filled geologic materials, or aquifers, may receive the water (and be recharged or replenished) from natural hydrologic processes, or the water may be introduced to the aquifer by active groundwater management. The water in these aquifers may be withdrawn through wells, or the water may discharge naturally, contributing to streamflow or to the supply of water for springs, seeps, and wetlands.

Figure 9-1 Conjunctive Management - Project Feasibility and Development



Groundwater remains an important water source for municipal drinking water, agriculture, and individual water users across California. Groundwater is also a vital source of flow in many streams, providing support for aquatic and riparian habitat. Benefits of groundwater storage, as compared to surface water storage, include smaller evaporation loss, lower susceptibility to adverse impacts from natural and human induced hazards, and less maintenance costs. Over the years, groundwater has played a leading role in transforming California into the nation's top agricultural producer, most populous state, and the eighth largest economy in the world.

According to the California Department of Public Health (CDPH), an estimated 30 million Californians, more than three quarters of the state's population, receives at least part of their drinking water from groundwater. Groundwater from either private domestic wells or other groundwater-dependent supplies not regulated by the State provides drinking water to an additional one to two million people (State Water Resources Control Board 2012; Department of Water Resources 2013a). Many small- to moderate-sized towns and cities (e.g., Fresno, Davis, and Lodi) rely solely on groundwater for their drinking water supplies. Statewide, about six million people rely 100 percent on groundwater (State Water Resources Control Board 2013). In California, public water supply systems alone use about 13,000 wells to supply water to the public (California Department of Water Resources 2013b). The demand on groundwater will continue to increase as California's population grows from 38 million in 2012 to a projected 51 million by 2050, based on current trends (California Department of Water Resources 2013c). The increased demand on groundwater has caused significant groundwater depletion in many locations, which needs to be recognized and addressed to ensure sustainability of this important resource.

The importance of groundwater to California water supply is increasingly being recognized. For example, in an average year (based on 2005-2010 data), groundwater meets about 40 percent of California's agricultural, urban, and managed wetlands water uses (about 16.5 million acre-feet per year). Depending on hydrology, this percentage varies from approximately 30 to 50 percent (California Department of Water Resources 2013b). The importance of groundwater as a resource varies regionally. Figure 9-2 depicts the importance of groundwater as a local supply for agricultural, urban, and managed wetlands water uses in each of California's 10 hydrologic regions (regions). In Figure 9-2, the map shows the total water use as well as the water use met by groundwater in the different regions. In the same figure, the pie chart shows the percentage of groundwater extraction in each region relative to the total groundwater extraction in the state as a whole.

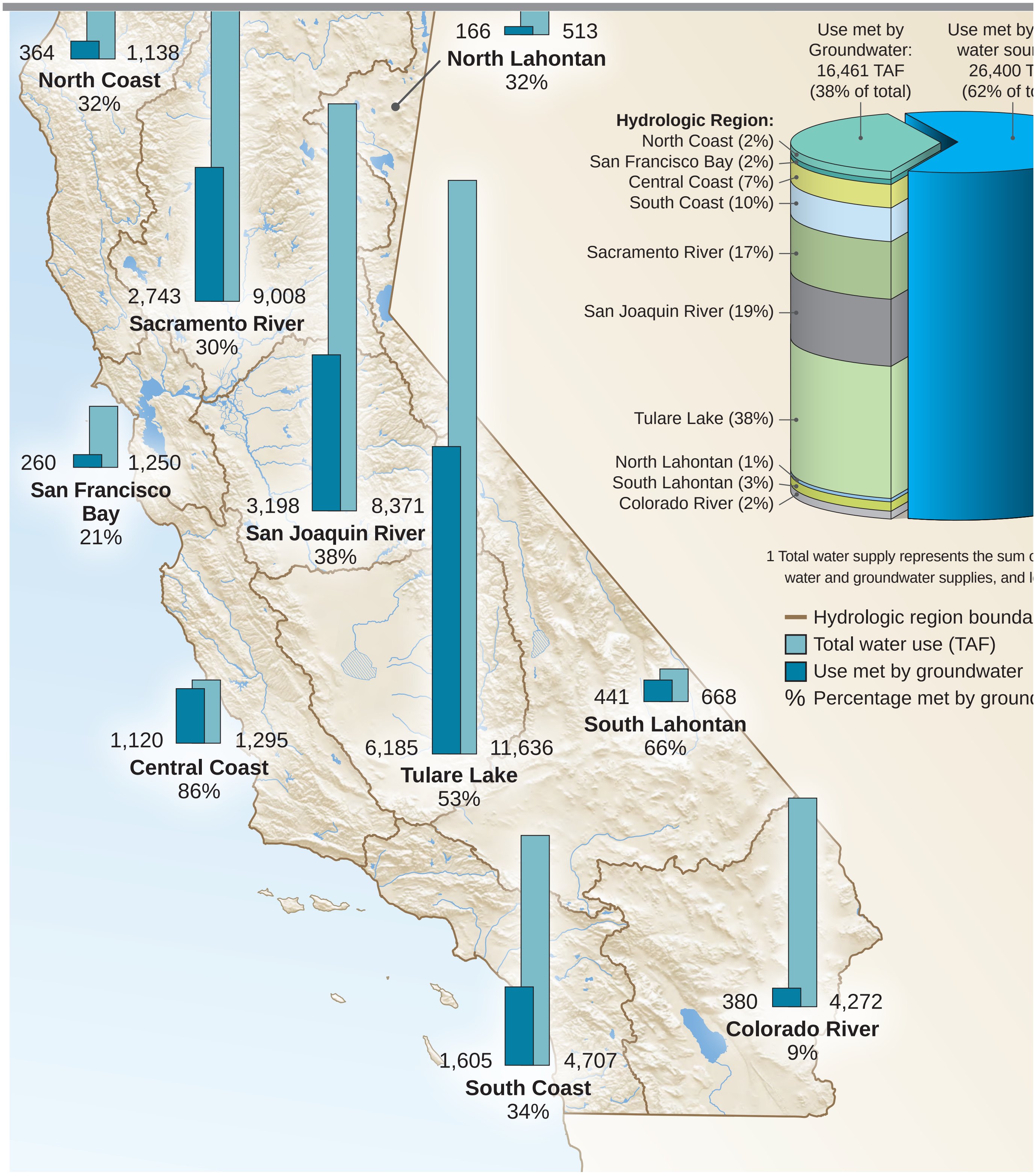
With more than 85 percent of water use met by groundwater in an average year, as shown in the map, the Central Coast Hydrologic Region is heavily reliant on groundwater to meet its local uses. The Tulare Lake Hydrologic Region meets more than 50 percent of its local uses from groundwater, and the South Lahontan Hydrologic Region meets more than 65 percent of its local uses with groundwater. The North Coast, San Francisco Bay, South Coast, Sacramento River, San Joaquin River, and North Lahontan regions meet between approximately 20 and 40 percent of their local uses with groundwater. In terms of percentage, groundwater provides less than 10 percent of supply in the Colorado River Hydrologic Region.

As shown in the pie chart, of all the groundwater extracted annually in the state in an average year (based on 2005-2010 data), more than 35 percent is produced from the Tulare Lake Hydrologic Region. Nearly 75 percent of groundwater extraction occurs in the Central Valley (Sacramento River, San Joaquin River, and Tulare Lake regions combined). More than 15 percent is extracted in the highly urbanized Central Coast and South Coast regions, while about 10 percent is extracted in the remaining five hydrologic regions combined. With the growing limitations on available surface water exported through the Sacramento-San Joaquin Delta and the potential impacts of climate change, reliance on groundwater through conjunctive management will become increasingly more important in meeting the state's future water uses.

Groundwater and Surface Water Interrelated

In the past, water resources in many regions have been developed and managed with the underlying assumption that surface water and groundwater are separate resources. Although for a number of basins in California, there has been an intuitive understanding of the interrelationship between surface water and groundwater, only in recent years have water scientists, planners, and managers unmistakably recognized that the extraction and use of one resource affects the other. Groundwater and surface water bodies are connected physically in the hydrologic cycle and interact with each other. At some locations or at certain times of the year, groundwater will be recharged through infiltration from the bed of a stream. At other locations or at other times, groundwater may discharge to the stream, contributing to its baseflow. Similarly, degradation of surface water quality may result in a corresponding degradation of groundwater quality. Pollution of groundwater may result in a corresponding pollution of surface water. Thus, changes in either the groundwater or surface water system will directly affect the other. Although this physical interconnection is understood in general terms, details of the physical, chemical, and residence time relationships remain the topic of a number current studies for certain basins by various State and federal agencies. Effective conjunctive management acknowledges the interconnection of the two resources and requires proper characterization of local and regional interconnections to ensure safety and effectiveness for specific programs and projects and to maximize the beneficial uses of the integrated water system (see Box 9-2).

Figure 9-2 Importance of Groundwater to California Water Supply



Meeting Multiple Objectives

Conjunctive water management projects may be implemented to meet many objectives including improving local or regional water supply reliability, increasing flood protection, meeting environmental needs, improving groundwater quality, countering land subsidence, or reducing groundwater overdraft. One example of conjunctive water management is recharging groundwater storage using surface water when additional surface water supplies are available and affordable. The surface water may be introduced into the aquifer through injection wells, spreading the water on permeable ground surfaces in recharge ponds, or introducing the water into streams that are connected to the aquifer through permeable streambeds. The stored water in the aquifer can then be withdrawn at a later time when surface water is not available or too expensive to meet local demands. In some areas, recharge may be accomplished by providing surface water to users who would normally use groundwater (also called in-lieu recharge), thereby leaving more groundwater in place for restoring groundwater levels or for later use. Some agencies also consider programs that reduce demands on groundwater via water conservation or water recycling as in-lieu recharge because these programs have the same effect in restoring groundwater levels as the provision of surface water. For further discussion on natural and managed (also called artificial or intentional) groundwater recharge, see Box 9-3.

A sustainable conjunctive water management program consists of several components that include investigating the groundwater aquifer characteristics, estimating surface water and groundwater responses, and appropriate monitoring of groundwater level and quality. In addition, reliable institutional systems for ensuring environmental compliance, providing long-term system maintenance, and managing contractual and legal features of the program are critical to sustainability. An important issue pertaining to legal features of a conjunctive water management program is addressing who actually owns the artificially recharged water in a managed recharge project, particularly if the timing of recharge has prevented natural recharge, which would belong to all the overlying landowners. The major legal issue is how to resolve the ownership/extraction rights related to water that has been artificially added into a multi-jurisdictional/multi-land owner groundwater basin. The question is whether the water that has been artificially added to a groundwater basin is the property of the entity that added it or, once it commingles with the existing groundwater, does it become groundwater governed by the prevailing statutes in the California Water Code (CWC)? A legal and scientific way of settling the issue of extraction rights would be an inescapably important factor in the public discussion of conjunctive management and groundwater storage.

Conjunctive management and groundwater storage are closely linked with other resource management strategies, such as groundwater remediation and recharge area protection. Groundwater remediation may be implemented in areas where the usability of the aquifer for groundwater storage has been compromised by aquifer contamination, thereby partially or fully restoring the capacity of the aquifer for storage or limiting the extent of the water quality problem.

Although conjunctive management programs often involve artificial recharge of aquifers with water from other sources, such as imported or recycled water, most California aquifers and therefore any conjunctive management programs using those aquifers, are heavily dependent on natural recharge of local water. As such, the resource management strategy for recharge area protection is critical to maintaining groundwater storage for long-term reliability of conjunctive management supplies.

Box 9-2 Groundwater and Surface Water, a Single Source

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths start at the water table, continue through the groundwater system, and terminate at the stream or at the pumped well. The source of water to the aquifer is infiltration through the unsaturated soil zone resulting from precipitation, irrigation applied water, managed recharge, etc. Flowlines from various aquifers to the stream can be tens to hundreds of feet in length and have corresponding travel times of days to several years or more (see Figure A below).

The interaction of streams with groundwater may take place in three different ways: streams may gain water from discharge of groundwater through the streambed (gaining stream), streams may lose water to groundwater by seepage through the streambed (losing stream), or streams may gain in some reaches (gaining reaches) and lose in some of the reaches (losing reaches). As shown in Figure B, for streams to gain water from groundwater, the stream water surface elevation must be lower than the surrounding groundwater table elevation. In contrast, as shown in Figure C and Figure D, for streams to lose water to groundwater, the stream water surface elevation must be higher than the surrounding groundwater table elevation. Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure C) or can be disconnected from the groundwater system by an unsaturated zone (Figure D). A distinguishing characteristic of a stream that is disconnected from groundwater is that shallow groundwater pumping in the vicinity of the stream does not necessarily induce additional seepage of water from the stream to groundwater (Winter et al. 1998).

The direction of flow between the stream and the groundwater system may change because of storms (or flood flows moving down the stream), causing water to flow from the stream to groundwater. The direction of flow between the stream and groundwater can alter as a result of groundwater pumping near the stream. In the case of a gaining stream, pumping is likely to decrease discharge from the aquifer to the stream and in some cases, high pumping rates can even modify a gaining stream to a losing stream. In the case of a losing stream, pumping is likely to further increase seepage from the stream to the aquifer (Winter et al. 1998).

The characteristics and extent of the interactions of groundwater and surface water in an area will likely define the success of conjunctive management projects. Therefore, a better understanding of the interconnection between groundwater and surface water is instrumental for effective conjunctive management.

Figure A

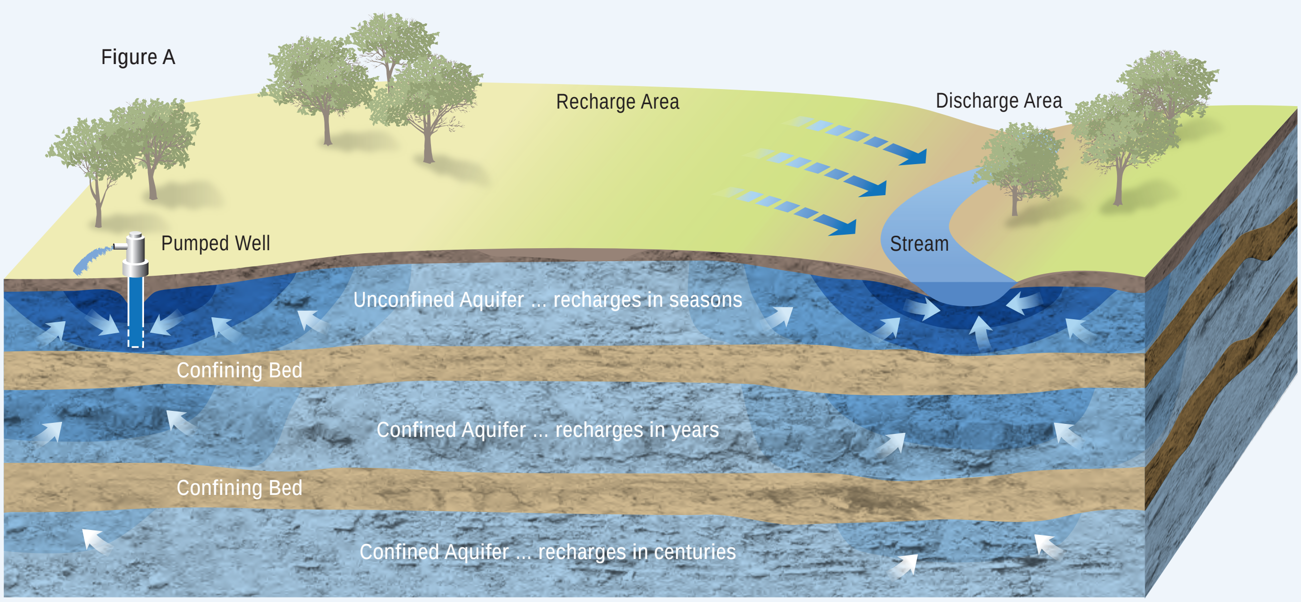


Figure B: Gaining Stream

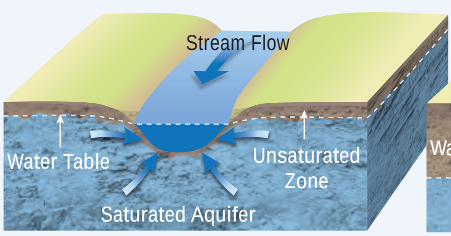


Figure C: Losing Stream

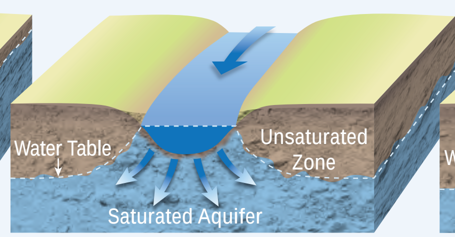
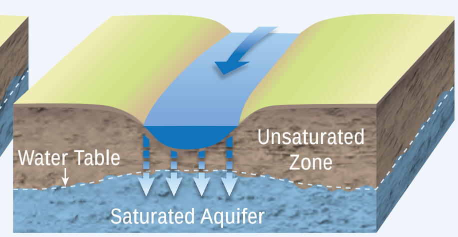


Figure D: Disconnected Stream



Box 9-3 Groundwater Recharge: Natural and Managed

Groundwater recharge is the mechanism by which surface water moves from the land surface, through the topsoil and subsurface, and into the aquifer, or through injection of water directly into the aquifer by wells. Groundwater recharge can be either natural or managed. Natural recharge occurs from precipitation falling on the land surface, from water stored in lakes, and from streams carrying storm runoff (Figure A). Managed recharge occurs when water is placed into constructed recharge or spreading ponds or basins, or when water is injected into the subsurface by wells. Managed recharge is also known as artificial, intentional, or induced recharge. Two widely used methods for managed groundwater recharge are recharge basins and injections wells. An additional, indirect method of managed recharge is called in-lieu recharge.

Recharge Basins. Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Recharge basins concentrate a large volume of infiltrating water on the surface. As a result, a groundwater mound forms beneath the basin. As the recharge starts, the mound begins to grow. When the recharge ceases, the mound recedes as the water spreads through the aquifer (Figure B). The infiltration capacity of recharge basins is initially high, and then as recharge progresses, the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Fine surface sediments may occasionally need to be removed mechanically to maintain the effectiveness of recharge basins.

Injection Wells. Injection wells are used primarily to recharge confined aquifers. The design of an injection well for artificial recharge is similar to that of a water supply well. The principal difference is that water flows from the injection well into the surrounding aquifer under either a gravity head or a head maintained by an injection pump (Figure C). As a large amount of water is pushed through a small volume of aquifer near the well face, injection wells are prone to clogging, which is one of the most serious maintenance problems encountered. Clogging can occur in the well perforations, in the well-aquifer interface, and in the aquifer materials. It is suspected that a combination of a build-up of materials brought in by the recharging water and chemical changes brought about by the recharging water are the primary causes of clogging. The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the well and the aquifer may be achieved during the pumping period. However, pretreatment of the water to be injected is always necessary to eliminate the suspended matter.

In-lieu Recharge. In some areas, “recharge” may be accomplished by providing surface water to users who would normally use groundwater, thereby leaving more groundwater in place for restoring groundwater levels or for later use. This indirect method of managed recharge is known as in-lieu recharge.

Another widely used method for managed recharge is through release of water into streams beyond what occurs from the natural hydrology (Figure D). Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance canals.

The major purpose of managed recharge is to increase water supply in an area by supplementing the existing groundwater supply. The use of managed recharge to enhance the availability and quality of groundwater has received increased attention in recent years. Numerous managed recharge projects have been implemented in California and others are planned.

Figure A, B, C, D Groundwater Recharge: Natural and Managed

Figure A: Natural recharge

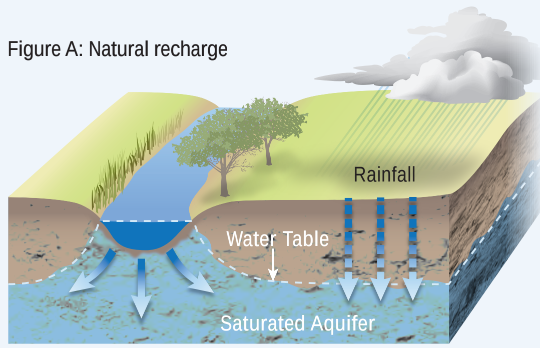


Figure B: Managed recharge - recharge basins

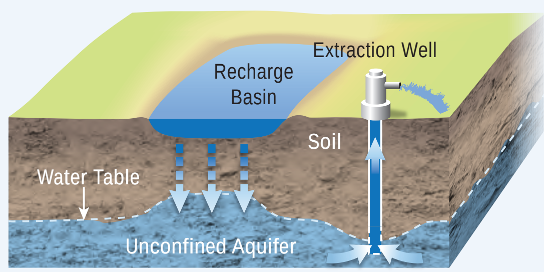


Figure C: Managed recharge - injection wells

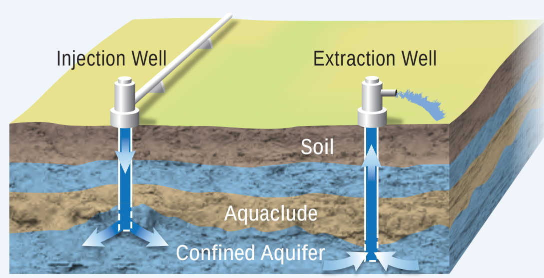
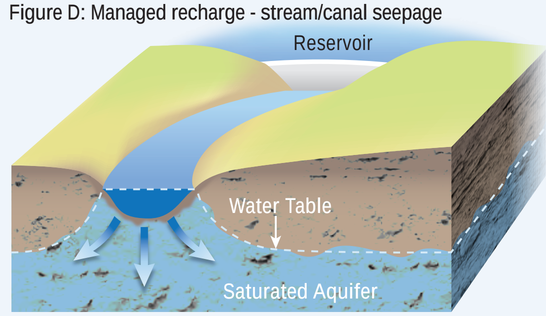


Figure D: Managed recharge - stream/canal seepage



Conjunctive management and groundwater storage, in the context of Integrated Regional Water Management (IRWM), may be intertwined with many other management strategies, including conveyance, desalination, drinking water treatment and distribution, ecosystem restoration, floodplain management, recycled municipal water, surface storage, urban land use management, water transfers, system reoperation, and watershed management. Examples of these relationships are discussed in this chapter and elsewhere in *California Water Plan Update 2013*.

Chronicle of Conjunctive Management and Groundwater Storage in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era (1770s-1830s). The first known managed (artificial or intentional) recharge of groundwater in California occurred in Southern California during the late 1800s, and managed recharge has become an increasingly important part of integrated water management (IWM) in many areas.

Unlike surface water use, groundwater use in California does not have a statewide management program or statutory permitting process. When the Water Commission Act became effective in 1914, surface water appropriative rights became subject to a statutory permitting process. The statutory permitting process is defined under California law, which stipulates that a water user must obtain, modify, or renew water rights permits from the State Water Resources Control Board (SWRCB). The Water Commission Act of 1914 was the predecessor to today's CWC statutes governing appropriation. In addition to surface water, groundwater classified as underflow of a surface water system, a "subterranean stream flowing through a known and definite channel," was also made subject to the statutory permitting process. However, most groundwater in California is presumed to be "percolating water," that is, water in underground basins and groundwater that has escaped from streams and is not subject to a permitting process. As a result, most of the body of law governing groundwater use in California today has evolved through a series of court decisions beginning in early 20th century (California Department of Water Resources 2003).

The California Legislature has repeatedly held that groundwater management is a local responsibility (Sax 2002). The State's role is to provide technical and financial assistance to local agencies and work with them for planning and implementing groundwater management efforts. There are three forms of groundwater management in California: local agency management, local groundwater ordinance, and court adjudication (California Department of Water Resources 2003).

More than 20 types of local agencies are authorized by statute to provide water for various beneficial uses. Many of these agencies also have statutory authority to institute some form of groundwater management, but their specific authority related to groundwater management varies. In 1991, Assembly Bill (AB) 255 authorized local agencies overlying basins that are subject to critical conditions of overdraft, as defined in DWR's Bulletin 118-80, to establish voluntary groundwater management plans within their service areas (California Department of Water Resources 2003).

The passage of AB 3030 in 1992 (CWC Section 10750 et seq.) greatly encouraged local agencies to adopt groundwater management plans for managing their groundwater resources whether or not the groundwater basin is in overdraft condition. In 2002, the Legislature passed Senate Bill (SB) 1938, which contained new requirements for local agency groundwater management plans and required adoption of these plans for groundwater projects to be eligible for public funds. At the time Bulletin 118-2003 was published in 2003, more than 200 local agencies had adopted AB 3030 groundwater management plans. An additional bill, AB 359, passed in 2011, 1) requires local groundwater agencies, as a condition of receiving State funds for groundwater projects, to include a map identifying groundwater recharge areas in their basins in groundwater management plans and to provide the recharge area maps to local planning agencies and, 2) includes additional local agency reporting requirements, including submittal of groundwater management plans to DWR.

With the emphasis in recent years on integrated regional water planning and management, IRWM plans have been prepared for many regions throughout the state, and the portion of the state covered by an IRWM plan is continually expanding as new IRWM plans are developed. In 2009, DWR went through a Region Acceptance Process (RAP) to accept regions into the IRWM Grant Program. As of the second round of RAP, there are a total 48 IRWM regions, two of which are conditionally approved (see http://www.water.ca.gov/irwm/grants/docs/ResourcesLinks/GraphicFiles/IRWM_E_48_Regions_Merged_Template_02132014.pdf).

An important consideration in the coordination of surface water and groundwater resources is the question of potential adjudications of water rights by tribal communities. Additionally, tribal rights to groundwater in some areas could be significant, for example, in San Diego County. Tribal water rights and adjudications, pertaining to both surface water and groundwater, are issues that must be substantively addressed for viable, long-term water resources planning in California.

Over the past few years, voters and the Legislature have provided significant funding to local agencies for improving water supply reliability and groundwater management. Proposition 13, approved by voters in 2000, provided $200 million for grants for feasibility studies, project design and the construction of conjunctive use facilities, and $30 million for loans for local agency acquisition and construction of groundwater recharge facilities and grants for feasibility studies of groundwater recharge projects. AB 303, enacted in 2000, created the Local Groundwater Assistance (LGA) fund and authorized grants totaling $38.5 million from 2001 to 2009 to help local agencies develop better groundwater management strategies to ensure the safe production, quality, and storage of groundwater.

Proposition 50, passed in 2002, and provided $500 million for IRWM projects. Although this funding is not specifically targeted for groundwater projects, many of the projects in the regional proposals would expand groundwater storage, desalt brackish groundwater, or improve groundwater quality to make new supplies available. Proposition 84, approved in 2006, and provided an additional $1 billion for IRWM projects.

Along with providing increased funding for IRWM projects as noted above, in 2009, the Legislature, as part of a larger package of water-related bills, passed SB X7-6, requiring that groundwater elevation data be collected in a systematic manner on a statewide basis and be made readily and widely available to the public. DWR was charged with administering the program, which was later named the California Statewide Groundwater Elevation Monitoring or CASGEM Program. The program is voluntary, although future eligibility of State grant funding for associated agencies could be affected if they choose not to participate. Monitoring outside of the state’s 515 alluvial groundwater basins and subbasins listed in DWR Bulletin 118-2003 is not required. SB X7-6 contains the following requirements.

- Local agencies, counties, and associations interested in volunteering to become Monitoring Entities shall notify DWR by January 1, 2011.
- DWR shall review prospective Monitoring Entity notifications and determine designated Monitoring Entities for each basin and subbasin.
- DWR shall work cooperatively with local Monitoring Entities to achieve monitoring programs that demonstrate seasonal and long-term trends in groundwater elevations.
- Monitoring Entities shall begin groundwater elevation monitoring in fall 2011 and report elevations to DWR by January 1, 2012.
- DWR shall make these groundwater elevation data widely and readily available to the public.
- DWR will perform groundwater elevation monitoring in basins where no local party has agreed to perform the monitoring functions.
- If local parties (for example, counties) do not volunteer to perform the groundwater monitoring functions and DWR assumes those functions, then those parties may become ineligible for water grants or loans from the State.
- DWR shall report findings to the governor and Legislature by January 1, 2012.
- DWR shall report findings to the governor and Legislature thereafter in years ending in five and zero.

As specified in SB X7-6, DWR has established a statewide groundwater elevation monitoring and reporting program. The following list provides the milestones of the CASGEM program achieved through 2012:

- DWR successfully conducted outreach to develop local support throughout the state.
- DWR developed the CASGEM Web site (http://www.water.ca.gov/groundwater/casgem/) and documents to provide easily accessible, up-to-date program information, and technical support.
- Local agencies, counties, and associations volunteered to become CASGEM Monitoring Entities and notified DWR.
- DWR reviewed the submitted notifications and designated Monitoring Entities for several groundwater basins and subbasins throughout the state.
- DWR worked cooperatively with local Monitoring Entities to develop groundwater elevation monitoring programs for their defined monitoring areas.
- DWR developed an online system for a monitoring plan, well information, and groundwater elevation data submittal, which provided public access to this information and data in both tabular and map formats.
- Monitoring Entities began submitting groundwater elevation data to the CASGEM Online System in fall 2011.
- DWR released the CASGEM Online System to the public in mid-November 2011, allowing access to submitted groundwater elevations.
- DWR released the first report of findings of the CASGEM program to the governor and Legislature in January 2012.

On January 1, 2012, Assembly Bill 1152 made revisions to the CWC related to the CASGEM Program, which include adding a new Monitoring Entity category, allowing alternative monitoring of groundwater basins, and removing the requirement for DWR to seek concurrence of the State Mining and Geology Board regarding adequacy of monitoring plans to demonstrate seasonal and long-term trends in groundwater elevations.

Data Collection and Management

Data collected throughout the state are important in planning and developing the conjunctive water management strategies. The data should include, in addition to those collected as part of the CASGEM Program, groundwater management-related information, groundwater quantity and quality, and water use in the state. DWR's Bulletin 118 series, titled *California's Groundwater*, provides information about the state's groundwater resources and its resource management practices. Bulletin 118 was last updated in 2003 and there is no dedicated funding currently for it, although recently the Governor's Water Action Plan made a recommendation to update it. Some agencies in the state continue to collect and analyze groundwater data, and proactively and effectively manage local groundwater resources. For many other agencies, however, without having access to reliable data and analysis on groundwater, the goal to manage this resource better will likely remain unattainable. To respond to this need, as part of Update 2013, DWR has initiated a process to enhance groundwater content in a major way. The objective is to "expand information about statewide and regional groundwater conditions to better inform groundwater management actions and policies through compilation and summarization of data and analysis." This effort will not solve all the statewide and regional issues related to groundwater, but it is intended as a starting point to bring all the available information together from a statewide and regional perspective. The information content on groundwater built through this initiative is anticipated to set the stage for future California Water Plan updates and related activities to provide on a long-term basis additional data, information, and analyses as well as policy needs for California's groundwater planning and management. The major proposed deliverables planned for Update 2013 include the following:

- Consolidated groundwater information from various State, federal, regional, and local water resource planning initiatives.
- Status of regional groundwater conditions, management activities, and problem areas.
- Data gaps to inform future groundwater monitoring needs and activities better.
- Estimates of regional annual change in groundwater storage.
- Illustration of successes and challenges of local and regional management of groundwater.
- Inventory and potential for conjunctive management of groundwater with other supplies.

The data and analyses resulting from the above deliverables were consolidated into a report available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article, "California's Groundwater Update 2013." The information also provided groundwater related contents for Volume 1, *The Strategic Plan* and Volume 2, *Regional Reports*, in *California Water Plan Update 2013*.

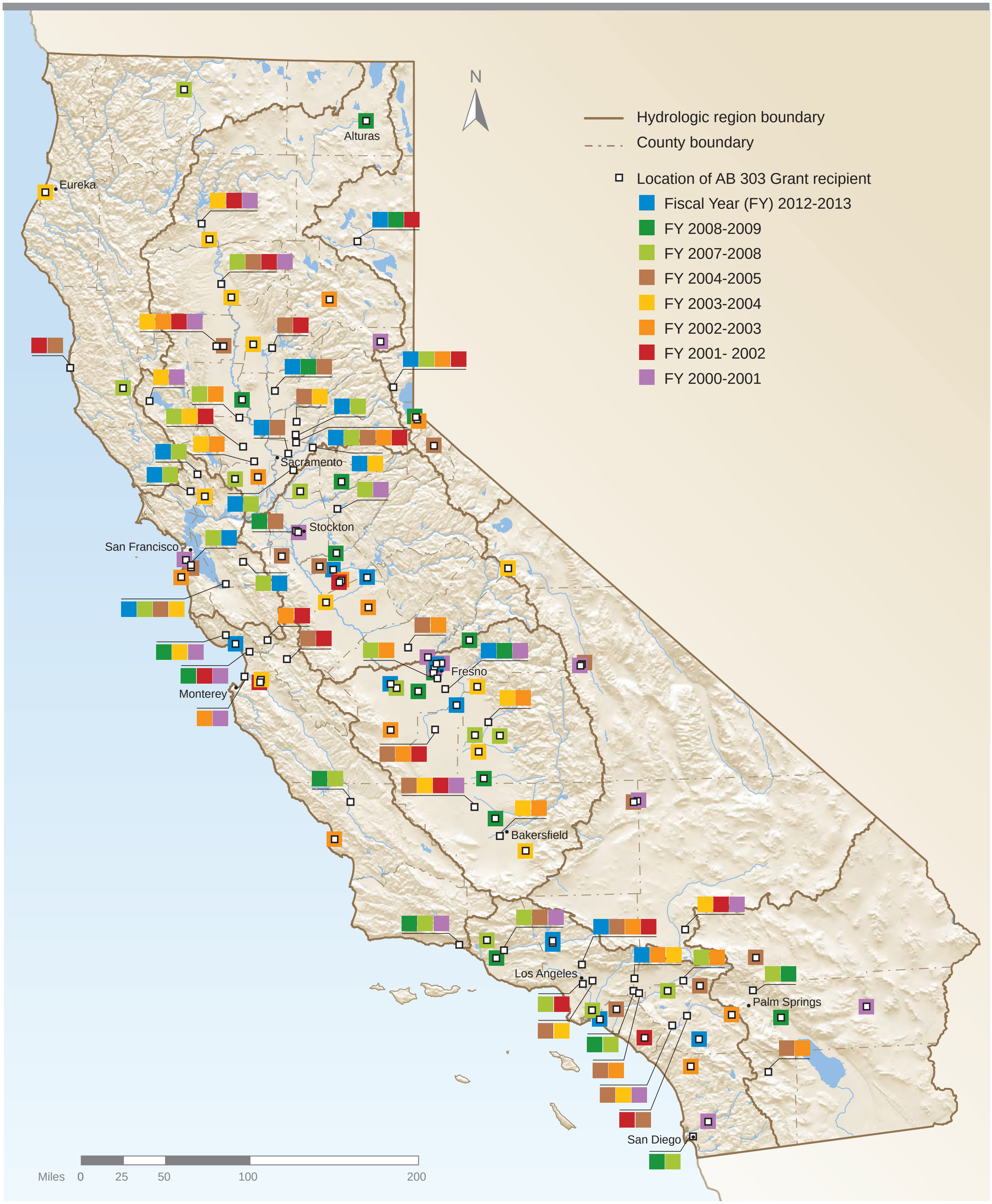
The Integrated Water Resources Information System (IWRIS), released by DWR in 2008, is the first centralized water data management system developed to help local and regional water management entities integrate and analyze existing data about their groundwater system and potential value of current groundwater management in their integrated planning processes. It serves as a centralized information system for accessing the data about groundwater as well as groundwater management and some DWR grant program funding statewide. Figure 9-3, generated from DWR IWRIS, shows a distribution of the AB 303 Grants from 2001 to 2008 for helping the development of groundwater management plans which in recent times often include conjunctive management as an important strategy for managing groundwater. Due to a lack of funding, the future of IWRIS remains uncertain. Fortunately, DWR has undertaken a project, Water Planning Information Exchange (Water PIE) that may subsume IWRIS. The ultimate goal of Water PIE is collecting and sharing data and networking existing databases and Web sites using GIS software to improve analytical capabilities and developing timely surveys of statewide land use, water use, and estimates of future implementation of resource management strategies. Phase I of Water PIE has been initiated, which is intended to develop the business and technical requirements for the web-based system. In Phase 2 of Water PIE, a pilot application will be conducted to assess the developed system and refine requirements and design before full implementation commences.

The groundwater elevation monitoring provisions of the CASGEM Program have increased availability of information useful for planning and implementing conjunctive management in the state. The availability of information is increasing as local and regional water management entities analyze the existing and potential value of active groundwater management in their integrated planning processes. It is important to have updated information on the various conjunctive water management planning and implementation activities statewide to achieve better coordination among future conjunctive water management planning activities and to avoid potential conflicts. DWR has started developing a statewide inventory of conjunctive management agencies and projects that is included in Update 2013. Detailed information on the inventory including communication with water agencies, data items requested, and level of responses received is available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article, "California's Groundwater Update 2013." This initial effort in Update 2013 was not as successful as intended because of the apparent reluctance of local and regional water agencies to release data to build such an inventory. The reluctance of these agencies to provide information was concluded to have emanated primarily from an apprehension about uncertainty in State regulations pertaining to groundwater recharge. This inventory will continue to be updated, refined, and expanded in future California Water Plan updates.

This resource management strategy chapter deals with general and statewide issues associated with conjunctive water management. Issues specific to individual hydrologic regions are discussed in their respective regional reports in Update 2013 Volume 2, *Regional Reports*. However, for general illustrative purposes, two case studies — one from Southern California and one from Northern California — are provided in Box 9-4 and Box 9-5.

As noted, conjunctive management and groundwater storage are considered an integral elements of IRWM, and it is actively promoted and supported by the State. In the context of the rapidly evolving IRWM effort in California, the issue of cooperative arrangement among regional water partners is gaining momentum. Box 9-6 provides a brief description of a four-county program in Northern California initiated to promote cooperation among participating counties for resolving regional water management issues across jurisdictional boundaries. This four-county program eventually expanded and added two additional counties to the group and formed the Northern Sacramento Valley Integrated Regional Water Management group. Cooperative agreements such as this can serve as a model of how legal constraints and issues related to regional water management, including conjunctive management projects, may be resolved.

Figure 9-3 Distribution of the AB 303 Grants from 2001 to 2013



Box 9-4 Conjunctive Management Case Study 1 in Southern California

Groundwater storage plays an important role in providing a reliable water supply in areas with limited surface water supplies. The Metropolitan Water District of Southern California (MWD) has performed a groundwater assessment study to analyze groundwater use from 1985-2004. The study shows that groundwater provides nearly 40 percent of the total annual water needs within MWD's service area. Between 1995 and 2004, an average of 1.56 million acre-feet (maf) of water per year was produced from the groundwater basins. The study also shows that groundwater production varies as much as 30 percent between the wettest and driest year (Metropolitan Water District 2007).

Groundwater is an important part of MWD's Integrated Water Resource Plan (IRP) for ensuring water supply reliability. To maintain baseline annual production during dry years, the IRP sets out reliability strategies for dry years, and has targeted a dry-year yield from service-area groundwater basins of 275,000 acre-feet per year (af/yr.) by 2010, and 300,000 af/yr. by 2020/25. Because MWD plans for the potential of three consecutive dry years, the yield targets are multiplied by three resulting in dry-year storage targets of 825,000 af by 2010 and 900,000 af by 2020/25 (Metropolitan Water District 2007). These strategies and targets are met by using conjunctive management of surface water and groundwater.

Conjunctive management not only uses groundwater storage for water supply, but also provides recharge and protection to groundwater storage. The 20-year study shows that an average recharge of 758,000 af/yr. resulted from active recharge programs (Metropolitan Water District 2007). About 90 percent of the groundwater recharge — approximately 681,000 af/yr. — was from direct recharge methods (injection or spreading) using imported water, treated recycled water and local runoff, and the remaining 10 percent was from in-lieu recharge (Metropolitan Water District 2007). When surface water supplies are available, MWD encourages in-lieu groundwater recharge by providing financial incentives. As a result of more groundwater recharge facilities becoming available during 1995-2004 as compared to 1985-1994, active recharge using local runoff increased by 7 percent while the proportion of imported water used for recharge declined by 5 percent during the later period (1995-2004). Treated recycled water can be used to prevent salt water intrusion to protect existing groundwater resources and maintain valuable groundwater storage. For example, as part of MWD's conjunctive management, imported water has been spread at Montebello Forebay and injected in the Central Basin of MWD service areas to control seawater intrusion. Recycled water meeting certain water quality standards are also used for irrigation and recharging the groundwater.

The total developed groundwater management capacity in MWD's service area currently includes the following (Metropolitan Water District 2007):

- More than 4,300 active production wells (municipal, agricultural, industrial, and private).
- 36 ASR (aquifer storage recovery) wells.
- 5,000 acres of spreading basins.
- 400 acres of water quality wetlands to improve quality of inflows to groundwater.
- 7 seawater intrusion barriers.
- 16 desalters.

Potential Benefits

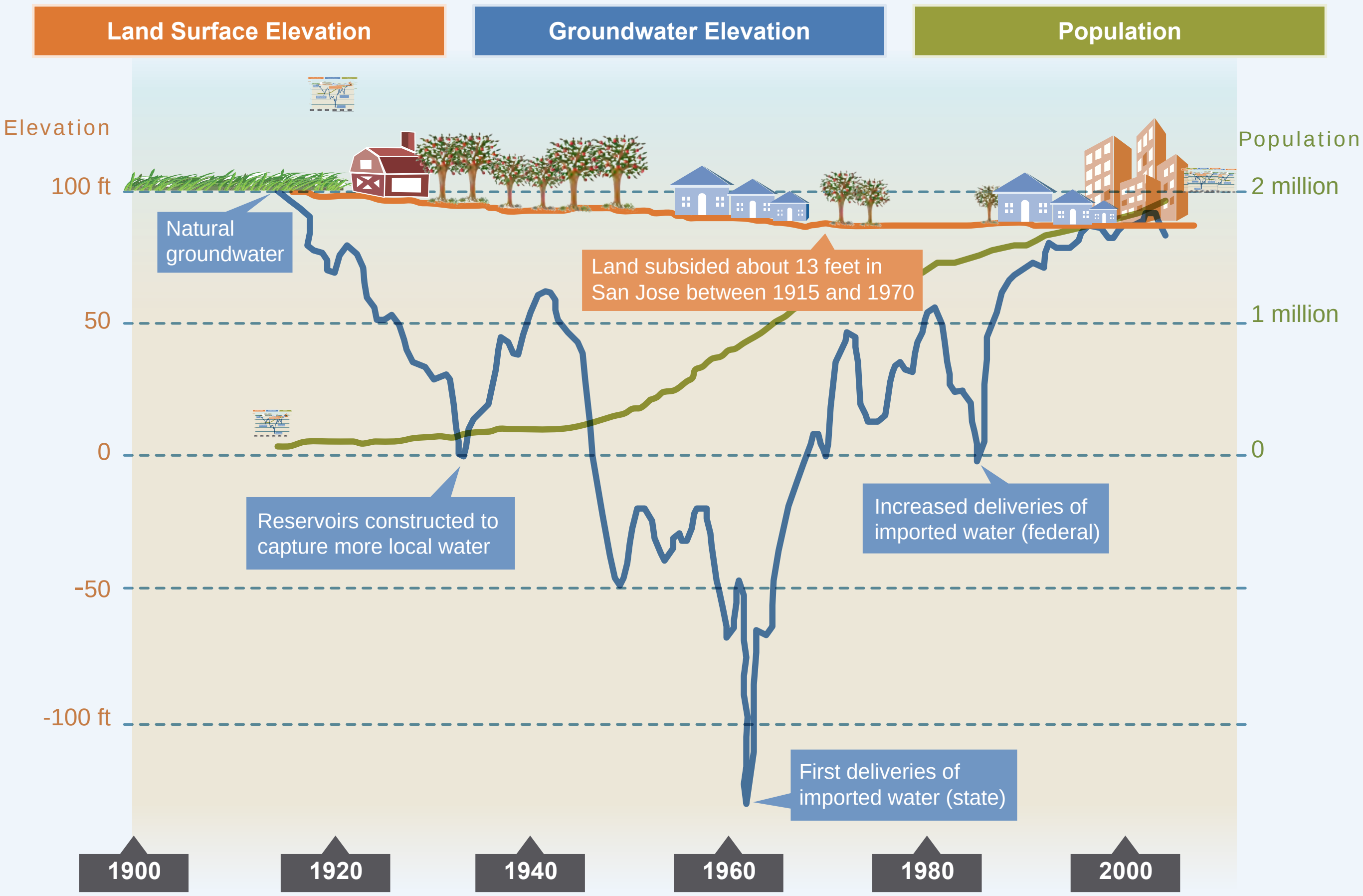
Conjunctive management is used to improve water supply reliability and sustainability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Overdraft is defined as the condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin

Box 9-5 Conjunctive Management Case Study 2 in Northern California

The Santa Clara Valley Water District (SCVWD) is the comprehensive water management agency for the residents of Santa Clara County. It supplies clean and safe water, manages local groundwater basins, implements flood protection projects and provides watershed stewardship. It serves approximately 2 million people — 1.8 million residents and 200,000 commuters — in 15 cities and unincorporated areas in the 1,300-square-mile county (Santa Clara Valley Water District 2008).

Similar to many other parts of California, the areas served by the SCVWD also witnessed remarkable agricultural and urban development in the last two centuries. These developments began in the latter half of the 19th Century post-Gold Rush era and continued throughout the 20th Century. The intense urban and agricultural growth resulted in increased groundwater extraction, which in turn, culminated in groundwater level declines of more than 200 feet and land subsidence of nearly 12 feet. To meet the water needs in the valley, in the late 1920s the SCVWD (or its predecessor) was formed (Santa Clara Valley Water District 2009). This set in motion a long succession of facilities construction for surface storage to increase water supply availability and recharge ponds to facilitate conjunctive management through managed groundwater recharge. Since the 1960s, the SCVWD has imported surface water to meet growing demands and reduce dependence on groundwater supplies. Currently, the SCVWD operates and maintains 18 major recharge systems, which consist of both instream and offstream facilities. Local reservoir water and imported water are released in more than 90 miles of more than 30 local creeks for managed instream recharge. In addition, the SCVWD releases locally conserved and imported water to 71 recharge ponds, which range in size from less than 1 acre to more than 20 acres; the total area of the groundwater recharge ponds is more than 300 acres (Santa Clara Valley Water District 2012). Through these streams and recharge ponds, the SCVWD recharges the groundwater basin with about 156,000 acre-feet of water each year (Parker 2007). Figure A illustrates how a conjunctive management approach through SCVWD's recharge programs, imported water deliveries, and treated water programs has resulted in remarkably improving groundwater conditions in the basin (Santa Clara Valley Water District 2012).

Figure A: Conjunctive Management Case Study 2 in Northern California



Note: This graphical representation is not intended as a technical exhibit.

Box 9-6 Regional Cooperative Arrangements in Northern California

An example of a regional effort that attempts to reach across jurisdictional boundaries is the four-county program. This program revolves around a cooperative memorandum of understanding (MOU), originally signed by the counties of Butte, Glenn, Tehama, and Colusa. The MOU, signed in early 2006, outlines how the counties will work together across jurisdictional boundaries on water management issues that are of concern to their collective constituencies. The MOU is accompanied by an addendum, which lays out how information regarding activities in neighboring counties will be conveyed to other counties within the region to ensure that all processes are transparent and each jurisdiction is aware of activities that have the potential to impact their citizenry. Although local ordinances may not cross jurisdictional boundaries, board members in each county have expressed that they do not want to cause harm to their neighbors. The cooperative efforts outlined in the MOU, and its Addendum One, discuss how the various boards intend to communicate and cooperate with each other (Board of Supervisors of Butte, Colusa, Glenn, and Tehama Counties, 2006; 2007). In 2009, Addendum Two added the County of Sutter to the group and Addendum Three documented a commitment by the counties to begin an Integrated Regional Water Management (IRWM) Planning process (Board of Supervisors of Butte, Colusa, Glenn, Tehama, and Sutter Counties, 2009a; 2009b). Addendum Four added the County of Shasta in 2010 and also renamed the IRWM effort to Northern Sacramento Valley IRWM group (Board of Supervisors of Butte, Colusa, Glenn, Tehama, Sutter, and Shasta Counties 2010).

over a period of years, during which the water supply conditions approximate average conditions (California Department of Water Resources 2003). Overdraft may cause land subsidence and damage to the environment and increase energy cost in pumping. An example illuminating the beneficial outcome of conjunctive water management in ameliorating groundwater overdraft is included in Box 9-7.

Potential benefits from conjunctive management are highly dependent on how well the surface water and groundwater are managed as a single source to adapt to the climate system to maximize use of the water in the managed area. Effective conjunctive management should optimize capture of excess water when it is available so that enough water is stored to meet beneficial use needs while providing a sufficient reserve to get through extended dry periods. However, the benefit derived from effective conjunctive management is limited by the combined, current surface water and groundwater production capacity of the management area.

The climate in California can usually be described as consisting of a wet season and a dry season in a water year. Most water (as rainfall and snow) is in the northern part of the state while most people live in the southern part. However, climate varies greatly over the state. Successful conjunctive water management must recognize the climate variability in California and maximize the use of water throughout the state.

Any conjunctive management strategy will produce changes to the water system. A sustainable conjunctive management strategy should optimize the beneficial and efficient use of the water in the system while balancing all of the objectives. Because of the uncertainty in water demand resulting from population growth, land use changes, and climate change, risk management and opportunity costs should be considered in conjunctive management planning. A good conjunctive management computer-aided tool can help identify and quantify the benefit and potential risk associated with conjunctive management projects. This tool can be considered one element of an overall robust, adaptive water management system for dealing with future uncertainties and

Box 9-7 Groundwater Overdraft and Conjunctive Management

The two hydrographs below show the response of groundwater levels to differing water management regimes. The first hydrograph (Figure A) shows groundwater levels declining in response to agricultural development in the San Joaquin Valley. Groundwater levels recover somewhat during the wet period of the early 1980s, but continue to decline through the 1980s and 1990s in the absence of a focused conjunctive water management action. The second hydrograph (Figure B) shows a similar groundwater level decline in response to development in southern Yuba County. However, groundwater levels begin to recover in the early 1980s when surface water imports from Yuba County Water Agency began, resulting in conjunctive water management. The hydrograph shows a decline in groundwater levels during the early 1990s drought as surface water imports were curtailed and groundwater was relied upon more heavily. Thereafter, continued conjunctive water management action resulted in the refilling of the South Yuba Groundwater Subbasin, which continues up to present.

Figure A Kings Basin, Fresno County

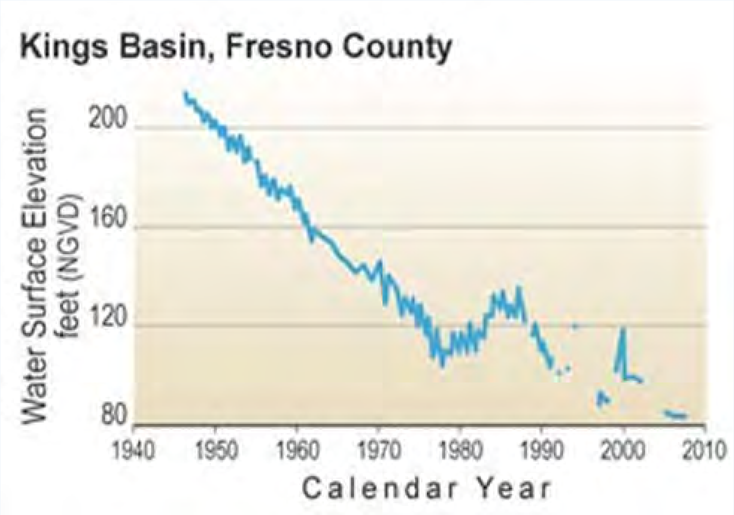
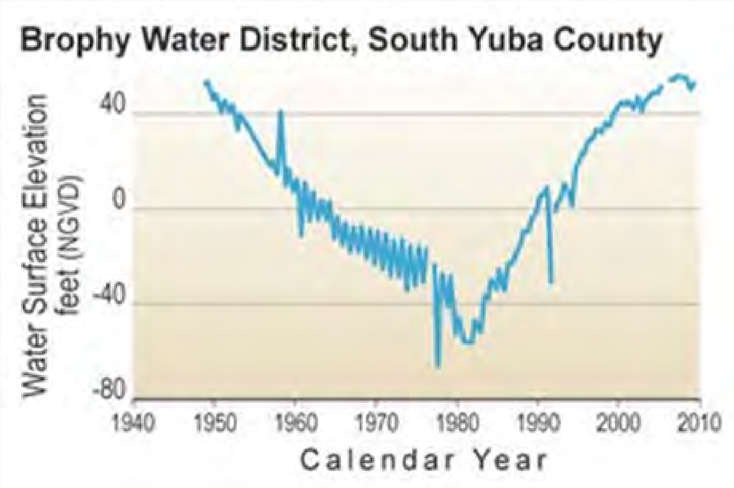


Figure B Brophy Water District, South Yuba County



provide safe, responsive, and effective oversight. Unfortunately, no such tool currently exists and developing such a tool is one of the recommendations made to improve conjunctive management, included at the end of this chapter.

Table 9-1 lists some of the many potential benefits of conjunctive management and highlights some of the major constraints that influence the usefulness and level of benefit that might be obtained. Example 1 in Table 9-1 can be used anywhere in the state to adapt to the two-season pattern so that more water can be captured in the wet season for beneficial use. Example 2 recognizes the fact of the relatively wet northern part of the state and shows the benefit of using groundwater storage in the reoperation of the State Water Project (SWP) and the Central Valley Project (CVP) to capture more flood flows, provide flood control benefits, and improve water supply availability and reliability. An example of the magnitude and frequency of variability in California's hydrology is furnished in Figure 2-1 of *Update 2013* Volume 1, *The Strategic Plan*, Chapter 3, "California Water Today." Figures such as those can be used as a guide for identifying the relatively wet areas in the state. Example 3 demonstrates a way of utilizing groundwater that could be used for agricultural production to urban water use to relieve drought emergencies and to provide induced groundwater recharge. Example 4 shows use of surface water for preventing salt water intrusion in coastal areas. Example 5 provides not only a solution to reduce or contain the flood risks resulting from the increased runoff due to urbanization, but also to maintain the natural groundwater recharge in the project areas and provide opportunity for treating storm water in detention ponds.

Currently conjunctive management in Southern California provides more than 2.5 maf of average annual water supply (Montgomery Watson and Water Education Foundation 2000). Conservative estimates of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 0.5 maf (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008).This estimate is based on the assumption of increased available groundwater through reoperation of existing groundwater systems. More aggressive estimates from studies indicate the potential to increase average annual water deliveries by two maf. For the purpose of comparison, the lower and higher estimates amount to 1.2 and 5.0 percent of the average annual water supply in California, and 3.0 and 12.1 percent of the average annual groundwater supply. The increase in groundwater supply may result in increased competition for the groundwater resources, which could potentially impact the agricultural economy of the state. As noted earlier, the attempt to build a solid inventory of data on conjunctive management projects on a regional and statewide basis did not meet with considerable success. As a result, estimates of range of supply increase from potential conjunctive management projects could not be further refined in *Update 2013*. Better estimates can only be developed once the inventory of conjunctive management projects is properly refined and updated in future California Water Plan updates.

The more aggressive estimates are based on assumptions that require major reoperation of existing surface water storage and groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports through the Delta and other conveyance facilities (California Department of Water Resources 2003; Montgomery Watson and Water Education Foundation 2000; Purkey et al. 1998; Purkey and Mansfield 2002; U.S. Army Corps of Engineers 2002; Kennedy/Jenks 2008). This estimate could be considerably lower if either major reoperation of existing surface water storage and groundwater storage is not feasible, or existing conveyance capacity constraints for exports through the Delta and other conveyance facilities are taken into consideration.

Table 9-1 Potential Benefits of Conjunctive Management Implementation

Potential Benefit of Managed Groundwater Storage	Example	Major Constraints
Improved local water supply reliability	Imported surface water supplies and/or floodflows are recharged to local alluvial groundwater basin during wet years/ seasons, increasing local water supply reliability.	• Availability of surface water supplies. • Limited capacity to capture and recharge high volume, short duration floodflows. • Water quality concern of the recharged water and the impact to the aquifer itself.
Improved statewide water supply reliability	Groundwater storage in the northern part of the state might be used as backup supplies to allow more aggressive operation of surface storages such as Oroville and Shasta reservoirs by permitting reduced carryover storages so that more floodflows in the wet seasons could be captured. This would increase SWP and CVP operational flexibility and could result in improved statewide water supply reliability and sustainability. The reduced carryover storage would be replaced annually by utilizing groundwater storage.	• Availability of a multi-regional/statewide conjunctive water management tool to model surface water and groundwater (including water temperature) responses accurately and to evaluate the proposed management strategy for its benefits, the impacts on third parties and the environment, project cost, etc. • Legal and water rights issues (associated impacts perhaps could be mitigated by compensation to injured parties if any, using the above tool if it were available).
Drought relief for urban water users and potential induced groundwater recharge	Groundwater substitution transfer and agricultural water transfer. Irrigators who are willing sellers stop a specific amount of surface water diversion and pump an equivalent amount of groundwater to replace surface water. As a result, more surface water becomes available downstream for purchase. Groundwater eventually recovers from increased streamflow to the groundwater system.	• A lack of a widely recognized mathematical model to accurately quantify the impact on other groundwater and surface water users and the environment. • Potential land subsidence and its quantification and evaluation.
Protection from salt water intrusion	Recharge groundwater using captured floodflows or recycled water in the vicinity of salt water interface to raise groundwater levels and prevent migration of saline water into freshwater production portions of the aquifer.	• Availability of freshwater supply. • Considerable infrastructure requirements.
Improved flood control and groundwater storage	Development of detention ponds at proposed residential subdivisions located in the groundwater recharge protection areas can offset the increased urban runoff due to the development while maintaining natural groundwater recharge.	• Possible water quality problems at detention ponds requiring effective urban stormwater management. • Requiring adoption of local ordinance or legislation to support implementation.

Potential Costs

Costs for implementation of conjunctive management and groundwater storage may include a wide range of facilities and depend on the site-specific nature of the program. Accordingly, the cost for a unit increase in water supply or delivery is highly variable.

Some projects require relatively minor changes in operations or upgrades of existing infrastructure, such as increased sizing of pumps in existing wells or increased releases of water from existing conveyance canals. Other projects may require extensive new facilities such as canal turnout structures, new pipelines and pumps, injection or extraction wells, or construction of new recharge basins. The highly variable nature of implementation costs requires that the feasibility of new conjunctive management projects or programs be evaluated carefully on a case-by-case basis. Generalizations of implementation costs without site-specific information on issues, such as available water supply and access to conveyance and groundwater storage, are rarely accurate.

The wide range of costs results from many factors including project complexity, regional differences in construction and land costs, availability and quality of recharge supply, availability of infrastructure to capture, convey, recharge, and extract water, intended use of water, and treatment requirements. Additional issues that may also need to be addressed are who has ownership of the water and who compensates for disputes among neighbors and impacts to or from third parties. In general, urban uses can support higher project costs than agricultural uses.

Major Implementation Issues

Uncertainty in Surface Water Availability from State and Federal Water Projects

For many regions in the state, water supply from SWP and CVP is a potential source for groundwater recharge. However, its availability has become increasingly uncertain because of the deterioration of environmental conditions in the Delta. Recent legal decisions (Wanger 2007a; 2007b; 2008a; 2008b; 2010; 2011a; 2011b) and biological opinions (U.S. Fish and Wildlife Service 2008, 2011; National Marine Fisheries Service 2009, 2011) have narrowed the time window of Delta pump operations. As a result, less water can be exported for delivery to south of the Delta. Information about SWP water supply reliability (updated every two years) can be obtained at http://baydeltaoffice.water.ca.gov/swpreliability/. The increased uncertainty in surface water availability from SWP and CVP could be a critical limiting factor to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Uncertainty in Evaluating Impacts of Groundwater Pumping on Surface Water Flows and Aquatic Ecosystems

Groundwater and surface water are usually connected hydraulically. Conjunctive water management can change existing surface water and groundwater interaction significantly. There are some regional groundwater flow models available for the Central Valley, and they can be used to evaluate the surface water and groundwater flow interaction. However, the accuracy of analysis, model resolution, and the size of the modeling area often limit their application for evaluation of local and regional as well as statewide conjunctive water management opportunities. Impacts to aquatic ecosystems often require the modeling of water temperatures and solute transport, land subsidence analysis, and identification of environmental flow targets. These modeling tools are not well developed or integrated for conjunctive management planning as discussed in the “Lack of Data and Tools” section, below.

Effects of Land Use Changes on New or Enlarged Recharge Facilities and Recharge Area Protection

A natural recharge area may be reduced or eliminated because of a new development or contamination from a development. The protection and the improvement of natural recharge areas are important in maintaining and improving groundwater storage. In California, floodplains and wetlands that provide natural recharge areas have been urbanized at a steady pace, although the pace has somewhat stabilized since the economic slowdown beginning in 2008. Proximity of some developments to existing groundwater recharge facilities precludes expansion of recharge area.

Land use planning that will preserve natural recharge areas by limiting the encroaching development (for example, by purchasing the land or by zoning the land for recharge-friendly uses) would be beneficial. However, protecting an important natural recharge area sometimes may not be a high priority for the county or local land use authorities, particularly if the groundwater basin being pumped is in another jurisdiction. Although federal, State, county, and local requirements may mitigate impacts of increased runoff resulting from new developments, these requirements may need to be further strengthened by additional provisions that may also include local land use ordinances. While recognizing that there is variability in hydrology, and local conditions and needs, these provisions or ordinances should generally be geared toward ensuring that new developments incorporate detention ponds so that the increased runoff and lost natural recharge can be offset by the planned detention ponds, accomplished in such a way that groundwater quality is not compromised. However, instead of this approach and if workable, an alternative basin-wide or watershed-scale approach may also be taken to mitigate the effects of new developments in a more cost-effective way at the basin or watershed level. The proposed detention ponds can provide flood protection and also help maintain natural recharge. Managed recharge facilities may be used to inject the increased runoff to the underlying groundwater basin. One significant initial step in this direction was the passage of AB 359 in 2011, which requires local groundwater agencies to include a map in groundwater management plans that identify groundwater recharge areas in their basins and to provide these recharge area maps to local planning agencies. The issues related to land use and recharge area protection are further discussed in Chapter 20, "Urban Stormwater Runoff Management," and Chapter 25, "Recharge Area Protection," in this volume.

Recently, Calaveras County has added a new dimension to the on-going discussion of land and water use nexus by introducing the concept of water element in its general plan. The county defines a water element as "a self-contained document that identifies and articulates goals, policies, and objectives for the multiple uses of water. It can address all or some of these uses, such as water supply, wastewater, water quality, stormwater management, flood management, watershed management, protection of habitat, and erosion control. It does not dictate land use planning; it informs land use planning." The goal as articulated by the county is "by integrating these various aspects in a Water Element there will be greater opportunity for improving the linkage between land use decisions and water planning; standardizing services; increasing public awareness; and…." (Montgomery Watson Harza 2009).

Inconsistency and Uncertainty in Regulatory Status with Respect to Recharge and Surface Commingling of Different Quality Water

Groundwater recharge involves using water from various sources to recharge a groundwater basin. The quality of water used for recharge is usually different from the water in the receiving groundwater basin. Uncertainty in regulatory status with regard to the quality of recharging and receiving waters increases the uncertainty in the planning effort of conjunctive management and may increase cost or even make a conjunctive water management project infeasible during implementation.

Lack of Data and Tools

Data and tools are very important in developing a reliable and advanced conjunctive water management strategy. Data are needed to understand the groundwater resource, to monitor and measure the progress of water management strategies, and to calibrate and validate computer modeling tools. However, data are often lacking. Tools are also not readily available for use and may need to be developed. Existing tools may also need to be refined and improved, as discussed later in this section.

Data are needed to evaluate conditions and trends laterally and vertically in a geographic area and over time. The CASGEM Program has been implemented to monitor groundwater elevations and the Groundwater Ambient Monitoring and Assessment Program (GAMA) has been implemented to monitor groundwater quality. Besides these two programs, there are few comprehensive basin-wide networks to monitor groundwater levels, water quality, land subsidence, and interaction of groundwater with surface water and the environment. There is no integrative web portal or information system providing access to various groundwater monitoring networks operated by various State and local agencies. DWR released the first such product called the Integrated Water Resources Information System (IWRIS) in May 2008 to the public, but IWRIS does not include or provide access to much of the available water quality data.

To understand the groundwater resources on a statewide basis, data from throughout the state are needed. Although it is common that groundwater data are not monitored in remote areas by local authorities, these data are important for understanding the statewide groundwater system. A statewide multi-resolution groundwater modeling tool can help identify cost-effective and necessary locations and frequency of groundwater monitoring for areas where monitoring is lacking or could be improved. An integrated statewide data and information management system such as IWRIS can also help visually identify the spatial data gaps in the state. Because of the lack of resources, incentives, or conflicts of interest, individuals or local agencies are usually not able to fill the spatial data gaps outside their management areas. State agencies could help fill the data gaps by providing the necessary resources to local agencies. Better cooperation and coordination are also needed among the agencies to best use available resources to develop a statewide groundwater monitoring program by minimizing data gaps and overlaps. The greatest obstacle to the continuation and success of any data program is the lack of dedicated funding for program execution by State agencies and participating local agencies. Success of these important data monitoring programs can only be ensured through long-term commitment and funding at the State and local levels.

One important aspect in data collection effort that is often overlooked is its coordination with the development of computer models. Computer models help identify potentially critical data collection locations (stations) and the desired frequency of collection, leading to improved monitoring of groundwater systems and performance measurement of management strategies. The coordination between data collection and model development would also help improve model calibration and reduce cost of data collection by minimizing data gaps and overlaps. While a model may have its own set of limitations, an easy-to-use computer aided conjunctive management tool is needed for assessing the management strategies and quantifying the values of the strategies. Ideally, State and federal agencies should collaborate with and assist local agencies to develop such a tool. The tool should allow resources managers to define and prioritize objectives and specify constraints in an easy-to-use interface. The tool should also be able to perform integrated surface water and groundwater modeling, land subsidence analysis, and economic evaluation.

Computer models have been developed to assist water resources planning and management and there is continued development of these models. CalSim II (Close et al. 2003), jointly developed by DWR and the U.S. Bureau of Reclamation, is a recognized water resources planning model for SWP and CVP operations running in monthly time step. Groundwater models are also under development for selected hydrologic regions. One of the groundwater models covering the Central Valley is the California Central Valley Groundwater-Surface Water Model (C2VSim). It simulates three groundwater layers and model calibration was recently completed (Brush 2013). The model was officially released in June 2013. A similar model, called the Central Valley Hydrologic Model (CVHM), was developed and released by the U.S. Geological Survey (Faunt 2009). However, before either C2VSim or CVHM can be used for local groundwater management, its modeling resolution needs to be improved. Effort to improve the spatial resolution of C2VSim has commenced recently. Availability of a model with finer spatial resolution is extremely important because while the State's goal is to encourage conjunctive water management statewide, the effects of bad management are felt locally by citizens dependent on groundwater. While many areas in the state rely on surface water or has access to surface water, in some areas more than 70 percent of the agriculture is groundwater dependent, as documented and available online in *California Water Plan Update 2013*, Volume 4, *Reference Guide*, in the article "California's Groundwater Update 2013."

A recently published report documents a planning level analysis performed to assess and quantify general viability of conjunctive water management projects in the Sacramento Valley. The analysis was conducted by sequentially using a simplified surface water model in conjunction with CalSim-II to simulate CVP/SWP operations and SacFEM based on MicroFEM (Hemker 2013) to assess impacts of proposed projects on groundwater levels and streamflows. The analyses provided a general estimate of potential benefits resulting from the proposed projects. However, the report notes that the analysis will need to be refined for specific project implementation by clearly incorporating infrastructure and operational protocols and analyzing response of the simulated surface and groundwater water system (CH2MHill and MBK Engineers 2010)

A recent effort to integrate C2VSim with an updated version of CalSim II called CalSim III (California Department of Water Resources 2013d), may offer a broader water resources modeling system and provide an opportunity for developing an integrated groundwater and surface water modeling system for the entire state (Young 2007; Joyce 2007). To be a good conjunctive water management tool, more modeling capabilities need to be added and integrated in the modeling system. Modeling capabilities that need to be added are:

- Water temperature modeling.
- Daily time step modeling of CalSim instead of monthly time step.
- A user-friendly interface.
- Capability to specify management objectives and constraints.
- Groundwater modeling beyond the Central Valley to cover possible salt water intrusion and address groundwater issues relevant to other hydrologic regions.
- Environmental and economic analysis.
- Analysis of climate change effects under a range of projected climate scenarios.

Other available models or modeling system also lack these capabilities. As conjunctive management is sensitive to the temperature shifts as well as the type, amounts, and patterns of precipitation that affect the hydrologic system, model refinements must also allow incorporation of variable climatological scenarios to provide confidence in its projections for conjunctive management. Although there has been recent increased effort to do that, these refinements need to be further improved to ensure that climate change projections are properly reflected in model simulations. Along with development of statewide modeling tools, the State should also support investigation of local and regional groundwater conditions by local agencies with funding and technical tools.

The lack of data and tools to evaluate the groundwater and surface water interaction has hindered conjunctive water management and water transfer practices because of the failure to quantify compensations to injured parties. The inability to identify the impact of groundwater pumping on surface water and aquatic ecosystems fully, adds to the risk of effective conjunctive water management planning. To overcome this hurdle, sufficient funding must be committed to State agencies and where applicable, local and regional agencies to ensure that the required data and tools are incrementally developed and refined.

Public Access to Well Completion Reports

Although there are many wells in the state, the well completion reports are not accessible to the public because of confidentiality requirements (CWC Section 13752). If the relevant CWC section is changed to remove confidentiality of well completion reports while upholding the coordinated national program to protect the nation's critical infrastructure, the geologic and groundwater related information in the existing well completion reports would be accessible to the public, which in the long-run could save money and time for collecting aquifer and groundwater information. To that end, SB 263 (Well-Reports-Public Availability) was introduced in 2011. It passed through the Senate and Assembly, but the governor vetoed it citing amendments to the bill that unduly restricted the use of the well completion reports and imposed severe criminal penalties for disclosure. A modified version of the bill, SB 1146, was introduced in 2012 to make well logs public information. The bill would have required DWR to make the well reports public subject to specified limitations. It was defeated in the Senate floor, but another version of the bill is expected to be introduced in the future.

Currently, DWR's Regional Offices fill requests for well completion reports as provided for in the CWC. Each year, thousands of well completion reports are made available to governmental agencies, persons doing groundwater clean-up studies, well owners, and other people as provided by the CWC.

It is unlikely that a change in the law to make well completion reports public would save the State money and time in the short-run. Indeed it would probably cost DWR time and money for several years. DWR may save time and money if all well completion reports were scanned and made available on the Web and if an online filing system were developed for well drillers to submit new well completion reports in the future. However, both of these systems would require significant amounts of money and time to develop.

Thus, changing CWC Section 13752 must be done based on sound and compelling arguments. The following capture some of the important considerations in that regard:

- Sufficient funds should be provided to cover the cost to implement changes in CWC Section 13752.
- Language must be included in the law for DWR to recover actual costs of providing well completion reports to the public.
- The law should ensure continuation of collecting the same level of information as is collected currently on the well completion reports, i.e., the usefulness and value of the well completion reports should not be diminished or sacrificed.
- The law should ensure that the quantity and quality of the information provided by the well drillers does not diminish.

Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Conveyance capacity for surplus imported water supplies is most available during the wetter and cooler months when water demand is low. However, this wetter period also coincides with reduced ability to accomplish in-lieu recharge (due to lower water demands) and with increased spreading of local runoff, which may limit the ability to recharge other sources of water. During the very wet year of 2004-05, active recharge throughout the Metropolitan Water District service area used only 60 percent of the total recharge facility capacity available throughout the course of the year (Metropolitan Water District of Southern California 2007).

Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta. Facilities that are operated for both temporary storage of floodwater and groundwater recharge require more frequent maintenance to clean out excessive sediment often present in floodwater.

The need to improve coordination of infrastructure and operations for flood control and recharge of storm flows for conjunctive management cannot be overstated. In Southern California as well as in other areas of California, the considerable opportunity to enhance groundwater recharge by local runoff remains unrealized because of a lack of streamlined and effective coordination.

Another issue that cannot be overstated is the urgent and crucial need for increased capacities for both surface water storage systems and Delta conveyance facilities. As a result of more stringent regulatory requirements coupled with potentially detrimental effects of climate change, availability of surface water is anticipated to follow more extreme cycles of extended dry spells intervened by short, high intensity wet spells. In the new reality of regulatory restrictions and climate change, absence of additional surface water storage and Delta conveyance would be critical limiting factors to manage water resources effectively and to derive optimal benefit from conjunctive management practices.

Surface Water and Groundwater Management

In California, as in other states, water management practices and the water rights system traditionally have treated surface water and groundwater as two unconnected resources. However, as explained previously, there is often a high degree of hydraulic connection between the two. Under predevelopment conditions, many streams receive dry-weather flow or baseflow from groundwater, and streams provide wet weather recharge to groundwater. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Incomplete understanding of these connections can lead to unintended consequences. The planning of conjunctive management should consider and evaluate potential impacts resulting from groundwater and stream interaction, including those on the environment. For example, studies by the University of California, Davis indicate that long-term groundwater pumping in Sacramento County has reduced or eliminated dry season baseflow in sections of the Cosumnes River with potential impacts on riparian habitat and anadromous fish (Fleckenstein et al. 2004).

The authority for managing different aspects of groundwater and surface water resources in California is separated among federal, tribal, State, and local agencies. Several examples highlight this issue.

1. State Water Resources Control Board regulates surface water rights dating from 1914, but not rights prior to 1914.

2. Regional water quality control boards regulate waste discharges that might impact groundwater quality, but not the rights to use groundwater.

3. County groundwater ordinances and local agency groundwater management plans often apply only to a portion of the groundwater basin, and counties or local agencies with jurisdictions that overlie the same groundwater basin do not necessarily have consistent management objectives in their groundwater ordinances or management plans.

4. Except in adjudicated basins and in some areas with adopted groundwater management plans, individuals have few restrictions on how much groundwater they can use, provided the water has beneficial uses. Because of the connection between surface water and groundwater, unmanaged groundwater use will eventually affect other water users and may have significant impacts on the environment and economy. Incomplete understanding of these connections can lead to unintended consequences if projects are designed and built to increase groundwater extraction without adequate safeguards to forestall the potential adverse impacts.

Because most groundwater systems are slow responding systems, any damage to the system may require long periods to recover and any effects on third parties may take a considerable time to reach detectable levels. Planning, monitoring, evaluating, and maintaining a management structure that is able to react to unplanned consequences is key for successful groundwater management. Sustainable conjunctive water management is an important strategy to deal with the existing and future water supply challenges. Management of the entire groundwater basin or hydrologic region is essential for effective conjunctive water management. Conjunctive management will be more effective and efficient if multiple hydrologic regions work together so that the weaknesses and strengths of regions can be coordinated and used for mutual benefit. However, the existing legal and regulatory framework on groundwater use will make it very difficult to plan any large-scale conjunctive water management strategies because groundwater management is a local responsibility (Sax 2002). Under this legal framework, the conjunctive management strategy that can be pursued with minimal effort is limited to groundwater recharge at the local level with local surface water. The State's role in conjunctive management is limited to providing funding to help willing local agencies plan and implement conjunctive management.

Most groundwater management ordinances restrict out-of-county groundwater uses. Some groundwater management plans specify trigger levels for groundwater levels in the basin management objectives (BMOs) to prevent overdraft or water quality problems. However, in many cases there are no mechanisms to address the non-compliance with the BMOs. The current groundwater ordinances, AB 3030 and SB 1938 groundwater management plans and local BMO activities, which were intended for localized groundwater management, appear not to be well suited for implementing regional groundwater management. Recent development in water planning through the collaborative IRWM framework may, however, pave a way to increase cooperation and collaboration among local and regional water entities to design and implement regional conjunctive management programs and projects that will preserve and promote the interests of all stakeholders. Legal and scientific ways of settling the issue of ownership/extraction rights in a multi-jurisdictional/multi-land owner groundwater basin would be a crucial hurdle to overcome to make regional conjunctive management projects viable and successful.

Water Quality

Groundwater quality can be degraded by naturally occurring or human-introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Recharge water can also improve groundwater quality. For example, the recharge of surface water with low nitrate will lower the nitrate in groundwater. Protecting human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or recycled water into groundwater. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than is needed for urban use, but certain crops can be sensitive to some constituents such as boron.

New and changing understanding of water quality constituents, including emerging contaminants and their risks to human and ecological health, result in changing water quality standards. While this may lead to more healthful water supplies, it also adds uncertainty to planning and implementing conjunctive management projects. A water source may, at the time it is used for recharge, meet all drinking water quality standards. Over time, however, constituent detection capabilities improve and new or changed water quality standards become applicable. As a result, contaminants that were not previously identified or detected may become future water quality problems creating potential liability. In some cases, conjunctive management activities may need to be coordinated with groundwater cleanup activities to achieve multiple benefits to both water supply and groundwater quality.

When water is diverted from streams providing inflows to the Delta, there should be an evaluation of the possible impacts on Delta salinity. Increasing surface storage releases is an option to reduce the impacts on Delta salinity. Various alternative options to address salinity and other critical issues in the Delta are being analyzed and evaluated under the Bay Delta Conservation Plan (California Natural Resources Agency 2013). The preliminary drafts of the plan have been released in multiple stages during March and April 2013.

Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered water that is "available" for recharge. However, flood flows serve an important function in the ecosystem. Removing or reducing peak flood flows may impact the ecosystem negatively. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be environmental impacts from construction and operation of groundwater recharge basins and new conveyance facilities. Conversely, groundwater recharge facilities in some locations may provide important habitat for a variety of wildlife.

Climate Change

Significant changes to California's hydrologic cycles have been measured by DWR and others in recent years. In the past 100 years, changes in snowpack, runoff timing, and sea level rise have all affected water manager's ability to capture and deliver water when needed. The anticipated future effects of climate change in California include more extreme flood events in the winter, an overall decrease in Sierra Nevada snowpack, more frequent droughts, and a continued sea level rise (California Department of Water Resources 2008). Managing California's water supply under 21st century climate conditions will involve adapting and reacting to changes while finding ways to minimize associated energy use. Higher temperatures and changes in runoff patterns resulting from climate change are expected to make droughts occur more frequently and continue for longer periods. As a result, many areas will rely more on groundwater due to reduced surface water supplies. In order to meet this challenge posed by climate change, surface and groundwater resources should be managed conjunctively with the long-term goal of sustaining both these resources.

Adaptation

The planning process for conjunctive management should consider the potential climate change impacts described above and include projects to increase regional resilience. Projects that provide climate adaptation benefits may include surface water storage and groundwater recharge facilities to capture flood flows, injection wells to prevent salt water intrusion in coastal areas and protect water quality, and conveyance facilities to move water from regions with excess supply to drought-affected areas. Conjunctive management plans that integrate floodplain management, groundwater banking, and surface storage could help facilitate system reoperation and provide a framework for the development of local projects with widespread benefits for larger regions.

Additional information on the potential for conjunctive management as a climate change adaptation strategy can be found in *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (California Department of Water Resources 2008).

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Conjunctive management can be a useful mitigation tool. Groundwater recharge prevents water tables from dropping and then being pumped from lower depths with high energy costs. Managing water in a way that keeps it available within a region during peak use periods prevents the use of energy-intensive alternative water sources. Conjunctive management can also be a source of greenhouse gas emissions from energy consumed by injection wells, conveyance systems, or the building and maintenance of conjunctive management facilities. Therefore, costs and benefits must be carefully weighed.

Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. Funding is available as incentives to local agencies to cooperate in the development and implementation of IRWM and groundwater management plans, to study and construct conjunctive management projects, and to track (both statewide and regional) changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, surface water flow, surface water quality, and the interaction of surface water and groundwater.

Recently, St. Amant (2013) in an insightful document further illuminates critical issues that could potentially hinder widespread implementation of conjunctive water management in the Sacramento Valley. The ten issues raised by St. Amant are listed below:

- Effects on non-participating neighbors.
- Problems related to water movement across property boundaries.
- Effects on shallow aquifers from threat of groundwater drainage into deeper aquifers.
- Database for safe and effective conjunctive management and impacts analysis.
- Potential salt water intrusion into aquifers that could result from increased pumping.
- Potential for aquifer compaction and subsidence.
- Gain in water availability from conjunctive management versus streamflow decrease.
- Monitoring of critical benchmarks for potential damage to the natural environment.
- Water quality standards for artificial recharge.
- Institutional system to protect interests of current water users.

Recommendations

1. **Implement a program to promote public education about groundwater.**

   A. By January 31, 2016, DWR and SWRCB will work with other State, tribal, local, and regional agencies and organizations to develop a program and materials for use in schools and other venues to teach groundwater concepts.

   B. Beginning on January 31, 2017, DWR and SWRCB will conduct regularly scheduled public events to explain the following:

i. Reasons for changes in availability of groundwater.
ii. Interconnection of surface water and groundwater.
iii. Benefits of recharging groundwater with surface water and recycled water.
iv. Importance of protecting groundwater quality and recharge areas.
v. Reasons for developing a groundwater budget.
vi. Seasonal versus long-term changes in groundwater levels.
vii. Potential impacts of climate change on groundwater resources.

2. **Improve collaboration, coordination, and alignment among State, federal, tribal, local, and regional agencies and organizations to help implement sustainable groundwater management to ensure evaluating and sharing data and tools, coordinating programs, and minimizing duplication.** By January 31, 2017, and on an ongoing basis, DWR and the SWRCB will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities:

   A. Provide State incentives to local water management agencies to coordinate with tribes and other agencies to take actions that ensure the long-term sustainability of groundwater supply and suitable water quality.

   B. Improve coordination among State, federal, tribal, and local agencies to:

      i. Prevent conflicting rules or guidelines.
      ii. Provide timely regulatory approval.

   C. Form an interagency task force to expedite environmental permitting process for the development, implementation, and operation of conjunctive management, recharge, groundwater cleanup, and water banking facilities when facility operations increase ecosystem services, and include predefined benefits/mitigation for wildlife and wildlife habitat.

   D. Establish a process led by the SWRCB to simplify the water rights permitting process for water transfers designated for conjunctive management in which the recharged water is part of a groundwater management plan and is a beneficial use.

3. **Develop a statewide groundwater management planning Web site or portal to promote easy access to groundwater information such as well completion reports, well drilling, construction, and abandonment standards, groundwater supply and demand, groundwater level and quality, land subsidence, groundwater recharge and conjunctive management, groundwater management plans, and basin studies.** DWR will coordinate with State, federal, tribal, local, and regional agencies and organizations to conduct the following activities:

   A. By January 31, 2016, DWR will prepare an estimate of additional resources needed to implement the required activities as well as the expected benefit of the action for improving management of groundwater in the state.

   B. By January 31, 2016, the Legislature will consider changes to CWC Section 13752 to improve public access to well completion reports while addressing key infrastructure security and private ownership concerns.

   C. If legislative efforts related to item B are successful, then by January 31, 2018, State agencies will work collaboratively with water agencies, local permitting agencies, and driller organizations to:

      i. Develop an online well completion report submittal system.

ii. Digitize and make available to the public existing well completion reports to allow improved analysis of groundwater data.
iii. Build upon efforts started in 2012 to update well drilling, construction, and abandonment standards.

D. By December 31, 2018, DWR will work with SWRCB to implement a Web-based Water Planning and Information Exchange (Water PIE) system that improves state-level integration of groundwater data and provides online access to:

i. Groundwater supply and demand information.
ii. Groundwater level and quality data.
iii. Groundwater recharge and conjunctive management activities.
iv. Land subsidence information.
v. Groundwater management plans.
vi. Groundwater basin studies.

4. **Build essential data to enable sustainable groundwater management by expanding and funding the California Statewide Groundwater Elevation Monitoring (CASGEM) Program with the purpose of maintaining baseline groundwater level data, funding, and providing technical assistance to improve local groundwater management for long-term sustainability, and monitoring impacts of droughts on groundwater resources.**

A. By January 31, 2015, the Legislature will consider amending the appropriate CWC(s) to commit long-term, dedicated funding to the CASGEM Program established by SB X7-6, and expand the scope of the program to implement monitoring, assessment, and maintenance of baseline groundwater levels data, including data for fractured rock aquifers in areas that are deemed important. The funding should be renewable in each five-year cycle ending in eight and three.

B. By January 31, 2015, and renewable in each five-year cycle ending in eight and three, the State will continue funding for local groundwater monitoring and management activities and feasibility studies that increase the coordinated use of groundwater and surface water by giving priority to projects that include filling regional and statewide data gaps and conjunctive management conducted in accordance with an IRWM plan. This will provide incentives to local water management agencies to implement groundwater monitoring programs to provide additional data and information needed for adequate characterization of a groundwater basin, subbasin, aquifer, or aquifers under the jurisdiction of the agency or adopted groundwater management plan. Box 9-8 lists the items that a data collection program should include.

C. By January 31, 2018, fund, develop, and integrate with CASGEM a program for monitoring impacts of droughts on groundwater resources, including using information from remote sensing-based monitoring of land subsidence associated with increased groundwater extraction by water users due to surface supplies cutback under extremely dry conditions.

5. **Under the CASGEM Basin Prioritization, improve understanding of California's high priority groundwater basins by conducting groundwater basin assessment in conjunction with the CWP five-year production cycle, identifying basins in decline with recognition of both short- and long-term aquifer health, assessing impacts of climate change, identifying management practices for sustainable groundwater management that will prevent waste and unreasonable use of groundwater, and reporting key findings to the Legislature.** By December 31, 2018, DWR will coordinate with State,

Box 9-8 Components of a Data Collection Program

Data collection programs should include

1. Hydrogeologic characterization of the aquifers.
2. Changes in groundwater levels.
3. Groundwater flow (interbasin flow as well as flow to or from streams).
4. Groundwater quality.
5. Land subsidence.
6. Surface water flow.
7. Surface water quality.
8. Interaction of surface water and groundwater.

federal, tribal, local, and regional agencies to utilize the CASGEM Basin Prioritization information to conduct the following groundwater basin assessment activities:

A. Develop the initial and reoccurring schedule and scope for groundwater basin assessments that will allow data and information sharing under the CWP five-year production cycle.

B. Use CASGEM and other data, reports, groundwater basin studies, and best available science to compile and evaluate new and existing groundwater supply and demand information, groundwater level and quality data, groundwater recharge and conjunctive management activities, surface water/groundwater interaction, groundwater management planning, and land subsidence information. The State should not duplicate information already being reported by local agencies that may be actively managing CASGEM high priority basins. The State should consult with agencies that have implemented successful conjunctive management programs for insights into specific problems or hurdles that, if removed, would increase the ability for multi-region cooperation to implement conjunctive management projects.

C. Utilize local groundwater management agency information and data, when available, and develop detailed groundwater basin assessment reports by hydrologic region and groundwater basin with a special focus on high priority basins that currently are not actively managed. The assessment reports will:

   i. Characterize the groundwater basins.
   ii. Identify basins in decline.
   iii. Assess the sustainability of groundwater resources in terms of historical and existing trends.
   iv. Evaluate anticipated impacts of climate change on groundwater resources using future scenario projections with a special focus on basins where groundwater budgets and management practices currently have not been established.
   v. Identify recommended incentives to establish basin-wide groundwater budgets and adaptive management practices which will promote sustainable groundwater quantity, quality, and the maintenance of groundwater ecosystem services. Box 9-9 lists the inflow and outflow components that make up a groundwater budget.

Box 9-9 Components of a Groundwater Budget

A groundwater water budget quantifies the amount of water flowing into and flowing out of a groundwater basin, subbasin, and aquifer. Using groundwater monitoring data, streamflow data, and groundwater extraction data that are collected by a local agency, the groundwater budget for each groundwater basin, subbasin, and aquifer under the jurisdiction of the local agency or of an associated basin-wide or regional agency should be developed using the following equation:

Inflow – Outflow = Change in Storage

Inflow:

- Infiltration of precipitation.
- Infiltration from stream channels and unlined canals.
- Groundwater flow into the aquifer.
- Artificial recharge.
- Deep percolation from irrigation.

Outflow:

- Contribution of groundwater to surface water flow out of the basin.
- Groundwater flow out of the aquifer.
- Groundwater extraction (pumping).
- Consumptive use.
- Evapotranspiration.

The most uncertain components in the groundwater water budget should be identified to assess potential sources of error.

D. Develop a summary report to the Legislature depicting the California's groundwater, which will highlight key findings and recommendations associated with the groundwater basin assessments.

6. **Convene a Statewide Groundwater Management Plan (GWMP) Advisory Committee to develop a GWMP Acceptance Process, evaluate and approve the completeness of existing GWMPs with a special focus on high priority basins that currently are not actively managed, prepare a guidance document of groundwater best management practices (BMPs), and develop improved standards for sustainable groundwater management by utilizing a public process.** In coordination with State, federal, tribal, local, and regional agencies DWR will conduct the following activities:

   A. By January 31, 2015, the Legislature will consider amending the appropriate CWC(s) to authorize DWR to evaluate and assess groundwater management and planning, improve standards for sustainable groundwater management, develop groundwater management and implementation guidance documents, and assist local agencies to equip themselves to manage groundwater resources sustainably.

   B. By January 31, 2017, convene a GWMP Advisory Committee, which will be composed of local and regional water supply and groundwater management entities throughout the state. With guidance from the GWMP Advisory Committee, conduct the following activities:

i. Implement outreach to local and regional agencies to determine the best path for moving forward by better understanding where and what the needs are.
ii. Develop a GWMP Acceptance Process.
iii. Evaluate and approve the completeness of existing GWMPs using the GWMP Acceptance Process.
iv. Develop a groundwater management and planning and program implementation guidance document that will provide a clear roadmap for GWMP development and implementation based on groundwater BMP.
v. Identify tools and data sharing needed to improve groundwater management.
vi. Develop a Web site for local agencies to upload groundwater management documents and allow interested stakeholders to download them.

C. By January 31, 2018, with guidance from the GWMP Advisory Committee and utilizing a public process, develop improved standards and groundwater BMPs, which should include:

i. GWMP verification and implementation.
ii. Goals, objectives, performance measures, and a clear description of additional management steps to be taken if performance measures are not met.
iii. Groundwater budgets to help understand the total inflow and outflow from the groundwater system.
iv. Addition of ecosystem services into basin management objectives.
v. Annual reporting of GWMP implementation activities and performance.
vi. Reporting groundwater quantity and quality sustainability under current and future scenario projections.
vii. Conduct impacts assessment (economic and environmental) under current and future scenario projections.
viii. Post GWMPs and annual reports online with groundwater budgets.

7. **Advance groundwater management within the framework of IWM by identifying and including the goals and objectives of local GWMPs in Integrated Regional Water Management Plans (IRWMPs), ensure no transfer of impacts among regions, make regions accept responsibility for addressing risks due to climate change, population growth, and groundwater depletion, adopt stronger standards for local and regional groundwater management, and consider legislation to provide the necessary local and regional authority to effectively manage groundwater resources.**

A. By January 31, 2015, encourage IRWMPs to identify and include the goals and objectives of local GWMPs.

B. By January 31, 2017, the Legislature will consider enacting legislation to ensure that local and regional agencies have the incentives, tools, authority, and guidance to develop and enforce groundwater management plans that protect groundwater elevation and quality as well as surface water-groundwater interaction regime and groundwater ecosystem services.

C. By January 31, 2017, the Legislature will consider enacting legislation to define local and regional responsibilities, give local and regional agencies the authority necessary to manage groundwater sustainably, and ensure no groundwater basin is in danger of being permanently damaged by overdraft which results from operating or utilizing groundwater basins in an unsustainable manner. The State will be given authority to protect basins that are at risk of permanent damage in the event that local authorized agencies have not made sufficient and timely progress to correct the problem until such time that an adequate local program is in place.

8. **Review analytical tools currently being used and assist local agencies to develop improved tools to assess conjunctive management and groundwater management strategies.** By December 31, 2018, DWR and SWRCB, in collaboration with State, federal, tribal, local, and regional agencies will conduct the following activities:

   A. Develop a conjunctive management tool that will help identify conjunctive management opportunities (projects) and evaluate implementation constraints associated with:

      i. Availability of aquifer space.
      ii. Availability of water for recharge.
      iii. Available means to convey water from source to destination.
      iv. Water quality issues.
      v. Environmental issues.
      vi. Jurisdictional issues.
      vii. Costs and benefits.
      viii. Potential interference between a proposed project and existing projects.

   B. The State will provide incentives to local and regional agencies to develop or adopt analytical tools to support integrated groundwater/surface water modeling and scenario analysis for assessing alternative groundwater management strategies as part of their IRWM planning activities.

9. **Increase local and regional groundwater recharge and storage to reduce groundwater depletion and enhance statewide water resource resiliency.** In coordination with State, federal, tribal, local, and regional agencies the following activities will occur:

   A. By January 31, 2015, under legislative directive and with guidance from the GWMP Advisory Committee, DWR and SWRCB will jointly review and recommend revised or new policies, regulations, and a timeline for implementing this action.

   B. By January 31, 2016, based on the recommendations by DWR and SWRCB, the Legislature will consider revising the CWC to:

      i. Create disincentives for actions which cause groundwater basin overdraft resulting from operating or utilizing groundwater basins in an unsustainable manner.
      ii. Provide incentives to actions that increase recharge.

   C. By January 31, 2016, DWR will make the groundwater recharge maps developed by local agencies as required by AB 359 available to the public and identify priority recharge areas in the state.

   D. By January 31, 2017 and on an ongoing basis, State agencies will work with federal, tribal, local, and regional agencies on other actions to increase local and regional groundwater recharge and storage including:

      i. Cataloging the best science and technologies applied to groundwater recharge and storage.
      ii. Improving interagency coordination and alignment.
      iii. Aligning land use planning with groundwater recharge area protection.
      iv. Completing rulemaking for groundwater recharge with recycled water.
      v. Identifying additional data and studies needed to evaluate opportunities for multi-benefit projects, such as capturing and recharging stormwater flows and other water that is not used by other consumers or the environment.

vi. Identifying and evaluating local and regional opportunities to reduce runoff and increase recharge on residential, school, park, and other unpaved areas.

E. By January 31, 2017 and on an ongoing basis, State agencies will work with federal, tribal, local, and regional agencies to support a comprehensive approach to local and regional groundwater management by funding distributed groundwater recharge and storage projects that are identified in groundwater management plans and removing obstacles to implementation of such projects.

10. **Evaluate reoperation of the State's existing water supply and flood control systems.** In collaboration with willing participants, DWR will complete a system reoperation study by 2015. The study will evaluate and document the potential options for reoperation of the state's existing water supply and flood control systems to achieve the objectives of improved water supply reliability, flood hazard reduction, and ecosystem protection and enhancement. The reoperation options will focus on integrating flood protection and water supply systems, reoperating the existing water system in conjunction with effective groundwater management, and improving existing water conveyance systems.

11. **DWR and the U.S. Bureau of Reclamation should:**

A. By the end of 2015, complete the North-of-the-Delta Offstream Storage, Shasta Lake Water Resources, and Upper San Joaquin River Basin Storage investigations.

B. By the end of 2016, complete the investigation of the further enlargement of the Los Vaqueros Reservoir.

C. By the end of 2016, complete an investigation to enlarge/raise B.F. Sisk Dam and San Luis Reservoir.

These projects will also:

D. Evaluate the potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the state's surface storage.

E. Identify the beneficiaries and cost-share partners for the non-public benefits by 2015.

F. Request funding from the water bond for the public benefits portion through the California Water Commission by 2016, if a state water bond passes in 2014.

References

References Cited

Board of Supervisors of Butte, Colusa, Glenn, and Tehama Counties. 2006. Memorandum of Understanding: Four County (Butte, Colusa, Glenn, and Tehama Counties) Regional Water Resource Coordination, Collaboration, and Communication.

———. 2007. Four County Memorandum of Understanding Addendum One: Statement of Principles Regarding Water Related Programs and Projects.

Board of Supervisors of Butte, Colusa, Glenn, Tehama, and Sutter Counties. 2009a. Four County Memorandum of Understanding Addendum Two: Adding Sutter County to the Four County MOU.

———. 2009b. Four County Memorandum of Understanding Addendum Three: Expression of a Commitment to Begin an Integrated Regional Water Management Planning Process within the Counties of Butte, Colusa, Glenn, Tehama, and Sutter.

Board of Supervisors of Butte, Colusa, Glenn, Tehama, Sutter, and Shasta Counties. 2010. Four County Memorandum of Understanding Addendum Four: Expression of a Commitment to Begin an Integrated Regional Water Management Planning Process within the Counties of Butte, Colusa, Glenn, Tehama, Sutter and Shasta.

Brush CB, Dogrul EC, Kadir TN. 2013. *Development and Calibration of the California Central Valley Groundwater Surface Water Simulation Model (C2VSim), Version 3.02-CG*. Sacramento (CA): California Department of Water Resources.196 pp. Viewed online at: http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/download/C2VSim_Model_Report_Final.pdf.

California Department of Water Resources. 2003. *California's Groundwater. Bulletin 118. Update 2003*. Sacramento (CA): 265 pp. Viewed online at: http://www.water.ca.gov/groundwater/bulletin118/update2003.cfm.

———. 2008. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water*. Sacramento (CA): [White paper.] 34 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf.

———. 2013a. Drinking Water Treatment and Distribution Resource Management Strategy. *California Water Plan Update 2013*, Volume 3, Resource Management Strategies. Sacramento (CA): California Department of Water Resources.

———. 2013b. California's Groundwater Update 2013. *California Water Plan Update 2013*, Volume 4, Reference Guide. Sacramento (CA): California Department of Water Resources.

———. 2013c. "Chapter 3, California Water Today" In: *California Water Plan Update 2013*. Volume 1, The Strategic Plan. Sacramento (CA): California Department of Water Resources. 66 pp.

———.2013d. CalSim-III Development. Sacramento (CA): [Web site.] Viewed online at: http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSim/Future/index.cfm.

California Natural Resources Agency. 2013. "Bay Delta Conservation Plan." Sacramento (CA): [Web site.] Viewed online at: http://baydeltaconservationplan.com/Home.aspx.

CH2MHill and MBK Engineers. 2010. *Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report*. Redding (CA): Prepared for the Glenn-Colusa Irrigation District and Natural Heritage Institute. 171 pp. Viewed online at: http://www.gcid.net/documents/Programs_and_Studies/ModelingReport_2-10.pdf.

Close A, Haneman WM, Labadie JW, Loucks DP, Lund JR, McKinney DC, Stedinger JR. 2003. *A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California*. Sacramento (CA): 129 pp. Viewed online at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/daviswoodland/daviswoodland_cspa_es9.pdf.

Dudley T, Fulton A. 2006. *Conjunctive Water Management: What is it? Why Consider it? What are the Challenges?* Red Bluff (CA): [Educational Newsletter.] 4 pp. Viewed online at: http://www.glenncountywater.org/documents/ConjunctiveWaterManagement.pdf.

Evans WR, Evans RS, Holland GF. 2009. *Conjunctive Use and Management of Groundwater and Surface Water*. Australia: Groundwater Governance - A Global Framework for Action. Thematic Paper 2. 50 pp. Viewed online at: http://www.groundwatergovernance.org/fileadmin/user_upload/groundwatergovernance/docs/Thematic_papers/GWG_Thematic_Paper_2_01.pdf.

Faunt CC (editor). 2009. *Groundwater Availability of the Central Valley Aquifer, California*. Reston (VA): U.S. Geological Survey. Professional Paper 1766. 225 pp. Viewed online at: http://pubs.usgs.gov/pp/1766/PP_1766.pdf.

Fleckenstein J, Anderson M, Fogg G, Mount J. 2004. "Managing surface water-groundwater to restore fall flows in the Cosumnes River." Journal of Water Resources Planning and Management. 130 (4):301-310. Viewed online at: http://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9496%282004%29130%3A4%28301%29.

Food and Agriculture Organization of the United Nations. 1995. Land and Water Integration and River Basin Management. Proceedings of an FAO informal workshop held in Jan. 31 – Feb. 2, 1993. Rome (Italy): Food and Agriculture Organization of the United Nations. FAO Land and Water Bulletin 1. 93 pp. Viewed online at: http://www.fao.org/docrep/v5400e/v5400e00.htm.

Hemker CJ. 2013. MicroFEM. Amsterdam (The Netherlands): [Web site.] Viewed online at: http://www.microfem.com/.

Joyce B. 2007. "Linking CalSim-III to C2VSIM via the Use of Discrete Kernel - Implementation." Presented at California Water and Environmental Modeling Forum 2007 Annual Meeting: "California Water: Where Change is Constant." February 26-28. Pacific Grove (CA): [PowerPoint presentation.] 46 pp. Viewed online at: http://www.cwemf.org/Asilomar/CWEMF_BJoyce.pdf.

Kennedy/Jenks. 2008. *Survey Results and Summary: Groundwater Banking Programs Survey*. Prepared for the Regional Water Authority (RWA) of greater Sacramento, Placer, El Dorado, and Yolo County Region. Draft [Unpublished.] Sacramento (CA): 57 pp.

Metropolitan Water District of Southern California. 2007. *Groundwater Assessment Study: A Status Report on the Use of Groundwater in the Service Area of the Metropolitan Water District of Southern California*. Report Number 1308. Los Angeles (CA): Metropolitan Water District of Southern California. 546 pp. Viewed online at: http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/gwas.html.

Montgomery Watson and Water Education Foundation. 2000. *Groundwater and Surface Water in Southern California: A Guide to Conjunctive Use*. Azusa (CA): Prepared for Association of Groundwater Agencies. 33 pp.

Montgomery Watson Harza. 2009. *Calaveras County General Plan Update: Water Element Goals & Policies Report*. Prepared for Calaveras County. San Andreas (CA): 60 pp.

National Marine Fisheries Service. 2009. *Biological Opinion and Conference Opinion on the Long-term Operations of the Central Valley Project and State Water Project*. Long Beach (CA): 844 p. Viewed online at: http://swr.nmfs.noaa.gov/ocap/NMFS_Biological_and_Conference_Opinion_on_the_Long-Term_Operations_of_the_CVP_and_SWP.pdf.

———. 2011. *2011 Amendments to the NMFS OCAP RPA*. Long Beach (CA): 189 p. Viewed online at: http://swr.nmfs.noaa.gov/ocap/040711_OCAP_opinion_2011_amendments.pdf.

Parker TK. 2007. "California's Quandary: Managed Aquifer Recharge for Increased Water Supply Reliability under A Very Complex Regulatory Environment – Will It Work?" In: Fox P, editor *Management of Aquifer Recharge for Sustainability. Proceedings of the 6th International Symposium on Managed Artificial Recharge of Groundwater, ISMAR6*. Oct. 28-Nov. 2. Phoenix, AZ. Acacia Publishing, Inc. pp. 109-125. Viewed online at: http://www.iah.org/recharge/downloads/AquiferRecharge_ISMAR6.pdf.

Purkey DR, Thomas GA, Fullerton DK, Moench M, Axelrad L. 1998. *Feasibility Study of a Maximal Program of Groundwater Banking*. Berkeley (CA): Natural Heritage Institute. 91 pp. Viewed online at: *http://www.weap21.org/downloads/BayDelta2.pdf*.

Purkey DR, Mansfield EM. 2002. *Estimating the Potential for In Lieu Conjunctive Water Management in the Central Valley of California*. Natural Heritage Institute. Berkeley (CA): 89 pp. Availability: *http://www.n-h-i.org/uploads/tx_rtgfiles/In_Lieu_in_PDF.pdf*.

Santa Clara Valley Water District. 2008. 2008 Valley Water Profile (Valley Water: A Profile of the Santa Clara Valley Water District). San Jose (CA):

———. 2009. "Santa Clara Valley Water District: History." San Jose (CA): [Web site.]. Viewed online at: http://www.valleywater.org/About/History.aspx.

———. 2012. "Where does your water come from?" San Jose (CA): Santa Clara Valley Water District: [Web site.] Viewed online at: http://www.valleywater.org/Services/WhereDoesYourWaterComeFrom.aspx.

Sax JL. 2002. *Review of the Laws Establishing the SWRCB's Permitting Authority over Appropriations of Groundwater Classified as Subterranean Streams and the SWRCB's Implementation of Those Laws*. Final Report. SWRCB No. 0-076-300-0. Sacramento (CA): 104 pp. Viewed online at: http://www.swrcb.ca.gov/waterrights/water_issues/programs/hearings/groundwater_classification/docs/substreamrpt2002jan20.pdf.

St. Amant T. 2013. *Conjunctive Water Management: The State Needs to Step Up to the Plate*. Chico (CA): Unpublished White Paper. 9 pp.

State Water Resources Control Board. 2013. *Communities that Rely on a Contaminated Groundwater Source for Drinking Water: Report to the Legislature*. Sacramento (CA): State Water Resources Control Board. 181 pp. Viewed online at: http://www.waterboards.ca.gov/gama/ab2222/docs/ab2222.pdf.

U.S. Army Corps of Engineers. 2002. *Conjunctive Use for Flood Protection*. Davis (CA): 151 pp.

U.S. Fish and Wildlife Service. 2008. *Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. Sacramento (CA): 410 p. Viewed online at: http://www.fws.gov/sfbaydelta/documents/swp-cvp_ops_bo_12-15_final_ocr.pdf.

———. 2011. *First Draft Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP)*. Sacramento (CA): 336 p. Viewed online at: http://www.usbr.gov/mp/BayDeltaOffice/docs/Signed_FINAL%202011-F-0043_%20SWP-CVP%20BO%20Dec%2014%20FIRST%20DRAFT.pdf.

Wanger, OW. 2007a. Judge Wanger, US District Court for the Eastern District of California, in Natural Resources Defense Council, et al. v. Kempthorne, 1:05-cv-1207 OWW GSA: Summary Judgment Invalidating the 2005 Biological Opinion Issued by US Fish and Wildlife Service and Order to Develop A New Biological Opinion by Sep. 15, 2008. May 25.

———. 2007b. Judge Wanger, US District Court for the Eastern District of California, in Natural Resources Defense Council, et al. v. Kempthorne, 1:05-cv-1207 OWW GSA: An Interim Remedial Order to Provide Additional Protection of the Federally-listed Delta Smelt Pending Completion of A New Biological Opinion for the Continued Operation of the CVP and SWP. Dec. 14.

———. 2008a. Judge Wanger, US District Court for the Eastern District of California, on the Cross-Motions for Summary Judgment filed in PCFFA et al. v. Gutierrez et al, 1:06-cv-245-OWW-GSA: A Memorandum Decision and Order Invalidating the Biological Opinion Issued by National Marine Fisheries Service in 2004. Apr. 16.

———. 2008b. Judge Wanger, US District Court for the Eastern District of California, on the Cross-Motions for Summary Judgment filed in PCFFA et al. v. Gutierrez et al, 1:06-cv-245-OWW-GSA: A ruling that California's Canal Water Systems are Placing Wild Salmon "unquestionably in jeopardy" without Issuance of Any Court-ordered Interim Remedies until the Final Operations Criteria and Plan Biological Assessment is issued by March 2, 2009. Oct. 21.

———. 2010. Judge Wanger, US District Court for the Eastern District of California. A summary judgment, finding the 2008 OCAP biological opinion unlawful and remanding it to the US Fish and Wildlife Service for further consideration per the findings in his Memorandum Decision.

———. 2011a. Judge Wanger, US District Court for the Eastern District of California. An amended Final Judgment, ordering the US Fish and Wildlife Service to complete a draft revised OCAP biological opinion by October 1, 2011, and a final revised OCAP biological opinion by December 1, 2013.

———. 2011b. Judge Wanger, US District Court for the Eastern District of California. A Memorandum Decision on the merits in the challenge to the NMFS OCAP biological opinion.

Winter TC, Harvey JW, Franke OL, Alley WM. 1998. *Groundwater and Surface Water: A Single Resource*. Denver (CO): U.S .Geological Survey. Circular 1139. 87 pp. Viewed online at: http://pubs.usgs.gov/circ/circ1139/pdf/circ1139.pdf.

Young C. 2007. "Linking CalSim-III to C2VSIM via the Use of Discrete Kernel - Theory." Presented at California Water and Environmental Modeling Forum 2007 Annual Meeting: California Water: Where Change is Constant. February 26-28. Pacific Grove (CA): [PowerPoint presentation.] 46 pp. Viewed online at: http://www.cwemf.org/Asilomar/CWEMF_CYoung.pdf.

Additional References

Anderson M. 2009. *The State of Climate Change Science for Water Resources Operations, Planning, and Management*. Draft. Sacramento (CA): California Department of Water Resources. 41 pp. Viewed online at: http://www.waterplan.water.ca.gov/docs/climate_change/CCScience_DWROperations.pdf.

CALFED Bay-Delta Program. 1999. *Conjunctive Use Site Assessment*. Draft. Sacramento (CA): CALFED Bay-Delta Program. 35 pp. Viewed online at: http://www.calwater.ca.gov/Admin_Record/D-014101.pdf.

———. 2004. Common Assumptions, Conjunctive Use Inventory. CALFED Bay-Delta Program. Sacramento (CA):.

Climate Action Team. 2009. *Climate Action Team: Biennial Report*. Draft. Sacramento (CA): 122 pp.

California Department of Water Resources. 2009. *California Water Plan Update 2009*. Volume 3, Regional Reports. Sacramento (CA): California Department of Water Resources.

———. 2009. "Chapter 19 Urban Runoff Management." In: *California Water Plan Update 2009*.Volume 2, Resource Management Strategies. Sacramento (CA): California Department of Water Resources.

———. 2009. "Chapter 25 Recharge Area Protection." In: *California Water Plan Update 2009*.Volume 2, Resource Management Strategies. Sacramento (CA): California Department of Water Resources.

———. 2009. "CalSim-III Development." Sacramento (CA): California Department of Water Resources. [Web site.]

———. 2009. "Objective 3, Chapter 7 Implementation Plan." In: *California Water Plan Update 2009*. Volume 1, The Strategic Plan. Sacramento (CA): California Department of Water Resources.

Purkey DR, Thomas GA. 2001. *The Hydrogeologic Suitability of Potential Groundwater Banking Sites in the Central Valley of California*. Natural Heritage Institute. Berkeley (CA): 116 pp. Viewed online at: http://www.n-h-i.org/uploads/tx_rtgfiles/Purkey_Report_in_PDF_01.pdf.

State Water Resources Control Board. 2002. *Water Transfer Issues in California: Final Report to the California State Water Resources Control Board by the Water Transfer Workgroup*. Sacramento (CA): State Water Resources Control Board. 107 pp. Viewed online at: http://www.waterboards.ca.gov/publications_forms/publications/general/docs/watertransfers.pdf.

Thomas GA. 2001. *Designing Successful Groundwater Banking Programs in the Central Valley: Lessons from Experience*. Natural Heritage Institute. Berkeley (CA): 116 pp. Viewed online at: http://www.n-h-i.org/uploads/tx_rtgfiles/7550_Conjusefinal.PDF.

Personal Communications

St. Amant T. Director of Strategic Analysis at the U.S. Air Force Center for Studies and Analyses (retired). Former Deputy Chief Administrative Officer for Butte County. Sept. 13, 2012 — e-mail correspondence with Kahn A, California Department of Water Resources — part of annotated comments made on draft Conjunctive Management and Conjunctive Management resource management strategy.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 10

Desalination (Brackish and Sea Water)

Port Hueneme, CA. This Naval Base Ventura County project provides a real-world test environment for long-term evaluation of desalination equipment and other water purification components, such as reverse osmosis membranes, pumps, and energy recovery devices.

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Chapter 10. Desalination (Brackish and Sea Water)

Desalination, the removal of salts from saline waters, is one of the few options available to augment California's water supply. California has facilities that desalinate sea water for coastal communities and brackish groundwater for inland water users — many of which have provided high-quality water to their customers for more than 10 years. As water supplies in California become more constrained, many water suppliers with nearby saline water sources are evaluating desalination as a way to provide reliable supply in response to uncertainties relating to future drought and climate change. While desalination is not a viable method for many water suppliers in the state, some not yet engaged in the process could realize significant supply and reliability benefits — even though desalination of both sea water and brackish groundwater comes with financial and environmental challenges. For water suppliers with desalination opportunities, how they implement environmentally sustainable projects is a key issue facing multiple California communities.

Introduction

This chapter presents the Desalination Resource Management Strategy (Desal RMS), which addresses key seawater and groundwater desalination issues and challenges. The chapter also provides a framework for how California communities and water users can move forward with brackish water and seawater desalination. The Desal RMS:

- Presents water desalination concepts and issues.
- Identifies where desalination is currently occurring and is being considered in California.
- Addresses issues related to a balanced approach to how desalination could support water sustainability in the state.
- Identifies recommendations for water suppliers and agencies to consider when evaluating desalination opportunities.

This chapter focuses on presenting a strategy for sustainable desalting of surface and subsurface waters of the state for the principal purpose of meeting municipal drinking water demands. It discusses desalination technology, as well as the legal and institutional framework to consider when planning and implementing projects. In addition to other issues, the Desal RMS addresses two special challenges for desalination: costs and environmental impact from water intakes and brine management. Desalinating water for uses other than community water supply, such as large-scale agricultural, industrial, and mining activities, is not addressed in detail in this chapter but may be discussed briefly within the overall context of desalination technology or implementation of the practice.

Sustainability is a common theme of the California Water Plan (CWP) and an objective in the planning and management of water desalination. As the term is used in this plan, water sustainability is the dynamic state of water use and supply that meets today's needs without compromising the long-term capacity of the natural and human aspects of the water to meet the needs of future generations.

Because of the complexity of desalination and the various ways desalination technologies are implemented in California, the Desal RMS presents brief summaries of key issues. Additional detail about desalination is presented in Volume 4, *Reference Guide*.

Salt and Salinity

Many details about water chemistry, drinking water regulations, and the interactions among water bodies are beyond the scope of this chapter but play a significant role in setting State and regional water quality and supply objectives and implementing a desalination strategy. Basic concepts and terms regarding salts and salinity of water are discussed below.

Salts occur naturally in the environment, but human activity often increases salinity in water and soil. Because of the negative impacts of salinity on human use or the water environment, salinity management is a critical resource management strategy. See Chapter 19, "Salt and Salinity Management," for additional information on this issue.

Definition of Desalination

Desalination is the removal of salts from water to produce a water of lesser salinity than the source water. Other terms that are interchangeable with desalination include seawater or saline water conversion, desalting, demineralization, and desalinization. For consistency, "desalination" will be used in this chapter.

Desalination can be used to reduce salinity in many sources of water. The term source water is used to identify the body of water from which water is taken for beneficial purposes. Source water for desalination can include surface water, groundwater, and municipal wastewater. Desalinated water can be used for potable uses, such as municipal drinking water, or non-potable applications, such as agricultural irrigation or industrial processes. The focus of this chapter is on desalination of surface water or groundwater for potable uses.

Description of Salts and Their Origin

The presence of certain impurities (e.g., minerals, elements, and chemical compounds) in water, especially at higher concentrations, can affect the aesthetics and use of water. For example:

- Halite, the mineral commonly known as table salt or sodium chloride (NaCl), readily dissolves in water into ionic forms and is found objectionable to human taste even at low levels.
- Sodium (Na) can affect soil properties and thus damage crops.
- Calcium carbonate (the chemical compound $CaCO_3$) deposits on household fixtures and industrial equipment, causing damage or increasing maintenance.

When solid substances mix with water or other liquids, they may separate (dissolve) into two parts called ions, one with a positive charge (such as sodium or calcium) and one with a negative charge (such as chloride or bicarbonate). This form of a dissolved solid is termed an ionic substance. The majority of dissolved solids in raw and finished municipal water supply sources, fresh or saline, are ionic inorganic substances, such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, bromide, and nitrate. These dissolved ionic elements or compounds are known collectively as “salt.”

The principal source of salt in the oceans and brackish waters is from the land. The salts are leached out a bit at a time as water flows over and through the land during each hydrological cycle. Over the millennia, the oceans, seas, and other saline bodies of water have become salty through the interaction of fresh water with rocks containing minerals, such as the sodium chloride compound. After water evaporates from the surface of a saline water body, the salt is left behind, further increasing the salinity. The oceans have developed a noticeably salty taste. The ocean and some inland low-lying bodies of water without drainage accumulate salts, and thus are called “salt sinks.” Salt sinks have traditionally not been used for municipal water supplies in California.

Salinity Measurements

The saltiness of water is referred to as its salinity. *Salinity* is generally defined as the amount of salt dissolved in a given unit volume of water. It is variously measured in units of electrical conductivity (EC), total dissolved solids (TDS), practical salinity units (PSU), or other units depending on the scientific discipline of the person doing the measuring and the purpose of the study or monitoring program.

The unit of measure most often used for TDS is milligrams per liter, or mg/L. Since one liter of pure water weighs one million milligrams at a referenced temperature, TDS is expressed as parts per million (ppm); parts per thousand (ppt); as well as the percentage of salinity. The generally accepted value for salinity of open sea water is a TDS of 35,000 mg/L or ppm, also expressed as 35 ppt TDS or 3.5 percent salinity (3.5 percent salt). TDS is one of the bases for federal and State standards for how much dissolved material is in a water supply.

While TDS is often the measurement of salinity, it should be understood that the TDS measurement includes other dissolved chemicals besides salts, including such metals as copper and iron and such elements as boron. Also, sodium chloride is often the most common salt with the highest concentration in water and is most frequently equated with salinity. However, many other dissolved salts in ionic form are found in natural waters.

There are a number of ways to measure saltiness in water or soil, each having its role in various sciences (e.g., oceanography, hydrology, geology). The most frequently applied metrics are shown in Table 10-1.

Degrees of Salinity

There is no fixed delineation between “fresh” and “brackish” water; for this chapter, a TDS concentration value of 1000 mg/L, or 0.1 percent salinity, is used as the dividing line, which is consistent with many references.

The term *brackish* generally refers to water that has more salinity than fresh water but less than sea water. There also is no rigid delineation between brackish water and sea water; however, 30,000 mg/L, or 3 percent salinity, is used for the purposes of this chapter to make a general delineation between brackish and sea water.

Table 10-1 Measurements of Salinity

Salinity Metric	Common Units	Comment
Electrical conductivity (EC)	µS/cm	EC is a measure of the concentration of dissolved ions in water, and is reported in µmhos/cm (micromhos per centimeter) or µS/cm (microsiemens per centimeter). A µmho is equivalent to a µS. EC may also be called specific conductance or specific conductivity of a solution.
Total dissolved solids (TDS)	mg/L or ppm	TDS is a measure of the all the dissolved substances in water and its units are milligrams per liter (mg/L) of solution.
Practical salinity units (PSU)	Unit-less	PSU is approximately equivalent to salinity expressed as parts per thousand (e.g., salt per 1,000 g of solution). Seawater is about 35 PSU. Its actual measurement is a complex procedure. Oceanographers are likely to use PSUs.

The average salinity of ocean water is generally taken to be 35,000 mg/L TDS, or 3.5 percent, with a range of 30,000 mg/L to 50,000 mg/L. Inland seas can fall within this range, such as the Salton Sea with a rising salinity currently near 44,000 mg/L TDS. A few inlands seas can exceed this range, such as the Great Salt Lake or the Dead Sea. For the purposes of this chapter, "sea water" or "seawater"as a salinity descriptor means a TDS between 30,000 and 50,000 mg/L.

The term *brine* is a general term having different meanings in industry, water management, and even household cooking. Depending on how the term is used, brine may have a salinity as low as 1,000 mg/L TDS or as high as the saturation point of salts in water, when the salinity reaches about 280,000 mg/L and the brine has the consistency of slurry of liquid and salt particles. In many food preserving processes, brines are concocted of varying salinity to achieve a specific purpose. Brine may refer to any naturally occurring water with a salinity level higher than sea water. Natural brines, like those found under the Salton Sea and other geothermally active locations, are usually hot with salinities that are much higher than sea water. The Salton Sea natural brines are approximately 280,000 mg/L TDS or eight times that of average surface sea water. Another meaning of *brine*, which is adopted for this Desal-RMS, is the saline reject water from a desalination process. Reject water, that is, brine, from a desalination facility using reverse osmosis technology may have concentrations as low as 4,000 mg/L TDS, such as in the case of desalting brackish groundwater, to 70,000 mg/L in the case of seawater desalination.

Describing a water body by using the terms "fresh," "brackish," or "sea" characterizes the degree of salinity or freshness of the source water, depending on the context. Table 10-2 provides salinity ranges for these common terms as they are used in this chapter.

Fresh, brackish, and sea are qualitative terms that do not necessarily specify an origin or the exact environment from which a water withdrawal is made. The common inference is that the term "brackish" refers to groundwater, and "sea" refers to surface water from the ocean. Nonetheless, water characterized by the terms fresh, brackish, or sea may be withdrawn from surface or subsurface locations. Because "brackish water" and "sea water" do not refer to locations but

Table 10-2 Degrees of Salinity

General Water Term	Relative Salinity, mg/L (ppm) TDS
Fresh (natural)	Less than 1,000[a]
Brackish	1,000 to 30,000
Sea	30,000 to 50,000
Hypersaline	Greater than 50,000 or that is found in the sea
Natural brine	Greater than 50,000 to slurries[b]
Discharge brine	1,000 to slurries[c]

Notes:

mg/L = milligrams per liter, NaCl = sodium chloride, ppm = parts per million, TDS = total dissolved solids

[a] Based on community drinking water standards. Salinity target values for municipal drinking water systems using desalination technologies are typically less than 500 ppm TDS.

[b] Also, brines or "salines" naturally derived from groundwater are 100,000 ppm or greater. TDS, NaCl-saturated solutions are approx. 260,000 ppm in concentration.

[c] Discharge brine concentrations vary widely and depend on technologies employed and processes used to discharge brine as a final waste stream to the environment. The concentration of reject water from a desalination facility may be referred to as "brine" but may only be 4,000 mg/L TDS in concentration.

are best applied as descriptors of degrees of salinity, brackish water does not necessarily refer to subsurface water (groundwater), and sea water does not necessarily refer to open or surface water, in discussions concerning desalination or saline waters. The subtitle of this chapter denotes "Brackish and Sea Water" as the two main types of saline water requiring desalination, regardless of whether their origin is underground or on the surface.

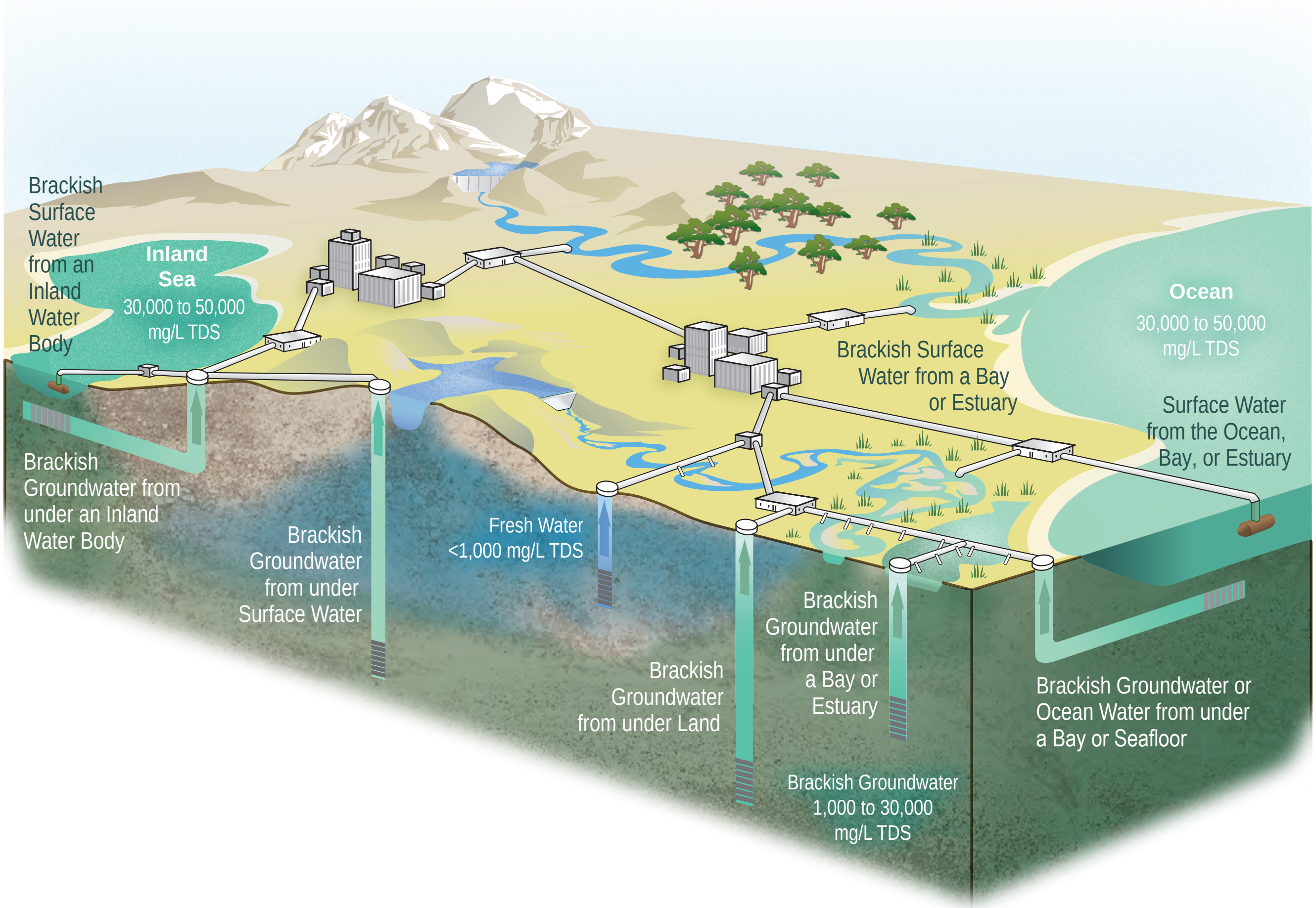
Sources of Water for Desalination in California

Various water sources are suitable for municipal drinking-water supply using desalination. Although desalination and other technologies are used to treat municipal wastewater for reuse, that topic is not covered in this chapter.

Typically, raw water sources must meet basic municipal water supply development criteria for quality and quantity. Municipal source waters should be capable of providing an adequate and sustainable amount of water for an intended beneficial use. Potential sources include oceans, bays, rivers, lakes, and groundwater aquifers. The determination of the safe yield from a water body is necessary for desalination as well as many other types of water supply projects. The ocean and other saline open-water environments afford the greatest safe yield potential for desalination water supply projects in California.

Typical water source types used for municipal water supplies throughout California, including those requiring desalting to provide fresh drinking water, together with a typical treatment facility, are shown in Figure 10-1.

Figure 10-1 Basic Municipal Drinking Water Facility and Source Waters in California



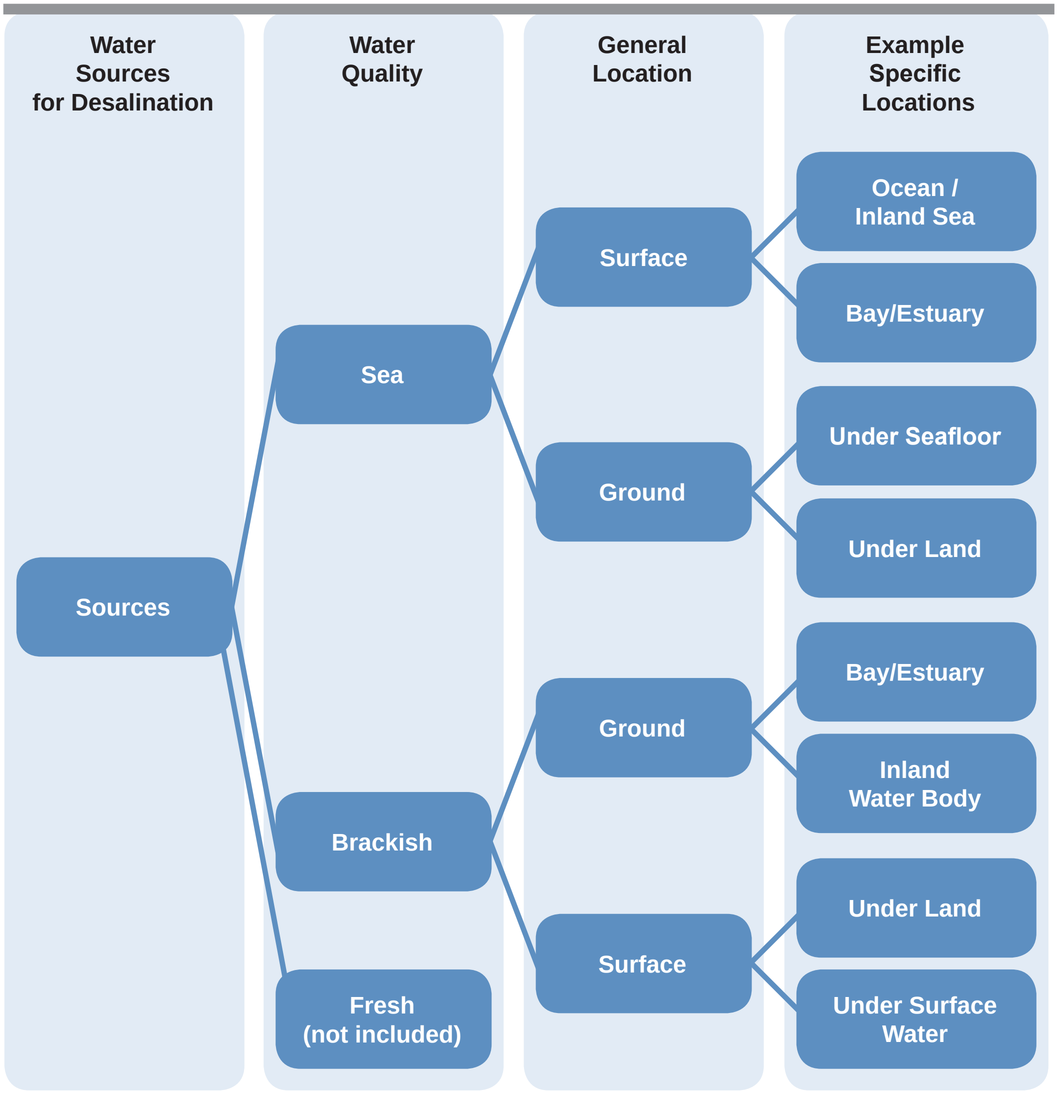
As a general rule most water sources with a TDS concentration higher than 1,000 mg/L are termed brackish and will need desalination treatment or blending with fresher water to meet municipal drinking water quality criteria.

A possible source of saline water is found in subsurface regions deeper than 3,000 feet below ground surface. Such water is not normally associated with the development of municipal drinking water in California, but may be discovered during oil and gas exploration and development. The California Department of Water Resources (DWR) has not compiled information or made assessments with regard to water found at depth and how it might be utilized to meet municipal water demands in the state. This topic is not addressed but may be further explored in future CWP updates.

Source Water Classifications

Differences between sources of water suitable for desalination affect cost, environmental impacts, greenhouse gas (GHG) emissions, and other feasibility factors. It is important to classify water by source and quality for clarity of discussion of related issues. In the scheme shown in Figure 10-2, source waters are divided between two general salinity levels — sea and brackish — as defined

Figure 10-2 Classification of Saline Water Sources



in Table 10-2. While fresh water sources exist, as shown in Figure 10-2, for the purposes of this chapter no further classification or discussion of fresh water will be made.

The next level of classification is the general source location of surface or subsurface (underground). More specific surface-location characterizations are the ocean, bays, estuaries, and inland surface water bodies, such as the Salton Sea, major salt marshes, or other salt sinks.

In the discussion of any specific project or in the reporting of data, it is important to avoid ambiguity by using precise characterizations.

Subsurface Water

Subsurface water sources are groundwater aquifers, but depending on their location they may be an indirect conduit for extracting saline surface water for desalination. Currently the most common source of water for desalination in California is brackish groundwater located inland from the ocean. The sources of salinity in the groundwater may be natural or caused by human activity. Natural sources may be salts dissolved from the minerals in the aquifer or salts picked up as water percolated from the land surface down to the aquifer.

The primary human-derived source of salts in groundwater is agricultural irrigation. Salts in irrigation water are left behind by the plants and tend to concentrate and migrate to groundwater. Animal wastes from dairies and feed lots can also be significant sources of salts. Landscape irrigation may contribute, as well.

Groundwater wells located adjacent to or underneath surface waters, in particular the ocean, are a way to extract saline surface waters when the groundwater is directly connected to and readily replenished by surface water. This is called groundwater under the influence of surface water. There can be advantages to extracting brackish or sea water from a surface water indirectly through wells. Sand adjacent to or underneath the seafloor can serve as a filter to reduce water treatment costs and reduce impacts on fish and other aquatic life living in open water.

When saline surface water is extracted for desalination indirectly through wells, it is important to classify this separately from open-water intakes. As discussed later in this chapter, the environmental effects can be significantly different between surface and subsurface water intakes, even if the source water is ultimately the same. This is why the classification system shown in Figure 10-2 distinguishes between groundwater under the land versus under a surface water body. Subsurface water under surface water is intended to mean groundwater under the direct influence of the surface water. Reporting the results of ocean water desalination is often achieved by combining data from open-water intakes and subsurface water intakes, and yet there are significant differences between intake types worth clarifying.

Surface Water

The ocean and connected bays have the potential to be major sources of surface waters for purposes of desalination in California. This supply alternative is unique in that ocean water does not depend on the hydrologic cycle and can be treated to produce fresh water reliably, even during the more frequent and longer droughts projected to be caused by climate change (Committee on Advancing Desalination Technology 2008). Because of the vast volume of water in the oceans, ocean and other saline open-water environments afford the greatest safe-yield potential for desalination water-supply projects in California.

At the same time, the sea provides vast resources beyond just a source of water supply. Sea water contains an array of nutrients supporting plankton blooms and is the broth for much of the marine environment's food web. The marine waterscape contains forests of kelps where young and mature fish and seals dwell along with crabs, snails, and other species of mammals, fish, and invertebrates.

The ocean is a composite of many smaller ecosystems of limited ranges that support marine life adapted to these ecosystems. Although the vastness of the oceans leads some to describe them as "inexhaustible," the term should be used with caution. The sustainable extraction of sea water for desalination to meet municipal freshwater demand depends on safeguarding the seawater environment. Various forms of pollution and the effects of climate change increasingly put the marine environment and the life within it in jeopardy, making them anything but "inexhaustible."

While 35,000 ppm TDS is the average salinity of open-ocean water, scientists know that salinity naturally varies throughout the open oceans and seas. Some marine life depends on a narrow range of salinity fluctuations. Marine biologists are trying to understand just how sensitive certain marine environments, such as the benthic regions on the ocean floor, are to changes in salinity levels. Since the discharge of brine could affect salinity levels, this could increase the mortality of the marine life, an undesirable effect.

Desalination as a Water Treatment Technology

Introduction

Desalination, as previously defined, is the removal of salts from water to provide a water of lesser salinity than the source water. Salt is but one of many contaminants found in source water used for municipal drinking water. There are many types of processes that use various water treatment technologies to remove these contaminants. Some desalination technologies can be arrayed and operated on skid-mounted or self-contained mobile units that can be deployed during disaster relief, thereby increasing preparedness and decreasing vulnerabilities associated with insufficient drinking water. More information may be found on drinking water treatment in California in Volume 3, Chapter 15, “Drinking Water Treatment and Distribution.”

Aside from the treatment technology to remove the salts, a desalination project must include other elements to convey and additionally treat the source water and to deliver the finished water to customers. Figure 10-3 depicts key elements of a desalination system, as will be discussed later in this section.

Not every element depicted in Figure 10-3 is necessary for all desalination systems. The “Pretreatment,” “Post Treatment,” “Blending,” “Solids Disposal,” and “Concentrate” elements do not occur in all desalination systems, while “Raw Water,” “Intakes,” “Desalination,” “Finished Water,” and “Distribution” are part of every full-scale desalination system. “Raw Water” and “Distribution” in this schematic emphasize where the water comes from and where it ends up, elements that in every desalination system affect feasibility, design, and environmental impacts.

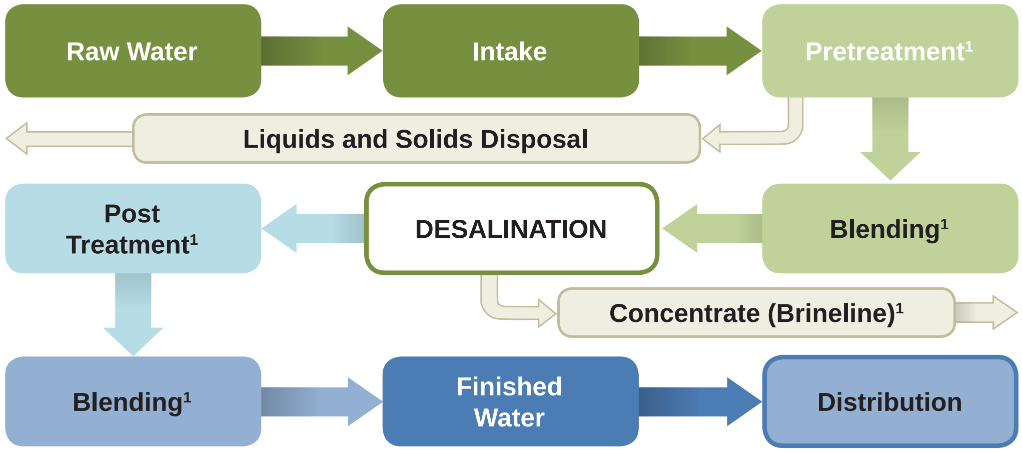
Other common terms may be used when discussing treatment processes. *Component* is widely used instead of “element” in many textbooks; *product water* and *permeate* may be used instead of “finished water”; *feedwater* and *influent* are often used instead of “raw water.”

This section will (1) provide an overview of the types of desalination technologies available and under research, (2) give some detail on the desalination technology known as reverse osmosis (RO), and (3) present the various elements of a municipal drinking water system that uses the RO technology for desalination.

Overview of Types of Desalination Technologies

There is a wide range of processes, technologies, and methods used to achieve a desired level of salt removal in water. This overview provides general information on both established and new or emerging desalination technologies.

Figure 10-3 General Desalination System Schematic



[1] May not occur at specific desalination facilities

Table 10-3 provides a list of desalination technologies and their general application. It is convenient to place desalination technologies or processes into three main categories: (1) thermal, (2) membrane separation, and (3) all others.

Thermal Distillation Processes

The oldest desalination process is distillation, which has been used for more than 2,000 years. Thermal desalination processes render safe and reliable water from almost any raw water source, including fresh water, brackish water, and seawater sources. Most large-scale thermal distillation facilities are coupled with power plants that use steam turbines to generate electricity. Waste heat from the cooling of the power generation system can be used in the distillation process to reap benefits of a “cogeneration” approach to produce drinking water and electric power in the same complex. No municipal drinking water in California is produced with a thermal distillation process. Many of the large-scale facilities that use thermal processes at the municipal or industrial level are in Middle Eastern countries.

Two of the most widely used thermal processes for seawater desalination are Multi-Stage Flash evaporation (MSF) and Multi Effect Distillation (MED). The processes deliver water of exceptionally high purity (less than 25 mg/L TDS) and have been successfully operated in very large sizes. Among the disadvantages are the high capital cost and the requirement for a large input of heat.

At least one new thermal process concept has been proposed for possible use in California that claims to eliminate disposing of brine wastewater back to the environment, operates with higher efficiencies than other distillation processes, and management of solid waste includes recovering useful mineral products for industry (U.S. Patent 8,946,787).

General Membrane Separation

Membranes exist in nature and technological advances are mimicking the separation of salts found in the natural processes in three important desalting processes: forward osmosis (FO), RO,

Table 10-3 List of Desalination and Associated Technologies

Technology	Brief Description
	THERMAL DISTILLATION
Multi-Stage Flash evaporation (MSF)	The thermal process by which distillation principles are employed through chambers at slightly different atmospheric pressures to flash liquid water into vapor and immediately condense the vapor in adjacent chambers as product water for use.
Multi Effect Distillation (MED)	The thermal process by which distillation principles are employed through pipes rather than chambers as in MSF. Once evaporation has occurred, water vapor is condensed within tubes (pipes) rather than chambers.
Vapor Compression (VC)	The thermal evaporative process where vapor from the evaporator is mechanically compressed and the heat from the compression activity is used to evaporate additional feedwater. VC is capable of achieving zero-liquid waste discharge requirements, even with very high salt concentrations in the feedwater.
	MEMBRANE SEPARATION
Electrodialysis (ED)	This technology uses an electrochemical separation process in which ions are transferred through specially designed ion-exchange membranes by the application of electrical current, leaving desalinated water as the product.
Electrodialysis Reversal (EDR)	This technology uses the same electrochemical principles as electrodialysis, except EDR periodically switches the electrical current flow direction (reversal), which decreases fouling and scaling of the elements.
Reverse osmosis (RO)	RO uses pressure to force water across a semi-permeable membrane from the saline water side to the desalinated product water side, leaving the salts and other impurities behind as brine reject.
Forward Osmosis (FO)	FO is a two-part process. In the first part, a semi-permeable membrane separates the saline feedwater from an artificial "draw" solution of higher salinity. Water is drawn across the membrane out of the saline feedwater and into the draw solution. In the second part, the water is separated from the draw solution, leaving desalted water and regenerated chemicals reusable for new draw solution.
Nanofiltration (NF)	This type of membrane will not remove salt ions but does remove other substances with very small particle sizes. Pores are near to or smaller than 0.001 micrometer (μm). NF may be used in pretreatment stages to RO systems to prevent fouling of the RO membrane.
Ultrafiltration Membranes (UF)	This type of membrane will not remove salt ions but is used to remove larger particles and high-weight dissolved organic compounds, bacteria, and some viruses. Pore sizes range of 0.002 to 0.1 μm. UF may be used in pretreatment stages to RO systems.
Microfiltration membranes (MF)	This type of membrane will not remove salt and is used to reduce turbidity and remove suspended particles, algae, and bacteria. MF membranes operate at lower pressures than the other types of membranes and have pore sizes ranging between 0.03 to 10 μm.

Technology	Brief Description
	OTHER TECHNOLOGIES
Ion Exchange	Ion exchange involves the selective removal of charged inorganic species from water by use of an ion-specific resin designed for the feedwater. The surface of the ion exchange resin contains charged functional groups that hold ionic species by electrostatic attraction. As water passes by the resin, charged ions on the resin surface are exchanged for the contaminant species in the water. When all of the resin's available exchange sites have been replaced with ions from the feedwater, the resin is exhausted and must be regenerated or replaced. This process may not reduce TDS but is suitable to soften water and remove specific undesirable chemicals.
Capacitive Deionization	Capacitive deionization is an electrosorption process whereby ions are removed from water by use of an electrical current to force flow. The saline feed flows through electrodes comprised of materials such as carbon-based aerogels. Salt Ions are separated in the process and fresh water is developed. This technology is likely suitable for brackish waters, not sea water.
Freeze Desalination	This process relies on thermodynamic properties of water when changing from liquid to solid state (freezing). Ice crystals form as salt water freezes and the salt is expelled in the process. The process requires further innovation to perfect the process of salt separation (washing) from the frozen fresh water without remixing of the salt occurring. Freezing of water at atmospheric conditions requires generally far less energy input (334 kilojoule per kilogram [kj/kg]) than evaporation (334 to 2,326 kj/kg), making this a still-promising technology.
Source: Committee on Advancing Desalination Technology 2008	

and electrodialysis (ED). A membrane for this purpose is a thin, film-like material that separates two fluids. It is semi-permeable, allowing some particles or chemicals to pass through, but not others. The objective is to allow water molecules to pass through the pores in the membrane and prevent the passage of other substances. In reality, what is filtered out depends on the size of the pores and the type of material used for a membrane. There are several types of membrane separation processes, but the most common processes used for desalination in the water industry are electrodialysis and reverse osmosis.

Considerable research has been invested in graphene, which is described as a one-atom thick layer of graphite. It holds potential as a desalination membrane with greatly reduced energy requirements. This would revolutionize the feasibility of desalination, but the practical application of graphene remains elusive.

Electrodialysis and Electrodialysis Reversal

ED and electrodialysis reversal (EDR) processes require membranes designed for the specific salts they will remove, in particular, membranes that will pass only positive or negative ions. Both ED and ERD use an electrical force to move salt ions through membranes, leaving behind desalinated water. The EDR and ED processes are similar except EDR periodically switches the electrical flow direction (reversal), which decreases fouling (when debris collects on the membranes) and scaling (when dissolved minerals are deposited on the membranes). EDR and ED are used most often used to treat brackish waters, not sea water.

Osmosis (Forward and Reverse)

If two bodies of water with different salinity are separated by a semi-permeable membrane, water will naturally migrate through the membrane from the solution of low salinity to the solution of higher salinity. This process is called *osmosis*.

If the objective is to remove water from the higher salinity solution to provide fresh water, the natural flow of water across a membrane can be reversed by applying pressure on the high-salinity side. This process is called reverse osmosis as illustrated in Figure 10-4. The brackish or seawater feedwater is pumped against a semi-permeable membrane and the water molecules will migrate from the high-salinity side to low-salinity side. Depending on the salinity of the feedwater, this process may need to be repeated until the permeate leaving the low-salinity side is of freshwater quality suitable for drinking. The excess salts left behind, the *reject*, also called concentrate or brine, must be disposed of or processed, as explained in the "Concentrate Management" section below.

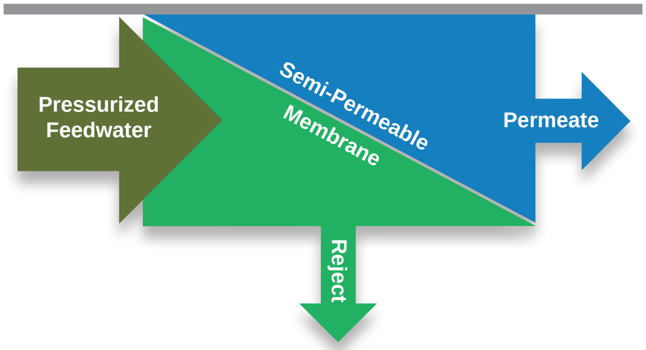
RO processes that use membranes are the most effective commercially available processes for salt removal today, but no membranes result in absolutely pure water. The removal of particles and dissolved chemicals from water can be accomplished through a variety of filtration technologies, while the size of the pores or passages determines the size of particles and chemicals that can pass through. Filters using sand or other granular material are a common technique for removing large particles from water, particularly during drinking-water and wastewater treatment. Filters using membranes with increasingly smaller pores are microfiltration, ultrafiltration, nanofiltration, and reverse or forward osmosis. Examples of the kinds of particles and chemicals removed by filtration techniques are shown in Figure 10-5. Brief descriptions of the various membranes are presented in Table 10-3. For the purpose of removing chemicals via desalination, the focus is on reverse or forward osmosis.

RO membranes typically come in the form of rolls called cartridges. The membrane sheets are sandwiched between spacers to allow feedwater to enter one side of the membrane and permeate water to pass through and leave the other side. The salts are left behind on the feedwater side of the membrane and build up in concentration, becoming brine. An assembly of RO cartridges looks like the photograph on the title page of this chapter.

In general, an energy input is required to use membrane separation. High pressures are needed to get water molecules to pass through the membrane at fast enough rates for functional municipal-scale applications and to overcome the inherent properties of the membrane. The amount of energy required generally increases as the particle size decreases and salt concentrations increase. The energy needed for RO treatment of brackish water is much less than for seawater treatment. Energy is a major factor in desalination, especially seawater desalination, and is discussed further in the "Major Implementation Issues" section of this chapter.

Experimentation is taking place on a two-part process called forward osmosis for drinking water applications, which takes advantage of the natural tendency of water to flow from low salinity to high salinity solutions across a semi-permeable membrane. Brackish or seawater feedwater is placed on one side of the membrane and an artificial solution of higher salinity, called the draw solution, is placed on the other side of the membrane. The water molecules are drawn out of the feedwater through the membrane, rather than pumped, leaving behind the undesirable salts in the brackish or seawater feedwater. A secondary step is needed to separate water from the draw solution, which is artificially high in salinity. The chemicals used for the draw solution are especially chosen to be easily separated from the water to leave behind fresh water and the chemicals that can be reused. Heating is one method of separating water from the draw solution. The expected results of testing of forward osmosis are lower costs and energy use. Two forward osmosis plants using proprietary technology of Modern Water PLC operate in Gibraltar and Oman.

Figure 10-4 Basic Reverse Osmosis Schematic



Among the various membrane separation technologies listed in Table 10-3, RO has matured rapidly over the last few decades and has become the process of choice for many desalination projects. In the United States, it has become the most economic process and is now widely utilized in the Southeast, Southwest, and West to provide an alternate source of supply derived from saline surface and groundwater. Because of its current prevalent position in the desalination arena in California, RO will be the focus of further discussion of desalination in this chapter.

Basic Elements of a Desalination System

Each element of a desalination system, as shown in Figure 10-3, is discussed in this section. The differences among systems that use surface sources (mainly sea water) and subsurface sources (brackish groundwater or groundwater under the direct influence of surface sea water) will be described. Figure 103 is a simplified schematic of a desalination system. Some systems omit one or more of these elements, arrange the elements in a different sequence, or combine various elements into a single component to create a desalination system.

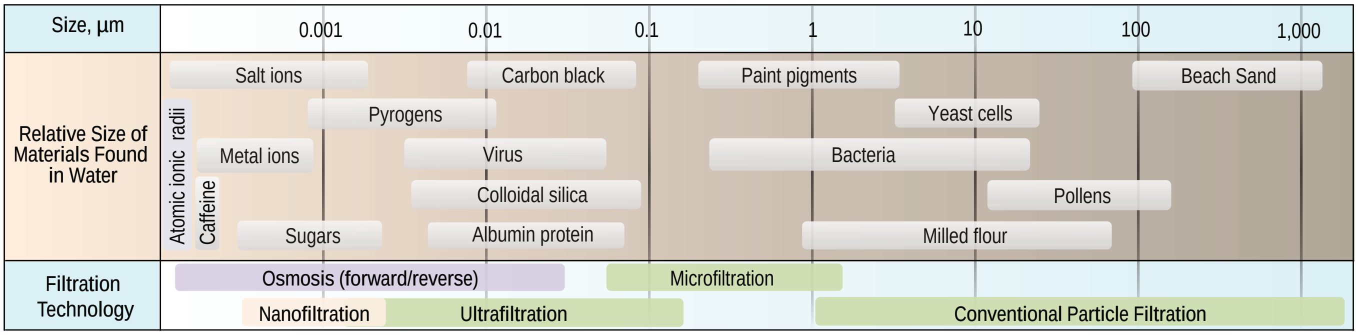
Raw Water

The raw water element is the source water for desalination, also referred to as feedwater. Encompassed in this element is not only the water itself but also the geophysical characteristics of the environment containing the water. The raw water characteristics affect the capability of a particular location to serve as a water source, the design of facilities to accomplish water extraction, and the protection needed for the environment and the raw water for long-term sustainability.

The typical raw water factors for surface water intakes that must be considered include oceanographic conditions, limnology of fresh water bodies, hydrogeology, episodic water quality changes, benthic topography, pollution, and adverse impacts on aquatic species. A surface water source supports an aquatic ecology that is especially susceptible to damage caused by water intakes. Design features can minimize those effects, as described in the next section, but

Figure 10-5 Filtration Spectrum for Desalination

Simplified scale for illustration purposes.
1 micrometer (µm) = a unit of length equal to 1x10^{-6} meter. It is equivalent to 10,000 angstroms.



mitigation measures may be needed to compensate for unavoidable impacts. More settleable (undissolved) solids are generally found in surface waters than in groundwater.

Typical raw water factors to consider for subsurface water intakes include water quality, long-term sustainable withdrawals (safe yield), interaction with surface water, and seawater intrusion impacts. Subsurface intakes, under the ocean floor or at inland near-shore locations, can be a means of using sea water while avoiding surface water intake effects on aquatic organisms. However, they can also cause seawater intrusion into, or depletion of, inland freshwater aquifers.

Intake

The uncertainties in many raw water environments regarding life cycles, food webs, and degrees of abundance or safe yield levels necessary to achieve water sustainability are reasons for an extra level of caution when implementing a water supply project, especially for the open-water intakes. The interface (intake element) between the raw water environment and the municipal water system delivering drinking water plays a crucial role in determining the water supply project's ongoing adverse impacts on the natural habitat.

The intake element consists of the entrance structure where raw water is withdrawn from the source and a pipeline used to route the water to the desalination facility; also, pumps might be used to lift and move the water. As previously mentioned, desalination intakes generally fall into two major categories — surface intakes located above the floor of the source water body, such as the ocean, and subsurface intakes located beneath the floor of a water body or below dry land. It is common to include a pretreatment element, a screen (see Figure 10-6), at the water intake to reduce any adverse impact on aquatic organisms (e.g., larvae sucked through the screen) and avoid taking in undesirable suspended debris or, in the case of groundwater wells, sand or other particles. Discussion of intakes will focus on those associated screens and other devices used to extract water from the environment.

For surface water intakes, also called open intakes, using conventional screen designs causes impingement and entrainment (IE) of organisms. An example of an open seawater intake is shown in Figure 10-6. *Impingement* occurs when organisms sufficiently large to avoid going through the intake screens are trapped against the screens by the force of the flowing source water. *Entrainment* occurs when aquatic organisms enter the intake. Impingement typically

Figure 10-6 Open-Water Intake Element

Photos courtesy of Dianne Gatza, West Basin Municipal Water District

Pre-Installation (60" Length by 13" Diameter)

Continuous Slot Style Screen (Wedgewire, 2 mm slot size)

Raw Water Environment (Ocean, 41" Length by 13" Diameter)

involves adult organisms (e.g., fish, crabs) that are large enough to actually be retained by the intake screens, while entrainment mainly affects aquatic species small enough to pass through the particular aperture size of intake screen. Entrained living organisms are typically not returned to the environmental alive, but instead are destroyed through the intake and pretreatment processes and routed to and combined with the brine waste stream or solid-waste disposal process.

Intake systems may require on-going maintenance, including underwater activities, excavation, dredging, embedment, pipe laying, and anchoring. Intake system maintenance and construction impacts might be minimized by sharing intakes with other facilities, such as power plants, or using existing infrastructure no longer needed for its original use. Modification of existing infrastructure, whether or not it is used for its original purpose, may provide the best benefits and minimize adverse impacts.

Pretreatment

Desalination treatment technologies, especially RO facilities, require a feedwater that meets certain minimum water quality parameters to avoid damage, corrosion, membrane fouling (clogging), impaired performance, or excessive maintenance procedures. Raw water often needs to be conditioned through pretreatment processes to improve water quality before the actual desalination occurs. Intake screens, as previously discussed, are often recognized as the first pretreatment component to prevent debris, weeds, algae, fish, shells, and to the extent feasible other aquatic life and aquatic food sources. Together, the intake and additional pretreatment components remove settleable and suspended particles and entrained organisms, as well as further condition the raw water to enable efficient and effective desalting. Figure 10-5, "Filtration Spectrum for Desalination," shows typical sizes and types of particles, molecules, and organisms along with filtration technologies used to remove them.

Certain source waters are subject to contamination by natural toxins generated by algal blooms (red tides); wastewater discharges (point and non-point); oil and hydrocarbon residues or spills; urban runoff; and agricultural pollution, such as animal wastes, fertilizers and pesticides. This contamination may necessitate robust pretreatment processes to ensure treatment reliability and safety. In the case of RO, pretreatment membranes often require disinfection, use of biocide, and/

or use of other chemical additives to control biological growth, scaling, and corrosion effects. Pretreatment may include other membranes or filtration equipment, such as microfiltration, to improve the efficiency of RO.

Subsurface intakes are a form of pretreatment — the filtering effect on water flowing through sediments in the ground before reaching the intake screen of a subsurface well. Such in-situ filtration removes most of the solids, including food and marine life normally found in surface waters. Subsurface intakes may also be insulated from algal blooms, direct pollution, and other natural or human-generated, system disrupting factors. To avoid IE effects on aquatic life, subsurface intakes from wells under the ocean floor can be used if the right geologic conditions exist.

Figure 10-7 shows a simple drawing of a vertical groundwater well with an intake screen and surrounding engineered gravel-pack envelope to reduce finer particles from migrating through the screen apertures and into the feedwater flowing to the treatment components. The location of the well or intake and the elevation of the screen are important to control the type of water being pumped. Several situations with regard to wells are illustrated in Figure 10-7, with a comparison to an open-water intake. A well in a transition zone could variously take both fresh water and brackish or sea water from the aquifer, creating vulnerability to brackish or seawater intrusion into the freshwater zone. There are several types of subsurface intakes, including groundwater wells (vertical and slant orientations), beach well galleries, and other configurations.

Blending

Blending may occur before or after the desalination treatment element. The water used for blending may be another raw water source or potable fresh water. The purposes for blending include improving either the desalination operation or the aesthetics of the finished water for customer acceptance.

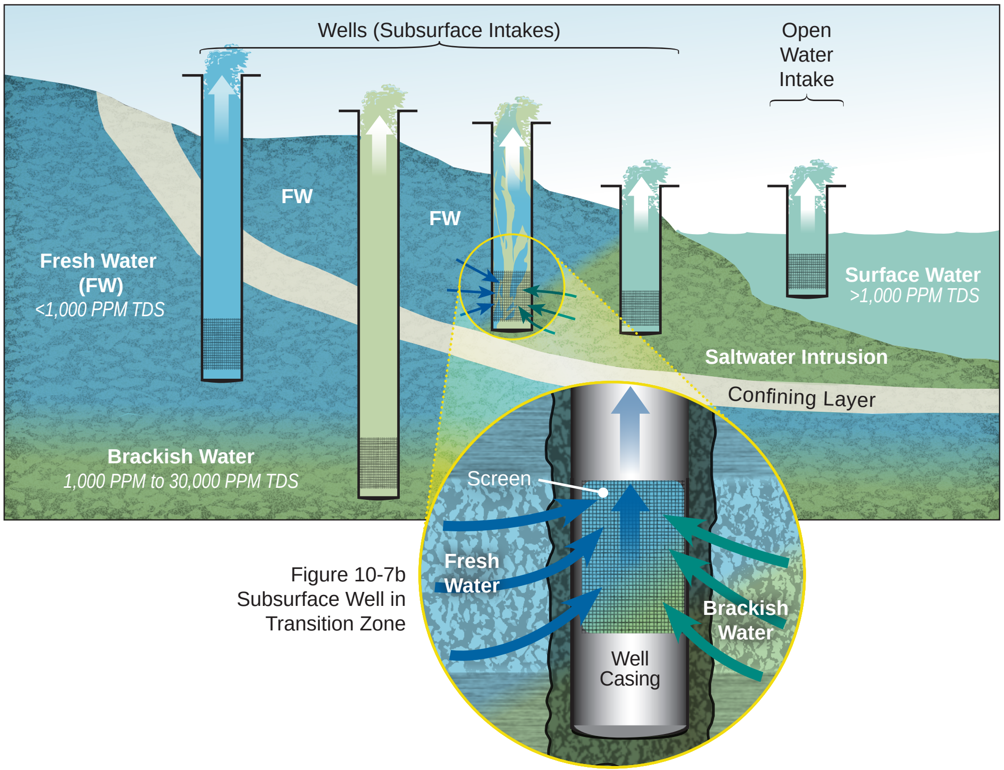
Desalination

The function of the desalination treatment element is the removal of salts and other contaminants not removed in previous treatment processes. It is the core of a desalination system. RO is the most common desalination technology for producing potable water in California. This element also includes pumps to force water through the RO membrane and energy recovery devices. Because of the high pressure needed for RO, desalination treatment is the most energy-intensive element of a desalination system, even with energy recovery devices.

Post Treatment

Permeate water leaving the RO process can be acidic and has little hardness (mineral content). It can be corrosive to pipes and have an unnatural taste and feel. Post treatment may include the addition of chemicals to produce acceptable water from the consumer perspective — some hardness is desirable. Blending with another source of water is another way of adjusting the quality of water for desirable drinking water. Post treatment includes providing the necessary disinfection and other treatments to produce finished water.

Figure 10-7 Cross-Section of Wells and Typical Engineered Gravel Pack



Notes: PPM = parts per million, TDS = total dissolved solids

Finished Water

The finished water element designates the end product of the treatment elements involved in a desalination facility. At this stage, the water may be distributed to customers. If the water meets all requirements, it will be considered safe and reliable for drinking purposes.

Distribution

The distribution element consists of the facilities needed to convey the finished water to the consumer. The facilities are pipelines, pumps, and storage tanks. Most communities considering desalination already have a water distribution system to deliver their existing sources of water. When a new desalination treatment plant is constructed, a pipeline is needed to connect the desalination treatment facility to the existing distribution system. If the source of brackish or sea water is far from the existing distribution system, the connecting pipeline and associated pumps or tanks, often called conveyance or transmission facilities, could be expensive. If the existing distribution system is not designed to receive a large, new flow of water, modifications may be necessary.

Solids and Liquid Waste Disposal

Most, if not all, solids are removed during the pretreatment stage of the desalination process. Typically, surface waters, such as open-ocean supplies, will contain more settleable solids than subsurface water supplies. Surface waters are more susceptible to water quality variation owing to weather, the seasons, or other events, such as La Niña and El Niño, which may require increased costs in operation and more solids removal. Solids include debris, organic particles (e.g., plants or animals), or inorganic particles (e.g., sand). The amount of solids to be removed and the inherent fluctuations in solids of a source water may influence overall intake design and affect feasibility of the plant or particular components. After removal of excess water these solids can often be hauled to a landfill as solid waste.

There are liquid waste streams that may be generated during normal operation and maintenance, such as cleaning screens or equipment and backwashing filters or the desalting membranes. The resulting liquid waste may vary in salt concentration, from raw-water to product-water quality. The liquid waste may contain small suspended particles or cleaning solutions. This liquid waste may be mixed with the brine waste or handled separately, such as when discharging to a municipal wastewater collection system.

Concentrate Management

Concentrate is defined as the resulting byproduct from the various separation processes used in desalination. The terms reject, brine, and wastewater are commonly used to refer to the concentrate generated and managed at desalination facilities. The term brine is commonly used in place of concentrate, as in brine management. Depending on the source water, desalting technologies, and the process configurations employed, the concentrate will be of a specific character that must be dealt with as a product or a waste.

There are several methods to manage and dispose of brine. The salinity of brine is greater from seawater desalination than from brackish water desalination. The quality of the brine and the location of the desalination facility affect the available management options. The main options are waste discharge to a surface water (especially into the ocean), discharge into a dedicated brine line (combined with other saline wastes for possible further treatment and disposal), subsurface discharge by injection into a deep well-aquifer, land application by irrigation, solar evaporation ponds, and thermal evaporation to produce solids suitable for landfill disposal. While brine is usually managed as a waste, the characteristics of the brine may make it suitable for processing into usable byproducts. If brine is managed by a process that reclaims the salt and other byproducts, it is said to be a *zero-discharge process*.

Concentrate management is an important issue discussed later in this chapter.

Desalination in California

Desalinated water currently is one of California's lowest volume drinking-water supplies. For most California water suppliers, desalination is neither practical because of a lack of suitable saline source water nor is it economically feasible because more cost-effective water supply alternatives are available. However, desalination is being considered more frequently as water supplies become constrained, more local supplies are sought to augment imported water, and desalination technologies improve and become more cost-effective. Additionally, with submittal of their 2010 urban water management plans (UWMPs) and the State integrated regional water management (IRWM) funding program plans, California water suppliers are now required to evaluate desalination as a method to meet their water resource management goals and objectives.

Some of these evaluations have become high-profile and contentious, but they have resulted in very important water supply reliability and sustainability discussions, as well as concrete steps to plan, design, and construct desalination projects.

History of Desalination in California

Water agencies began considering desalination in California in the late 1950s. The first major facilities involving desalination came on line in the 1960s, primarily to support cooling processes at power plants, such as Pacific Gas and Electric Company's Morro Bay and Moss Landing facilities. Since then, desalinated sea water has been successfully integrated into industrial and non-potable uses at multiple coastal sites.

In the 1960s, it was envisioned that desalination could play an increasing role in California's water supply and power generation needs. In the 1960 transmittal letter for DWR Bulletin 93, titled "Saline Water Demineralization and Nuclear Energy in The California Water Plan," DWR Director Harvey O. Banks wrote to Governor Edmund G. Brown and members of the Legislature of the State of California:

> Although no saline water demineralization technique yet developed can compete with the costs of large scale development of natural sources of water in California, it is probable that saline water conversion plants will have a definite place in the water program. The Department of Water Resources will continue to take a definite and continuing interest in those areas of research and development that may have promise of eventually producing low cost converted water.

Desalination technologies were extensively tested in California in the late 1950s and early 1960s to address water supply issues. Experiments and pilots testing of different technologies and projects were conducted using both ocean and underground source water (California Department of Water Resources 1960, 1963).

Data collected on water desalination in California for 2006 and 2009 are shown in Tables 10-4 and 10-5. These data are for projects whose primary purpose is salt removal for potable use. Desalination technology for pollutant removal, as in wastewater treatment, or for industrial water use, is not included.

Brackish Groundwater

Coalinga was the site of the first operational brackish groundwater desalination facility in California. It operated from 1959 to the early 1960s, reducing groundwater salinity from 2,100-2,400 to under 500 mg/L (California Department of Water Resources 1963). This Coalinga site now receives surface water from the U.S. Bureau of Reclamation (USBR).

In the 1970s and 1980s, DWR tested the feasibility of desalinating agricultural drain water to address San Joaquin Valley drainage issues. RO testing facilities were constructed in Firebaugh and Los Banos. These projects assessed biofouling issues and implementation requirements. Ultimately, because of agricultural drainage issues identified at Kesterson Reservoir, the project was discontinued in 1989. DWR continues to be involved with efforts to reduce salt accumulation

Table 10-4 Summary of California Desalting, 2006

Feedwater Source	In Operation		In Design and Construction		Planned	
	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY
Groundwater	14	46,200	5	31,100	8	56,300
Seawater	4	1,150	1	250	9	187,100
Total	**18**	**47,350**	**6**	**31,350**	**17**	**243,400**
Cumulative			**24**	**78,700**	**41**	**322,100**

Notes:

Capacity in acre-feet per year.

Data courtesy of California Department of Water Resources Exhibit-H1, California Perspective on Desalination Meeting, Jeanine Jones, May 24, 2006.

in soil and aquifers throughout the state by investigating desalination technologies for agricultural tail water. Tail water, or specifically drainage water from irrigated lands, may be put to beneficial use through desalination. For more information about desalination and other advanced treatment related to agricultural practices and water use, visit http://www.water.ca.gov/drainage/.

During and after the severe drought of the early 1990s, water agencies launched large-scale conservation and water recycling programs and began to consider additional local resources, including desalination. Rapid advances in RO membrane efficiency, energy recovery technology, and innovative process designs also occurred during the 1990s. Several communities constructed brackish groundwater desalination facilities in the 1990s. An example is the City of Tustin, which completed its groundwater desalter in 1989. Over a dozen other facilities were constructed and began operation by the end of the decade. These facilities were primarily located in the near-coastal and inland areas of the greater Los Angeles area.

Data for groundwater desalination projects in 2006 and 2009 are shown in Tables 10-4 and 10-5. Capacities of operational facilities were tracked, but actual production amounts were not. The source water for these groundwater projects is assumed to be of brackish water quality.

Sea Water

There are approximately 1,100 miles of coastline in California, making sources of saline waters accessible in many locations. The first ocean desalination facility in California was constructed in San Diego in 1962, but intake issues involving kelp and sea grass caused operational challenges. The U.S. Navy also began early California desalination operations and research at Port Hueneme (California Department of Water Resources 1963).

In the 1970s and 1980s, several communities completed potable water desalination facilities, but for various reasons, each of those projects operated only briefly. Decommissioned or non-operational facilities are or were in San Simeon and Santa Barbara. Marina Coast Water District has a standby desalination facility. Reasons cited for ceasing desalination include operational expense and challenges, availability of less expensive supply, and end-of-drought conditions.

Table 10-5 Summary of California Desalting, 2009

Feedwater Source	In Operation		In Design and Construction		Planned	
	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY
Groundwater	20	82,200	4	30,000	3	57,300
Seawater	6	1,700	3	50,800	13	257,000
Total	**26**	**83,900**	**7**	**80,800**	**16**	**314,300**
Cumulative			**33**	**164,700**	**49**	**479,000**

Source: California Department of Water Resources 2009.

Note: Capacity in acre-feet per year.

In addition to Morro Bay and Moss Landing, desalination for power plant operation was implemented in 1960 at Southern California Edison Mandalay steam station (now Reliant Energy Mandalay), in Ventura County and later at the Contra Costa Power Plant on the San Joaquin River in Contra Costa County (California Department of Water Resources 1963).

By the late 1990s, the costs of seawater desalination became competitive with alternative new supplies in some areas. To evaluate its potential, water agencies conducted numerous feasibility studies and several pilot projects. The pilot projects — miniature desalination plants used to develop design parameters — included research into alternative treatment processes, baseline environmental conditions, innovative seawater intakes, public outreach, and other pre-construction issues. Many of these studies were partially funded through State and federal grants. The pilot projects represent a significant investment in the future of desalination in California.

Data for seawater desalination projects in 2006 and 2009 are shown in Tables 10-5 and 10-6. Actual production data for those years were not reported. All of the operational projects extracted water either directly from the ocean or from groundwater wells adjacent to the ocean. The salinity of the water from these wells was probably brackish rather than seawater quality.

Current Desalinated Water Use in California

Water desalination projects currently active as of 2013 in California and their status are shown in Table 10-6. The locations of these projects are shown in Figure 10-8. Actual production of the desalinated water is provided for 2010. These data are for projects with the primary purpose of salt removal for potable use. Projects classified as proposed are in some stage of planning, from conceptual to final feasibility, and the time frame for implementation may be as much as a few decades away. Pilot studies may be taking place for proposed projects. For greater precision, “ocean water” as a water source replaces “sea water” found in previous reporting. Ocean water includes subsurface intakes of groundwater recharged primarily by the ocean. The brackish surface water project in planning would take water from the San Francisco Bay.

Table 10-6 Summary of California Desalting, 2013

General Source Water Designation	In Operation			In Design and Construction		Proposed	
	NO. OF PLANTS	2010 PRODUCTION	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY	NO. OF PLANTS	ANNUAL CAPACITY
Brackish groundwater	23	79,812	139,627	3	9,050	17	74,629
Brackish surface water	0	0	0	0	0	1	22,403
Ocean water	3	130	562	1	56,007	15	381,791
Total	**26**	**79,942**	**140,189**	**4**	**65,057**	**33**	**478,823**
Cumulative	**--**	**--**	**--**	**30**	**205,246**	**63**	**684,069**

Note: Production and capacity are in acre-feet per year.

Current Brackish Groundwater Desalination

Groundwater desalting plants are generally designed to reclaim groundwater of impaired quality and are located in urban areas, from the San Francisco Bay Area to San Diego. Currently, there are at least 23 operating groundwater desalting plants, 22 of which are located in Southern California and one plant in the San Francisco Bay Area. Plant capacities range from 0.2 to 15 million gallons per day (mgd) (226-16,800 acre-feet per year (af/yr.)).

The source groundwater quality ranges significantly, depending on the project. The primary constituent typically targeted for removal by these projects is TDS, but nitrate removal may also be an objective. One of the key constraints for groundwater desalination is brine disposal. Existing facilities are located either near a brackish or saline water body or near a brine disposal line, such as the Inland Empire Brine Line (also known as the Santa Ana Regional Interceptor (SARI)). Waste in the SARI line is treated with other wastewater and discharged into the ocean. These regional interceptors enable sustainable disposal of brine wastes. Several additional lines are planned for Southern California, and constructing them will be a key component of the expansion of brackish groundwater desalination.

As it now stands and as groundwater desalination expands in the future, groundwater overdraft issues will be an integral consideration. At this time, the majority of groundwater desalination occurs in basins with some degree of groundwater management or adjudication. This enables groundwater desalination to be strongly linked to other groundwater uses and recharge activities, IRWM, and local supply.

Current Seawater Desalination

Current seawater desalination reported in this section is limited to those municipal water-supply facilities in operation or in construction in the state. There are three active desalination facilities providing municipal water. These are relatively small systems at Santa Catalina Island (Avalon), San Nicolas Island (U.S. Navy Air Strip), and Marina (Fort Ord) with a combined annual capacity of 562 acre-feet (af). Only the Santa Catalina Island Desalination Facility reported production for year 2010 (128 af). Because of operating expenses, potable seawater desalination facilities often operate intermittently and may represent emergency and standby sources of water. An example is the Marina Desalination Facility, which is in operational-standby/emergency status with no reported production for 2010. There are two existing but inactive seawater desalination facilities at Morro Bay and Santa Barbara. The Morro Bay Desalination Facility houses two treatment trains, one for sea water and another for brackish groundwater. The Morro Bay Seawater Unit was listed as inactive for 2010, but the brackish groundwater treatment unit was and continues to be active. In the past, the Sand City Desalination Facility in Monterey County was listed as a seawater facility but now is listed with existing brackish groundwater facilities, based on system design.

There is currently one seawater desalination facility under construction by Poseidon Water (Poseidon) at Carlsbad. The Carlsbad Seawater Desalination Facility is designed to deliver 50 mgd (56,007 af/yr.) and is being constructed and operated as a public-private partnership. When completed, the Carlsbad facility will be the largest ocean-water desalination plant in the Western Hemisphere. The San Diego County Water Authority has a 30-year water purchase agreement with Poseidon. Poseidon will own and operate the plant. San Diego has the option to buy the plant after 10 years and to take ownership after 30 years, at essentially no cost. Poseidon has also designed and started to construct a 10-mile pipeline to deliver the desalinated ocean water; the pipeline will be publicly owned and operated. Deliveries are scheduled to begin in 2016. More about the project may be found at http://carlsbaddesal.com.

Future Desalination in California

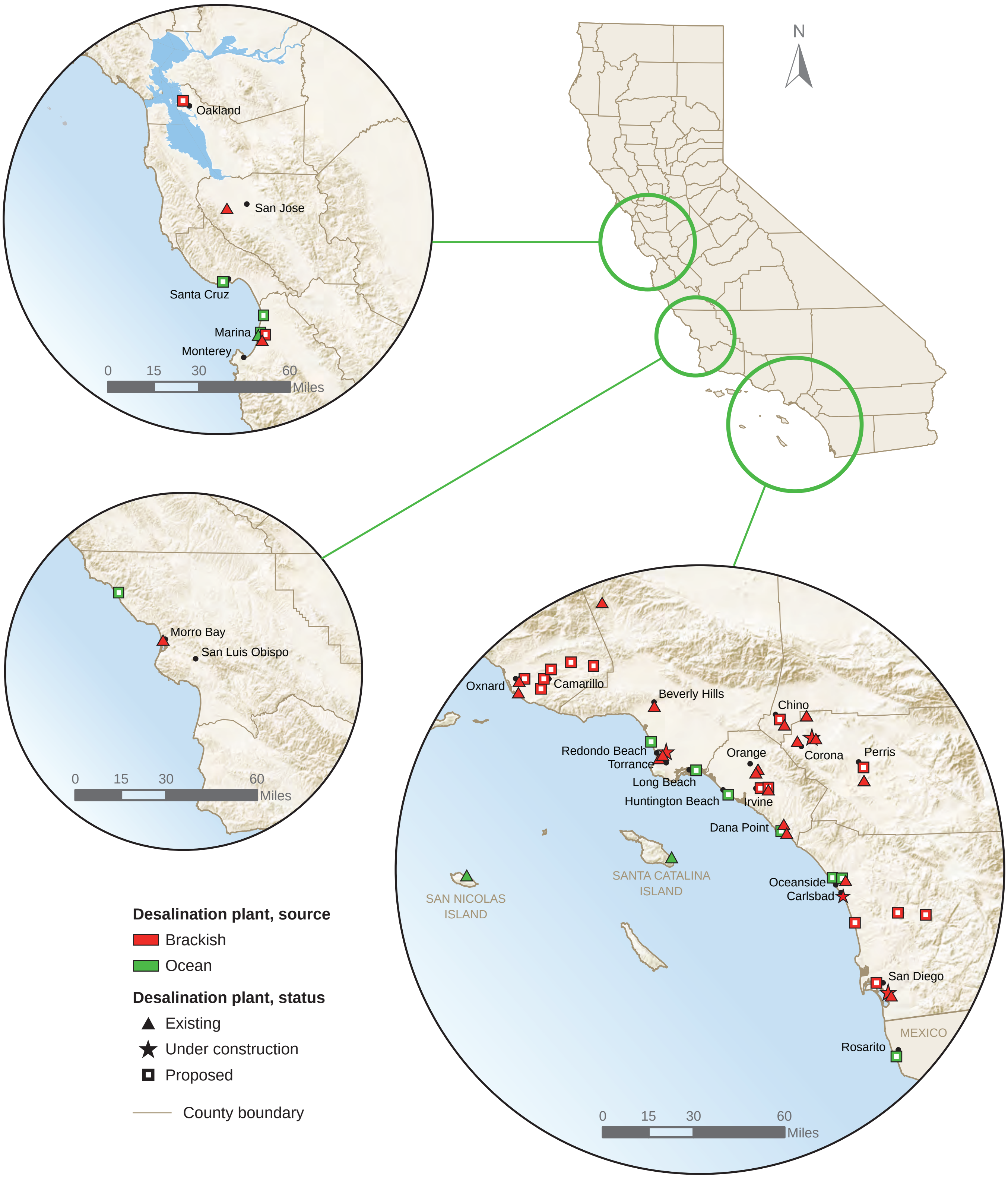
There are approximately 17 proposed brackish groundwater plants, including existing plant expansions scheduled to occur before 2030. Most of these proposed facilities are at the final feasibility phase or in advance planning and design. Proposed brackish groundwater facilities have the potential to increase municipal water supplies in California by an estimated 74,600 af/yr. (66.6 mgd).

There is one active brackish surface water facility, the Bay Area Regional Desalination Project (BARDP), being planned in the San Francisco Bay Area with a reported potential design capacity of 22,403 af/yr. (20 mgd). The Marin Municipal Water District (MMWD) has planned a desalination project that could use brackish surface water; however, the MMWD has placed a hold on any further implementation of the project as of the end of 2013, so it is considered inactive and not included in the proposed project data.

Fifteen ocean desalination projects are under consideration with an estimated potential capacity of 382,000 af/yr. (341.0 mgd). There are two seawater desalination projects included in the planning that would be located in Mexico, where desalinated water would cross the border into California just west of San Ysidro. The projects involve raw water intakes and desalting works in the Mexican city of Rosarito Beach, pipelines crossing into the United States, and final treatment of the desalted ocean water in California to meet the State's drinking water standards. Each plant has a potential capacity of 50 mgd (56,007 af/yr.).

Many sources of data were compiled to assess the current status of desalination projects. Many projects previously reported as proposed or even in operation were found to be currently inactive

Figure 10-8 California Municipal Desalination Facilities



or no longer proposed. It cannot be assumed that current proposed projects will be or even could be implemented by any given date. UWMPs required for major water suppliers were an important source for evaluating current project status. In some cases, lead agencies were contacted to gain better status information on proposed and existing facilities.

Legal and Regulatory Framework of Desalination in California

Water supply projects utilizing desalination technologies are subject to State statutes and regulations, as well as local laws. Over 20 permitting authorities have been identified for the planning, management, and operation of desalination facilities.

Planning and Management of Water Resources

A general policy framework for desalination in California was set forth in 1965 in the Cobey-Porter Saline Water Conversion Law (Water Code Sections 12946-12949.6). The people of the state have a primary interest in development of economical desalination processes that could:

- Eliminate the necessity for additional facilities to transport water over long distances, or supplement the services provided by long-distance facilities.
- Provide a direct and easily managed water supply to assist in meeting the growing water requirements of the state.

DWR is directed to find economic and efficient methods of desalination so that desalted water (e.g., drinking or other water) may be made available to help meet the growing water requirements of the state.

Protecting Water Quality

The brackish water and seawater environments are important to preserve and protect. Utilizing desalination techniques requires compliance with State and federal laws governing water quality.

The federal Clean Water Act (CWA) established a permit system known as the National Pollutant Discharge Elimination System (NPDES) to regulate point sources of discharges into navigable waters of the United States.

The Porter-Cologne Water Quality Control Act (Porter-Cologne Act) is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the state's water. This act requires the adoption of water quality control plans by the State Water Resources Control Board (SWRCB) and the state's nine regional water quality control boards (RWQCBs) for watersheds within their regions. These plans designate beneficial uses for each surface water and groundwater body within the state, water quality objectives to protect these uses, and implementation measures.

The Porter-Cologne Act also establishes a permitting system for waste discharge requirements for point and nonpoint sources of discharges to both surface water and land. The U.S. Environmental Protection Agency (EPA) has delegated authority to the RWCQBs to issue NPDES permits.

These permits are issued in tandem with waste discharge requirements. These permits are required for disposal of brine from desalination facilities. The permits incorporate provisions in the water quality control plans, including protections of the brackish-water and seawater aquatic ecosystems.

Protecting Drinking Water

Safe drinking water depends on protection of the surface and underground sources of water from pollution, as well as maintaining appropriate water treatment to remove harmful chemicals and pathogens before they enter the drinking water supply. The primary agency responsible for regulating drinking water systems is the California Department of Public Health (CDPH). However, the SWRCB and the RWQCBs also have an important role.

The federal Safe Drinking Water Act (SDWA) directed the EPA to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of constituents. Local water suppliers are required to monitor their water supplies to assure that regulatory standards are not exceeded. The finished water of a municipal desalination facility must meet these standards. Under the SDWA, the State is required to develop a comprehensive Source Water Assessment Program that will identify the areas that are used to supply public drinking water systems, inventory possible contaminating activities, assess water system susceptibility to contamination, and inform the public of the results. This assessment could include surface and subsurface sources for desalination projects.

The CDPH has primary responsibility for implementing the SDWA in California, as well as provisions in State law. In 1999, CDPH issued the Drinking Water Source Assessment and Protection (DWSAP) Program (revised in 2000). The program, primarily voluntary on the part of water agencies, involves their performing source water assessments. As of 2003, between 82 and 97 percent of surface water and groundwater sources were covered by assessments. There is no requirement that these assessments be updated. The implementation measures to protect source waters are a mix of voluntary and mandatory actions by local water and land use planning agencies and the regulatory programs of county health departments, CDPH, SWRCB, and the RWQCBs.

The primary safeguard against pollution of source waters is the RWQCBs, through their permitting systems for discharges and other nonpoint-source control programs. These permits are based on protecting the beneficial uses of water bodies specified in water quality control plans. By default, bodies of surface and groundwater in California are considered suitable or potentially suitable for municipal or domestic water supply and are classified as MUN in water quality control plans (SWRCB, Resolution No. 88-63). One of the exceptions is water bodies where the TDS exceeds 3,000 mg/L, because these saline water bodies are not reasonably expected by RWQCBs to supply a public water system. However, RWQCBs are to assure that the beneficial uses of municipal or domestic supply are designated for protection wherever those uses are presently being attained. With a few exceptions, RWQCBs have not designated for protection brackish groundwater or ocean water sources currently being treated with desalination for municipal water supply.

Environmental Laws for Protecting Resources

The California Environmental Quality Act (CEQA) is a California statute passed in 1970 to institute a statewide policy of environmental protection. CEQA directly followed passage of the federal National Environmental Policy Act. CEQA does not directly regulate land uses or other activities. CEQA requires State and local agencies within California to adopt and follow protocols of analysis and public disclosure of environmental impacts of proposed projects and carry out all feasible measures to mitigate those impacts. CEQA makes environmental protection a mandatory part of every California State and local agency's decision-making process.

Applying CEQA requirements equally among water supply alternatives (e.g., fresh, brackish, sea, and recycled water) is essential for determining the best water-supply project to implement.

Protecting Endangered Species and Habitats

There are federal and State laws to protect endangered species of wildlife and their habitats. These laws are encountered with desalination intakes and brine discharges.

Federal Endangered Species Act. The federal Endangered Species Act (ESA) is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery. Under the ESA, an *endangered species* is one that is in danger of extinction in all or a significant part of its range, and a *threatened species* is one that is likely to become endangered in the near future. The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service (NMFS).

Federal agencies, in consultation with the USFWS or NMFS, must ensure that their actions do not jeopardize the continued existence of the species or habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions, including issuance of federal permits, such as the dredge and fill permit required under Section 404 of the CWA, trigger ESA requirements that stipulate the project proponent must demonstrate no feasible alternative exists consistent with the project goals that would not affect listed species. Mitigation is required if impacts on threatened or endangered species cannot be avoided.

The ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. *Take* is broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in taking listed species. The permit normally contains conditions to avoid taking listed species and to compensate for habitat adversely affected by the activities.

California Endangered Species Act. The California Endangered Species Act (CESA) is similar to the federal ESA. Listing decisions are made by the California Fish and Game Commission. All State lead agencies are required to consult with the California Department of Fish and Wildlife (DFW) about projects that affect State-listed species. DFW is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless overriding social or economic conditions make such alternatives infeasible. For projects causing incidental take, DFW is required to specify reasonable and prudent measures to minimize take. Any take that results from activities that are carried out in compliance with these measures is not prohibited.

Many California species are both federally listed and State listed. CESA directs DFW to coordinate with the USFWS and NMFS in the consultation process, so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Regulatory and Permitting Agencies

Most of the primary agencies that exercise regulatory and permitting authority with regard to water supply facility planning, construction, and operation, and that could exercise authority over construction and operation of desalination facilities in California, are listed in Table 10-7 along with their primary role. There is a current effort within the State agencies to improve the permitting process of projects along the California coast, and all stakeholders recognize the need to formally adopt a coordinated permitting process.

Regulations for Water Use Efficiency

The State Urban Water Management Planning Act requires urban water suppliers that serve more than 3,000 customers or more than 3,000 af/yr. to prepare and adopt UWMPs. The plans must contain several specified elements, including identifying feasible desalination water supply alternatives. The act requires water suppliers to review and update their plans at least once every five years.

Potential Benefits

Desalination can improve a water supplier's ability to provide safe and reliable drinking water to its customers. When adopted as part of a diversified resource portfolio, desalination can provide many potential benefits, including:

- Expanding local water supply.
- Improving overall supply reliability by diversifying resource portfolios.
- Providing emergency supplies during drought periods and after extraordinary events.

Expanding Local Water Supplies

For California communities with limited water supplies and viable saline water sources, both brackish groundwater and seawater desalination can provide a local water source. Development of local water resources reduces dependence on imported supplies (e.g., State Water Project or Colorado River water) and vulnerability to water supply reductions that result from drought, climate change, or disruption of imported water. This enables water suppliers to have more confidence in their water supplies, supports water supply reliability and community planning, and reduces the potential for water-related conditions beyond the local suppliers' control.

Table 10-7 Regulatory Roles for Municipal Desalination Projects

Organization	Role
FEDERAL	
National Marine Fisheries Service	Provides Endangered Species Act (ESA) Section 7 consultation to address potential incidental take of federally listed species.
National Marine Sanctuaries	Issues Research Permit or Authorization, Education Permit, or Authorization Permit. Reviews other State and federal permits (including U.S. Army Corps of Engineers, RWQCB 401, and NPDES permits) with activities/discharges into waters and wetlands.
U.S. Army Corps of Engineers (USACE)	Issues Clean Water Act Section 404 permit for discharge of dredge/fill into waters of the United States, including wetlands. Issues Rivers and Harbor Section 10 permit for activities, including the placement of structures, affecting navigable waters. Issues permit for survey activities, such as core sampling, seismic exploratory operations, soil surveys, sampling, and historic resources surveys, under Nationwide Permit No. 6, Survey Activities. Issues permit for activities related to the construction or modification of outfall structures and associated intake structures where the effluent is authorized by NPDES under Nationwide Permit No. 7, Outfall Structures and Associated Intake Structures.
U.S. Coast Guard	Provides consultation on Coastal Commission Coastal Development Permit. Provides consultation on USACE Section 10 Permit.
U.S. Environmental Protection Agency	Issues permits for injection wells used for brine disposal by deep well injection
U.S. Fish and Wildlife Service	Provides Endangered Species Act (ESA) Section 7 consultation to address potential incidental take of federally listed species. Provides comments to prevent loss of and damage to wildlife resources under the Fish and Wildlife Coordination Act.
Other Entities	Specific permits or consultations may be required on a project-specific basis.
Federal Energy Regulatory Commission Tribes NOAA	
STATE	
State Water Resources Control Board, Regional Water Quality Control Board	NPDES, General Permit For Storm Water Discharges Associated With Construction Activity. NPDES Permit in accordance with the Clean Water Act (CWA), Section 402. Water Quality Certification in accordance with CWA Section 401. Waste Discharge Requirements (WDR) per Porter-Cologne Water Quality Control Act.

Organization	Role
California State Lands Commission	Issues Land Use Lease (Right-of-Way permit) for right-of-way across State lands.
California Department of Fish and Wildlife (DFW)	Issues Incidental Take Permits where a State-listed candidate, threatened, or endangered species under California ESA may be present in the project area and a State agency is acting as lead agency for CEQA compliance.
California Coastal Commission (CCC)	Issues a Coastal Development Permit within the Coastal Zone, excluding areas where local jurisdictions have approved Local Coastal Plans in place.
California Department of Public Health (CDPH)	Issues a permit to operate a public water system.
California Department of Parks & Recreation Office of Historic Preservation	Consults with project applicant, appropriate land management agencies, and others regarding activities potentially affecting cultural resources, under Section 106 of the National Historic Preservation Act.
California Department of Transportation	Issues Encroachment permits for State roads and highways.
Other Entities	Specific permits or consultations may be required on a project-specific basis.
California Independent System Operator (ISO) California Energy Commission	
REGIONAL AND LOCAL	
Local Lead Agency	Approves CEQA documentation.
County and City Departments, including but not limited to Planning, Transportation, Public Works, Environmental Health, Building, and various utilities (electrical, gas, solid waste, wastewater, water, and stormwater)	Issue use permits. Issue Coastal Development Permit / Exemption for development within the Coastal Zone where City or County has jurisdiction through Local Coastal Program Consistency. Issue encroachment permits for activities within rights-of-way. Issue grading permits; issue electrical permits; issue erosion control permits; issue building permits; issue right-of-way permits. Issue haul route permits; issue connection permits. Approves hazardous materials management plan. Issues well permits, where jurisdiction is granted.
Air Pollution Control District	Issues permit to construct; issues permit to operate.
Other Entities	Specific permits or consultations may be required on a project-specific basis.
Adjudicated basin watermaster Groundwater management	Adjudicated basin watermaster Groundwater management

Notes:

CEQA = California Environmental Quality Act, ESA = Endangered Species Act, NOAA = National Oceanic and Atmospheric Administration, NPDES = National Pollutant Discharge Elimination System, RWQCB = Regional Water Quality Control Board.

Because desalination makes use of saline water sources that otherwise are unused and unusable, desalinated supplies represent a "new" supply source to the state.

Improving Water Supply Reliability

Improving water supply reliability can be accomplished by having supplies that are consistently available or by having a diverse water supply portfolio, that is, multiple sources from which water can be obtained. A water supplier with a diverse water supply portfolio has more flexibility, particularly when managing how it supplies water to its customers under changing conditions. Changing conditions can include customer demands, available supplies, or environmental or climatic conditions. For example, if surface water supplies are constrained, having groundwater, recycled water, and/or desalinated water available enables water suppliers to look at cost, system conditions, and other factors involved in meeting demands.

Both brackish groundwater and seawater desalinated supplies can be a highly reliable component of a water supply portfolio because they tend to be less influenced by changing conditions than other sources.

Providing Emergency Supply

Some communities have established desalinated water as an emergency supply option. Because desalinated supplies tend to have a higher unit cost than other sources, these water suppliers maintain desalination facilities on a stand-by basis and only operate them when other sources of water are not available. This approach enables water suppliers to maintain a base level of water supply in times of extreme shortage, but it can require higher capital and maintenance costs than other sources. For suppliers in water-constrained regions, this approach can provide needed flexibility and supply. For example, Marina Coast Water District and the City of Morro Bay maintain standby seawater desalination facilities.

Mobile water treatment units, including those capable of desalting sea or other saline waters, can provide emergency potable water supplies for small towns and communities during droughts, emergencies, or unplanned disruption of their primary water supplies. Unlike permanent desalination plants, temporary mobile units can be commissioned, installed, and put into production relatively quickly, provided environmental and other concerns are addressed. They can also be quickly moved or decommissioned, as necessary. A white paper prepared in 2009 by DWR (BenJemaa 2009) on mobile desalination units is available on the DWR's Desalination Web page: http://www.water.ca.gov/desalination/.

Potential Costs

While technological improvements over time have reduced the cost of desalination, it still remains one of the most expensive options for water supply. Nonetheless, it is typically the case that, in areas where a new water supply is being sought, many of the low-cost alternatives have already been implemented. The costs are rising for new conventional supplies and expanded water conservation and recycling. Desalination offers benefits of reliability during droughts and resiliency during interruptions of other supplies that may offset the higher cost. Within the context of overall water management objectives, desalination is becoming a more feasible alternative despite cost considerations.

Each component of the desalination system shown in the general schematic of Figure 10-3 has capital and operational costs associated with it. The cost of desalination is especially influenced by the type and salinity of source water, the available concentrate disposal options, the proximity to potable water distribution systems, and the availability and cost of power. The cost of desalination treatment is also influenced by size. The unit cost of construction of a 50 mgd membrane desalination plant may be half the cost of a 1 mgd plant. Combined capital and operating costs of existing groundwater desalters in Southern California range from $600 to $3,000 per acre-foot. Recent estimates for proposed large-scale seawater desalination projects in California range from about $1,600 to $3,000 per acre-foot. Pre construction planning costs, including feasibility evaluations, pilot studies, and environmental monitoring, can also be considerable for seawater desalination. Caution should be exercised when using reported values of costs, including the costs above, because of site-specific variation of costs and the varied assumptions incorporated into reported costs. Often, costs of various system components shown in Figure 10-3 are not included.

A significant cost of desalination is the cost of energy. This is illustrated in Figure 10-9, showing the distribution of costs by type of cost for a seawater RO plant with conventional pretreatment. Energy constitutes 36 percent of total capital and operational costs. Much of the research on desalination is focused on technology that can reduce energy needs.

Major Implementation Issues

The major implementation issues associated with desalination as a viable resource management strategy can be placed in the following categories:

- Permitting and Regulatory framework.
- Energy use and sources.
- Climate change.
- Funding.
- Intakes and ocean and freshwater ecosystems.
- Concentrate (brine) management.
- Subsurface extraction.
- Planning and growth.

These implementation issues are discussed in the following sections.

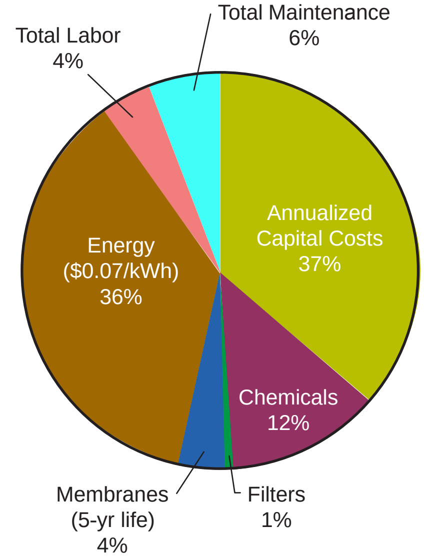
Permitting and Regulatory Framework

Two permitting and regulatory issues have been identified: coordination of permitting and protection of source waters used for municipal drinking water. As described in the “Legal and Regulatory Framework of Desalination in California” section above, there can be over 30 federal, State, and local agencies that have some regulatory or permitting authority over desalination projects. While any single project may not have to encounter all of these, the regulatory process can be formidable and lengthy. A need for coordination among agencies has been identified (California Department of Water Resources 2003).

One effort to improve coordination was the creation of the Seawater Desalination State Interagency Workgroup in 2012. It has been proposed that the State permitting agencies establish an agency priority sequence for permit reviews to improve coordination at the project level.

A key element in the protection of sources of drinking water is the designation of water bodies for this beneficial use in water quality control plans adopted by the RWQCBs and SWRCB. As described in the "Legal and Regulatory Framework of Desalination in California" section, brackish and seawater sources used for municipal drinking water after desalination are not designated for this beneficial use. Desalination is very effective in removing constituents in water that could be harmful to human health; however, desalination does not remove all chemicals, including some chemicals with known health effects. General concern is circulating among water quality management regarding the thousands of manufactured chemicals introduced into the environment, with little or no testing for human or environmental effects. These chemicals are commonly referred to as chemicals of emerging concern. A regulatory strategy has not been developed to prevent potentially harmful chemicals of emerging concern or other chemicals of known health effects from occurring in brackish or seawater sources of drinking water. Source water assessments could be used to identify zones of protection for saline waters used for drinking water, assess the potential contaminant activities, and identify chemicals that desalination cannot be expected to remove. Water quality control plans could designate zones in saline waters for protection as sources of drinking water after desalination and include appropriate regulatory measures, such as water quality objectives or implementation programs, to provide reasonable protection for this use.

Figure 10-9 Annual Cost Breakdown in 50 mgd Seawater RO Plant with Conventional Pretreatment



Source: Committee on Advancing Desalination Technology 2008

Notes: kWh = kilowatt hour, mgd = million gallons per day, yr = year

Energy Use and Sources

Energy use is a significant factor in water desalination projects for reasons of costs and environmental impacts of energy generation. Each of the elements in a desalination system, as shown in Figure 10-3, entails energy use, but the most significant energy use is in the treatment process where the salt ions are removed. Generally, the energy requirement of RO desalination is a direct function of the salinity level and the temperature of the feedwater source. Given similar operating conditions and treatment plant parameters, brackish water desalination is usually less energy intensive, and hence less costly, than seawater desalination. Several summary reports on desalination and energy intensity of water supply and treatment systems have been published that report data on the energy intensity of desalination processes. Drawing from an array of studies (Klein 2005; GEI Consultants/Navigant Consulting 2010; Wilkinson 2000; Cooley and Heberger

2013; Cooley and Wilkinson 2012; WateReuse Desalination Committee 2011), it has been determined that energy intensity for seawater desalination ranges between 3,300 kilowatt hour per acre-foot (kWh/af) and 5,900 kWh/af, and for brackish water desalination between 1,000 kWh/AF and 2,700 kWh/AF.

To compare the energy intensity of desalinated water supplies with the energy intensity of other water supplies provided in each regional report, a factor for water treatment would have to be added to the energy intensities of "raw water" provided in the regional reports (see Volume 2). The energy of conventional water treatment is typically between 50 kWh/af and 650 kWh/af, depending on the capacity of the treatment plant and the quality of incoming raw water (Cooley and Wilkinson 2012; WateReuse Desalination Committee 2011).

For a seawater desalination RO facility, 28 percent to 50 percent of total annual costs, including annual capital recovery costs, are devoted to energy consumption (WateReuse Desalination Committee 2011). However, improvements in RO membranes and the incorporation of energy recovery devices in treatment facilities have resulted in reduced energy needs for new facilities compared with older projects. While research continues, it is not expected that further major reductions will occur in the near term.

Because of the high energy requirements for desalination, it is especially important to look at the sources of power used to operate plants. Although there has been an overall emphasis on expanding reliance on sustainable/renewable energy sources within California, fossil-fuel-based power plants continue to be a major source of energy, about 62 percent of total in-state electricity generation. Significant improvements in energy generation technology have reduced the environmental impacts associated with energy generation; nonetheless, energy generation (including exploration, extraction, and conversion to electricity) continues to result in significant environmental impacts. Air pollution, including GHGs, groundwater pollution, water use, and despoiling of scenic views and wildlife habitat are major concerns associated with new and existing energy generation. Many of these concerns apply not only to just fossil energy sources, but also to renewable power.

Aside from drawing electricity from a power grid to operate desalination facilities, it has been proposed that renewable energy generation be incorporated directly into such facilities. In some proposals, seawater desalination would take advantage of its proximity to the natural energy within the ocean environment. A commercial-scale wave energy project is being constructed by Carnegie Wave Energy Ltd in Western Australia, to provide hydroelectric power to a naval base. The project is also designed to provide water pressure to a desalination pilot plant (Australian Renewable Energy Agency 2014). In addition, research is being conducted on two concepts funded by the EPA: the microbial desalination fuel cell and desalination with a solar evaporation array.

Climate Change

General

As water resource planners and managers move to develop water supplies, they will need to address potential climate change impacts. Climate change projections include warmer air temperatures, diminishing snowpack, precipitation uncertainty, increased evaporation, prolonged droughts, and sea level rise. These anticipated changes could further reduce water supply in many regions, including those that are already experiencing difficulty meeting current water demands. Climate change impacts will put additional stress on aging freshwater collection, storage, and conveyance infrastructure, thereby reducing the capacity to provide a stable source of drinking water.

DWR projects that the Sierra snowpack will experience a 25-40 percent reduction from its historic average by 2050, limiting the amount of water that can be supplied during the summer and fall months. Prolonged droughts with changes in precipitation and runoff patterns will likely affect communities that rely on surface water deliveries, making them more dependent on groundwater sources. Sea level rise could increase salt water intrusion to coastal freshwater aquifers, resulting in brackish waters that would require treatment to attain drinking water standards. Aside from water availability impacts resulting from climate change, initial estimates of watershed models show that increases in temperature and consequent increases in evapotranspiration will cause a higher water demand. Sea level rise could put at risk facilities at low elevations.

Adaptation

As the impacts of climate change continue to intensify, desalination may become a more attractive adaptive strategy. Desalination provides a water supply that remains robust even during extreme drought periods; desalination capacity will not be affected by rising sea levels, decreased exports from the Sacramento-San Joaquin Delta, or changes in snowpack runoff. For these reasons, desalination is an adaptation strategy to improve the resiliency and reliability of a region's water supply, even in the face of uncertain future climate conditions. To remain a reliable water source, all municipal drinking water facilities, especially coastal desalination facilities, need to be located away from or protected from rising sea levels and other events that could increase their vulnerability to flooding and erosion.

Mitigation

Because of the higher energy intensity of desalination (when compared to most alternative water supplies), energy use and associated GHG emissions from desalination pose a major concern. While desalination may be used to increase water supplies and provide a climate-resilient and robust water supply, operation of desalination facilities may have associated substantial GHG emissions, depending on the type of energy used to operate them. Some energy sources contribute to existing atmospheric GHG concentrations and lead to larger future climate changes. Potential mitigation opportunities include reduced energy consumption by increasing operational and process efficiencies and coupling or dedicating renewable/sustainable energy sources not generating GHGs to desalination facilities.

The energy factors provided in the "Energy Use and Sources" section of this chapter can be converted to GHG emissions by using a GHG emission factor for the region or the energy utility that would provide power for desalination. The California region (Comprehensive Air Quality Model with Extensions, or CAMX) average GHG emissions rate for electricity is 0.300 metric tons of carbon dioxide equivalent (CO_2e) per megawatt hour (MWh). Emissions rates for specific utilities' service areas and other states can be found at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html. Looking at specific proposed seawater desalination projects in California, Cooley and Heberger (2013) arrived at an average of 0.39 metrics tons of CO_2e/MWh.

As previously stated, though desalination is a proven technology, its energy requirements are higher in most cases than levels necessary for importing and treating water or using local groundwater and surface water sources. Brackish water desalination is comparable in energy intensity to recycled and imported water supplies, while seawater desalination is considerably more energy intensive than most other water supply options. As an energy-intensive process, desalination has the potential to counteract the GHG reduction goals of California if fossil-fuel-powered plants are used as a primary energy source. Then again, desalination operations can take measures to optimize efficiency, purchase renewable energy, minimize GHGs on-site, and mitigate for emissions off-site to reduce their overall carbon footprint.

Funding

The California Legislature emphasized the importance of water desalination in 2003 with the passage of Assembly Bill 314, which declared that it is the policy of the State that desalination projects developed by or for public water entities be given the same opportunities for State assistance and funding as other water supply and reliability projects (California Water Code, Section 12947).

Implementation of water desalination involves capital financing to plan, design, and construct facilities and revenue sources to pay for debt service (loan repayment) and operational costs. To advance desalination technology and address implementation issues, financing is also needed for research and special studies.

Capital financing is often through borrowed funds, especially the sale of bonds. Many agencies set aside a part of their annual revenue in a capital reserve fund for future projects. Grants and low-interest loans from State and federal governments are also available at times.

Annual revenues are derived primarily from the sale of water. Other sources include parcel tax assessments and incentive rebates from regional water suppliers. Individual water users may also pay for projects that directly benefit them, such as an industrial facility installing on-site or off-site infrastructure to receive or produce desalinated water.

The following list provides potential sources of financial assistance to local agencies seeking to facilitate the implementation of water desalination.

- **Water Desalination Grant Program.** DWR administers this program funded by Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002. Chapter 6 of that proposition authorized $50 million in grants for desalination projects. The program assists local public agencies with the development of local potable water supplies through the construction of feasible brackish water and ocean water desalination projects and advancement of water desalination technology and its use by means of feasibility studies, research and development, and pilot and demonstration projects. Two cycles of funding under this grant program awarded approximately $46.25 million in grants to 48 projects. Five projects were subsequently cancelled, leaving 43 projects as shown in Table 10-8. The five construction projects produce approximately 30,000 af/yr. of water. A third round of funding was released in early 2014, awarding approximately $8.7 million from unused grant funds.

- **Integrated Regional Water Management Grant Program.** DWR administers this program funded by Proposition 50 and Proposition 84, which was approved in 2006. The IRWM grants are for water supply and management projects, including desalination, arrived at through a cooperative process with stakeholders to cost-effectively meet the regional goals and objectives. This program has resulted in more than 10 desalination projects. Additional funding will be available from this program.
- **Title XVI: Water Reclamation and Reuse Program.** This federal program (authorized by Title XVI of Public Law 102-575), administered by USBR, funds water projects, which include those reclaiming naturally impaired water, throughout the western United States. This program has funded several desalination projects or studies in California.
- **Other Federal Programs.** Potential funding sources administered by USBR include the Basin Studies program, which could incorporate desalination planning; Advanced Water Treatment Pilot and Demonstration Grants, which aim to encourage pilot and demonstration projects that address technical, economic, and environmental viability of treating and using brackish groundwater, sea water, impaired waters, or otherwise create new water supplies within a specific locale; and the WaterSMART Water and Energy Efficiency Grant Program.

National desalination research and development efforts have been funded through at least nine federal agencies and laboratories, each with their own research objectives and priorities. The majority of federal desalination research and development funding also comes from congressional earmarks, which limit the ability to develop a stable research program (Committee on Advancing Desalination Technology 2008). National foundations have been active in funding desalination research, especially the WateReuse Research Foundation and Water Research Foundation. DWR, by using Proposition 50 funds, also has contributed to research efforts.

Financial aid and other funding opportunities are critical to the progression of the desalination strategy at the national, State, regional, and local levels. The recent successful progression of desalination from a cost-prohibitive alternative to the alternative of choice is attributable, in part, to funding contributions from State and federal governments and the foundations.

Intakes and Ocean and Freshwater Ecosystems

A primary concern associated with coastal desalination plants using open-water intakes is the impact of feed-water intake on aquatic life. Surface intakes of sea water result in impingement and entrainment of marine organisms. This impact can be avoided or reduced to insignificant levels by proper design of open water intakes or use of subterranean intakes (e.g., beach wells and under-ocean-bed intakes), wherever feasible. It is important to have a strong regulatory structure to ensure protection of the ocean and other aquatic environments.

Desalination may be a means of protecting freshwater or inland ecosystems by reducing reliance on water extracted from inland zones. Restrictions put in place to protect fish and wildlife within an inland watershed zone may prevent a community from meeting its freshwater supply sources within the affected watershed zone.

In the past, seawater desalination has been able to gain cost efficiency by sharing intake and discharge structures with coastal power plants. This option, however, has been diminished. To

Table 10-8 Proposition 50 Desalination Funding by DWR

Project Category	Number of Awarded Projects	Awarded Projects Total Cost	Awarded Grant Amount
Construction Projects	5	$92,162,000	$11,700,000
Feasibility Studies	11	$5,059,700	$2,318,448
Pilots and Demonstration Projects	14	$46,434,279	$15,704,793
Research and Development Projects	13	$21,298,077	$8,730,710
Total	**43**	**$164,954,056**	**$38,453,951**

reduce the harmful effects power-plant cooling water has on marine and estuarine life by using sea water with surface water intakes, the SWRCB has adopted a policy preventing any new once-through cooling power plants (State Water Resources Control Board 2011).

Concentrate (Brine) Management

The desalination process produces a salty concentrate (brine) that must be properly managed. This brine must be handled in an environmentally safe and sustainable manner in accordance with regulations. The quantity and salinity of the concentrate varies with the type of technologies employed in operating the plant.

The main options for concentrate management are listed in the "Concentrate Management" section, above. The discharge of brine into water bodies poses problems when the salinity of the brine is significantly different from the receiving water. Higher saline brine will tend to sink to the bottom, adversely affecting organisms that reside in the benthic zone, that is, the ecological region of the sediment surface and immediately below the sediment surface. Brine applied on land, either in ponds, landfills, or irrigation sites, can contaminate groundwater if the salts are allowed leach downward.

The adverse effects from discharge of brine into such water bodies as the ocean can be reduced by inducing rapid mixing of the brine with receiving water to reduce its concentration and tendency to sink. Nonetheless, while the plume of brine is suspended before complete mixing, there is a zone within the water that is harmful to fish and other aquatic life. Considerable attention and testing is devoted to brine discharge diffusers to enhance the mixing and minimize the adverse effects on either the benthic zone or the water column.

Percolation of saline water coming from brine applied on land can be prevented through proper design of evaporation ponds or landfills. Irrigating with water that contains brine is not common because it is only practical where the brine is of low concentration, as from brackish water desalination, and of low volume, and when it is applied to salt-tolerant plants.

It is more likely that brackish water plants in California discharge their concentrate to municipal wastewater collection systems where it is subsequently treated and disposed of with other municipal wastewater. For brackish water desalination plants, this type of concentrate management is likely to continue where the wastewater treatment system capacity is adequate. Seawater desalination produces a concentrate approximately twice as salty as sea water. In addition, residuals of other treatment chemicals may be in the concentrate of brackish and sea water. Some plants currently being planned will use existing power-plant or wastewater plant outfall systems to take advantage of dilution and mixing before discharge to the ocean or adjacent water bodies. The option of sharing brine discharge with power-plant cooling water discharges is diminishing as restrictions are placed on power plants. On the other hand, co-locating concentrate discharge with wastewater effluent in ocean outfalls might have some environmental benefits to the extent that the concentrate from the desalination plant would increase the salinity of the wastewater effluent to levels comparable or closer to that of sea water.

Brine discharges from desalination facilities are regulated by the SWRCB through the issuance of a NPDES permit that contains conditions protective of aquatic life. Concentrate management requires integration with other plans adopted by the State, such as the Ocean Plan and Enclosed Bays, Estuaries and Inland Surface Waters Plan. At the time this chapter was written, these plans did not address the impacts of intakes and brine discharge. However, an amendment of the Ocean Plan to address desalination is expected in 2014, to be followed by an amendment to the Enclosed Bays, Estuaries and Inland Surface Waters Plan.

Subsurface Extraction

When considering a source for water supply, the safe yield of the water body must be determined. While *safe yield* has previously been defined to include only groundwater sources, USBR defines it as the annual quantity of water that can be taken from a supply source over a period of years without depleting the source beyond its ability to be replenished naturally in wet years (U.S. Bureau of Reclamation 2012). Groundwater overdraft, even of brackish water, can have negative consequences. Overdraft can cause land subsidence. Surface water bodies, such as streams or lakes, connected to aquifers might become depleted through the extraction of groundwater, affecting both water rights and aquatic life. When the safe yield of a subsurface water source is limited, it may be best to reserve the water for such emergencies as droughts.

The extraction of saline water for desalination should not cause intrusion of lower quality water, such as sea water or polluted water, into a fresher water source. *Seawater intrusion* is the subsurface flow of sea water into a subsurface water body. The higher density of sea water allows it to flow beneath the fresher water and move inland. Groundwater extraction exacerbates the inland flow by lowering the groundwater level and reducing the overlying pressure, allowing sea water to flow further inland. Because sea water has high salt content, the influx causes a degradation of water quality. This can result in higher water treatment costs or wells being abandoned. Brackish groundwater extraction near the coast could exacerbate seawater intrusion.

Because aquifers are often interconnected to surface water bodies, such as streams or lakes, groundwater extraction affects these surface water sources. The known ecological impacts of groundwater overdraft in California include diminished stream flow and lake levels, damaged vegetation, effects on fish and migratory birds, and land subsidence. The interaction of groundwater with surface water needs to be considered when brackish groundwater is a desalination source.

Planning and Growth

There are many factors to consider before deciding whether to implement a water desalination project. Desalination should be analyzed in comparison with other alternatives that could achieve the same project objectives. In the context of this resource management strategy, obtaining a municipal water supply would be a primary objective. Established feasibility criteria applied in water resources planning are:

- Ability to meet project objectives.
- Technical feasibility.
- Economic justification.
- Financial feasibility.
- Environmental feasibility.
- Institutional feasibility.
- Social impacts.

As with any water resources project, desalination cannot be evaluated on the basis of any single criterion. Water supply alternatives rarely include an outstanding alternative that meets all of a community's vision for the future and the needs and goals to achieve that vision. All alternatives, including desalination, need to be evaluated together by applying the evaluation criteria listed above.

Drawing on the work of the California Water Desalination Task Force, which was convened in 2003, DWR published the *California Desalination Planning Handbook* (California Department of Water Resources 2008). This handbook is a valuable resource for project proponents and communities. It provides a planning framework for developing, where appropriate, economically and environmentally acceptable desalination facilities in California. The planning process outlined in the handbook is intended to identify and address siting, regulatory, technical, environmental, and other issues, which should be considered when determining whether and how to proceed with a desalination project.

There are major issues facing desalination, as described in other sections, including cost, environmental impacts, GHG emissions, and growth inducement. A methodical planning process with community involvement is the best way to minimize negative impacts and to weigh these impacts against those of other water supply options and the supply reliability and other benefits of desalination. Even the presence of some unavoidable adverse impacts may be acceptable. The regulations implementing CEQA state the following:

> CEQA requires the decision-making agency to balance, as applicable, the economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposed project against its unavoidable environmental risks when determining whether to approve the project. If the specific economic, legal, social, technological, or other benefits, including region-wide or statewide environmental benefits, of a proposal project outweigh the unavoidable adverse environmental effects, the adverse environmental effects may be considered 'acceptable'. (California Code of Regulations, Title 14, Division 6, Chapter 3, section 15093[a])

One of the issues has been the assertion that desalination is "growth-inducing." Any water supply or water management alternative, including water conservation, which augments or frees up water supply to accommodate new water demands, has the same potentially growth-inducing impact. A community's vision for population growth and land development ideally should be resolved in a broader context of community planning, such as county general plans, not water supply planning. State CEQA guidelines require that growth-inducing impacts of a proposed project be discussed in environmental documents. Nonetheless, as stated in the guidelines, "It must not be assumed that growth in any area is necessarily beneficial, detrimental, or of little significance to the environment" (California Code of Regulations, Title 14, section 15126.2[d]).

The goal of a water resources planner is to meet the needs of the community for a reliable water supply now and in the future, aligned with how the public envisions future land use and population. Desalination is part of the portfolio of potential supplies that should be considered. An analysis of desalination is required as part of UWMPs to comply with the Urban Water Management Planning Act (California Water Code, Section 10631) and IRWM plans submitted as part of DWR's Integrated Regional Water Management Grant Program.

Recommendations

Desalination of brackish and sea water is a proven technique to augment water supplies in a balanced water supply portfolio. Treatment of brackish groundwater for beneficial use is a common practice in California, and in some places it approaches conventional treatment status. Small-scale seawater desalination facilities (less than 5 mgd) have been built, but as of 2013 seawater desalination has not become an established method to meet municipal water demands.

Desalination, particularly of sea water, has been a challenge. If desalination is to be an appropriate and successfully implemented component of California's water supply, certain constraints need to be agreed on and certain actions need to be taken in the planning, regulatory, and scientific arenas.

Nevertheless, sea and brackish surface waters constitute potential water supplies in many parts of California, even as they already are throughout the world, and water supply planners in California are increasingly looking to desalination as a means of diversifying water supply portfolios.

Policy

1. The State recognizes that desalination is an important water supply alternative and, where economically, socially and environmentally appropriate, should be part of a balanced water supply portfolio that includes other alternatives, such as conservation and water recycling.

2. Desalination should be implemented in a manner consistent with environmental protection and water sustainability goals. Regulatory agencies should have a strong regulatory framework, with adequate resources to establish technically sound criteria that provide adequate environmental safeguards for water supply projects, including desalination.

3. The State recognizes that desalination requires energy to operate; to mitigate the energy needs where economically and environmentally appropriate, project sponsors and water suppliers are encouraged to consider coupling energy from sustainable sources.

Actions

4. Project sponsors and water suppliers should evaluate the potential for groundwater and surface water desalination as a means of meeting current and future water demands. This evaluation will provide communities across the state with the information they need to make sound choices on water supply options, and where appropriate via science-based decision-making for a sustainable future.

5. When planning a water supply project as part of an IRWM plan prepared in order to acquire State funding, project sponsors and water suppliers shall consider desalination as a strategy to meet the goals and objectives of the region (California Water Code, Section 10530).

6. Desalination should be evaluated using the same well-established planning criteria applied to all water management options, using such feasibility criteria as water supply need within the context of community and regional planning; technical, economic, financial, environmental, and institutional feasibility; social impacts; and climate change. *The California Desalination Planning Handbook*, published by DWR, should be one of the resources used by water supply planners (California Department of Water Resources 2008).

7. Project sponsors and water suppliers should evaluate desalination within the context of integrated water management to better reflect community and regional needs and priorities with respect to water quality protection, water supply, growth management, brine disposal, and economic development. Water management planning should occur within a wider context of community values and visions for the future. Key stakeholders, the general public, and permitting agencies need to be engaged in the planning process.

8. DWR, in collaboration with regulatory agencies, should lead an effort to create a coordinated, streamlined permitting process for desalination projects. Because of the many regulatory agencies involved in desalination of ocean, bay, or estuarine waters, a coordinated framework to streamline permitting approvals without weakening environmental and other protections should be explored. Establishing an appropriate sequencing of approval by the various agencies may be appropriate. The Ocean Protection Council may be an appropriate and a reasonable choice for the role of coordinating regulatory reviews and guiding project sponsors through the regulatory process.

9. Project sponsors and water suppliers should evaluate climate change impacts, primarily with regard to GHG generation from energy consumption, for proposed desalination projects within the context of available water-supply alternatives. Note that desalination should not be precluded solely on the basis of energy consumption, because the allocation of energy to meet water supply needs and reliability may be considered of higher social value to a community than other uses of energy.

10. Desalination projects developed by public agencies, as well as utilities regulated by the California Public Utilities Commission, should have opportunities for State assistance and funding for water supply and reliability projects.

11. Research and investigations should continue to develop new or improved technologies to advance and refine desalination processes, feedwater intake and concentrate management technologies, energy efficiencies, and the use of alternative and renewable energy sources. The State legislature is urged to provide additional funding for desalination research.

12. DWR should be adequately funded to maintain technical expertise and current data on the status of brackish and seawater desalination in California, to support the planning and policy roles of State government and to be an information resource to the public.

13. The SWRCB, in consultation with CDPH and DWR, should develop an effective regulatory framework, via source water assessment plans and water quality control plans, for protection of saline waters for the beneficial use of municipal drinking water after desalination treatment. The framework should provide reasonable protection against chemicals of emerging concern and constituents that are known to be harmful in drinking water and cannot reliably, readily, and feasibly be removed with existing technology, such as that currently employed in RO desalination systems.

Desalination in the California Water Plan

Desalination in Resource Management Strategies

The following resource management strategies included in this volume have additional information related to the use of desalination or issues addressed in this chapter:

- Chapter 12, "Municipal Recycled Water."
- Chapter 15, "Drinking Water Treatment and Distribution."
- Chapter 19, "Salt and Salinity Management".
- Chapter 24, "Land Use Planning and Management."

References

References Cited

Australian Renewable Energy Agency. 2014. "Perth Wave Energy Project." [Web page.] Viewed online at: https://arena.gov.au/project/perth-wave-energy-project/. Accessed: January 24, 2014.

BenJemaa F. 2009. *Logistics for Deploying Mobile Water Desalination Units*. Sacramento (CA): California Department of Water Resources, Water Use and Efficiency Branch, Water Recycling and Desalination. 9 pp. Viewed online at: http://www.water.ca.gov/desalination/Publications/. Accessed: January 14, 2014.

California Department of Water Resources. 1960. *Saline Water Demineralization and Nuclear Energy in California Water Plan, Bulletin No. 93*. Prepared by Division of Resources Planning.

———. 1963. Saline Water Conversion Activities in California, Bulletin No. 134-62. California Department of Water Resources.

———. 2003. Water Desalination — Findings and Recommendations. 17 pp. Available at: http://www.water.ca.gov/pubs/surfacewater/water_desalination_findings_and_recommendations/findings-recommendations.pdf.

———. 2008. *California Desalination Planning Handbook*. Prepared by Center for Collaborative Policy, California State University, Sacramento. Viewed online at: http://www.water.ca.gov/desalination/pud_pdf/Desal_Handbook.pdf.

———. *California Water Plan Update 2009*. Volume 2, Chapter 9, "Desalination," Table 9-1. Viewed online at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm.

Committee on Advancing Desalination Technology. 2008. *Desalination: A National Perspective*. National Research Council. Washington (DC): The National Academies Press. ISBN: 0-309-11924-3.

Cooley H, and M Heberger. 2013. *Key Issues for Seawater, Desalination in California: Energy and Greenhouse Gas Emissions*. 37 pp. Oakland (CA): Pacific Institute.

Cooley H, and R Wilkinson. 2012. *Implication of Future Water Supply Sources for Energy Demands*. 82 pp. Alexandria (VA): WateReuse Research Foundation.

GEI Consultants/Navigant Consulting, Inc. 2010. *Embedded Energy in Water Studies, Study 1: Statewide and Regional Water-Energy Relationship*. Prepared for California Public Utilities Commission, Energy Division.

Klein G. 2005. *California's Water-Energy Relationship: Final Staff Report*. Report No. CEC-700-2005-011-SF. California Energy Commission.

State Water Resources Control Board. 2011. *Statewide Water Quality Control Policy on the Use of Coastal and Estuarine Waters for Power Plant Cooling, as amended July 19, 2011*. Sacramento (CA): State of California, State Water Resources Control Board.

U.S. Bureau of Reclamation. 2012. "Glossary." [Web site.] Viewed online at: http://www.usbr.gov/library/glossary/#.

WateReuse Desalination Committee. 2011. *Seawater Desalination Power Consumption: White Paper*. Alexandria (VA): WateReuse Association. 16 pp.

Wilkinson R. 2000. *Methodology for Analysis of Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integral Water-Energy Efficiency Measures*. Berkeley (CA): Ernest Orlando Lawrence Berkeley Laboratories, California Institute for Energy Efficiency. 90 pp.

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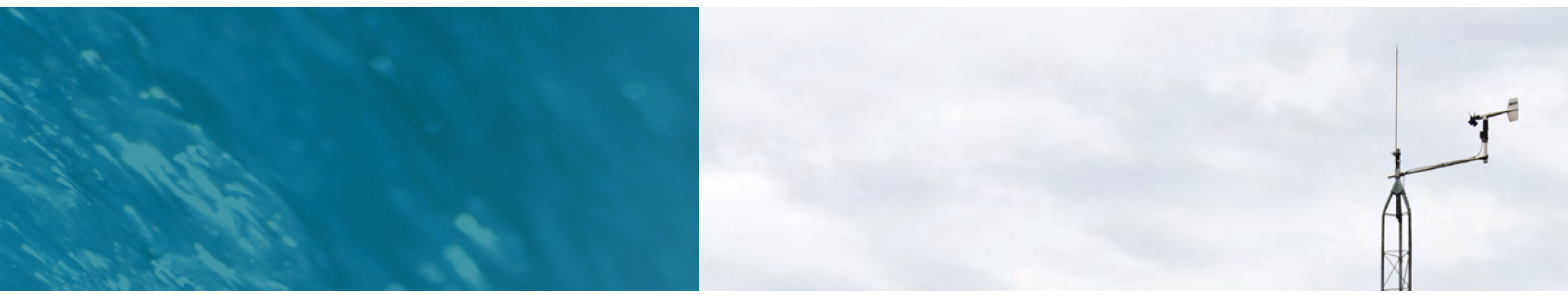
CHAPTER 11

Precipitation Enhancement



Bodega Bay, CA. NOAA staff installs a 10-meter-high meteorological tower, which measures atmospheric pressure, temperature, relative humidity, wind speed, wind direction, precipitation, and net radiation, at the Bodega Marine Laboratory (March 2013).

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Precipitation enhancement, commonly called “cloud seeding,” artificially stimulates clouds to produce more rainfall or snowfall than they would produce naturally. Cloud seeding injects substances into the clouds that enable snowflakes and raindrops to form more easily. Precipitation enhancement is the one form of weather modification done in California. Forms conducted in other states include hail suppression (reducing the formation of large, damaging hailstones) and fog dispersal (when fog is below freezing temperature). (There are some unconfirmed reports of hail suppression attempts in the San Joaquin Valley, using hail cannons, but the scientific basis for this method is dubious.)

Winter orographic cloud seeding (cloud seeding where wind blows over a mountain range, thereby causing clouds and rain or snow by lifting the air) has been practiced in California since the early 1950s. Most of the projects are along the central and southern Sierra Nevada, with some in the Coast Ranges. The projects generally use silver iodide as the active seeding agent, supplemented by dry ice if aerial seeding is done. Silver iodide can be applied from ground generators or from airplanes. Occasionally, other agents, such as liquid propane, have been used. In recent years, some projects have been trying hygroscopic materials (substances that take up water from the air) as supplemental seeding agents. Figure 11-1 shows rain and snow enhancement programs that were considered operational in 2011. Most rain and snow enhancement projects are long-term projects that operate in all or most years. A few, such as Monterey County’s project, only ran for one or two seasons. Historically, the number of operating projects has increased during droughts, up to 20 projects in 1991, but has leveled off at about a dozen in wet or normal water years. Most of the agencies or districts doing precipitation enhancement projects suspend operations during very wet years once enough snow has accumulated to meet their water needs.

State requirements for sponsors of weather modification projects consist of filing a notice of intent (NOI) initially, and every five years after for continuing projects; some record keeping by operators; and annual or biennial reports to the California Department of Water Resources (DWR). The information to include in the NOI can be obtained from DWR. In addition, sponsors need to comply with the California Environmental Quality Act and should send annual letter notices to the board of supervisors within affected counties and to DWR. The National Oceanic and Atmospheric Administration (NOAA) also requires activity reports, which give the number of days and hours of operation and the amounts of seeding material applied.

Policy statements by both the American Meteorological Society in 1998 and the World Meteorological Organization in 2007 support the effectiveness of winter orographic cloud-seeding projects, although they acknowledge that results may be uncertain because of the high degree of background variability of weather. A more detailed treatment of weather modification capabilities, position statements, and the status of the discipline is in *Guidelines for Cloud Seeding to Augment Precipitation* (American Society of Civil Engineers 2006).

An editorial in the international journal *Nature* in June 2008 advocated for a renewed push for scientific research into weather modification activities. For years, weather modification supporters faced a perceived negative bias in the scientific community because early increase

Figure 11-1 Weather Modification Project Areas in 2011

claims were exaggerated. The editorial in a widely respected scientific journal may mark a turn in opinion. Massive weather modification efforts in China for the 2008 Olympics did not go unnoticed in the press that year. Also, in 2011, evaluations of a five-year experimental program in the Snowy Mountains of southeastern Australia confirmed a significant precipitation increase in seeded storms.

Since 2009, the last time the California Water Plan was updated, there have not been many new developments in weather modification in California. Most of the projects have continued to operate as before. The demise of one of the oldest commercial operators in the field, Atmospherics Inc. in Fresno, led to some changes as sponsors had to find a substitute operator. A new firm, RHS Consulting Ltd., entered the field and in 2011 was conducting operations in the San Joaquin, Kaweah, and Kern river watersheds in the southern Sierra Nevada mountains.

Pacific Gas and Electric Company (PG&E) had planned a new project on the Pit and McCloud rivers in Northern California on the headwaters of Shasta Lake, but this has been dropped to avoid further controversies in light of criticism of PG&E after one of its gas pipelines exploded in San Bruno in 2010. This would have been one of the more productive precipitation enhancement projects in California because the region gets frequent storms and has the ability to take advantage of natural storage by increasing precipitation recharge of the large volcanic aquifers that feed the Pit and McCloud rivers year round (also increasing hydroelectric power production on these rivers). Potential yield could have been as much as 200,000 acre-feet (af) of precipitation. Much of the added precipitation would have gone into recharging the large volcanic aquifer, which supplies the year-round springs in the region.

Another area of interest to California is the Colorado River basin, where a lengthy drought has caused the seven states of that basin — Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming — to look at all potential options. The best hope of augmenting Colorado River water supply is wintertime cloud seeding in the headwater states of Colorado, Utah, and Wyoming. There are already many seeding programs in place. However, the basin states have agreed to work together in a program for implementing new programs and to designate new areas for seeding and possibly longer seasons of operation for existing projects. There were 15 projects already operating in the Upper Basin; there may be potential for up to 15 more in the region, including four in Arizona. From a 2006 study (Griffith and Solak 2006) by North American Weather Consultants, which does weather modification, the combined potential yield of the new programs could be 800,000 af per year on average. This is based on a 10 percent increase in precipitation. Additional amounts could be obtained by augmenting the existing programs, primarily by funding a longer season of operation. As a start, the Lower Basin states added about $390,000 per year in the three years from 2010 through 2012 to enhance Upper Basin cloud-seeding efforts.

More research in weather modification is desirable. The kind of research needed and the equipment needed are beyond the ability and funding of independent project sponsors, although much can be gained from piggybacking research onto existing programs. To this end, legislation was introduced in the 110th Congress by Sen. Kay Bailey Hutchison of Texas and then-Rep. Mark Udall of Colorado for federal funding of weather modification research and to increase the effectiveness of existing programs through applied research. This federal research funding effort was unsuccessful.

In California, proposals have been made to the California Energy Commission's (CEC's) Electric Program Investment Charge program (formerly named the Public Interest Energy Research Program [PIER Program]) for additional research into cloud seeding to evaluate the effectiveness of existing programs in the state and optimize their effectiveness. Justification would be the potential impact on hydroelectric energy production. This approach would survey the latest scientific advances in cloud physics, remote sensing, atmospheric science, seeding technologies, and evaluating strategies and would recommend the best course of action to maximize the contribution of operational cloud-seeding programs to California's water and energy supplies. Researchers could also study the potential effect of climate change and atmospheric pollution on seeding practices and capabilities. DWR recommends that the Electric Program Investment Charge program include and fund research on cloud seeding in its activities.

The State of Wyoming has undertaken a major weather modification research program, which is now in its seventh year (it began in 2006). The objective is to evaluate, with help from the scientists at the National Center for Atmospheric Research (NCAR), the potential for increased snowpack in the Sierra Madre and Medicine Bow Mountains of southern Wyoming with a randomized experimental design. Some storms are seeded, and some are left unseeded, with extensive measurements of moisture tracking in the air and of results on the ground. The program will need another couple of years after the current one to gain the 120 to 150 cases needed to detect with statistical confidence a positive increase in snowpack due to seeding.

Progress in confirming snowfall enhancement has been made in the Snowy Mountains of Australia. A recent scientific paper by Manton and Warren (2011) shows a 14-percent increase in precipitation when comparing seeded and unseeded experimental units from 2005 through 2009 during the passage of winter cold fronts.

Potential Benefits

In California, all precipitation enhancement projects are intended to increase water supply or hydroelectric power. The amounts of water produced are difficult to determine, but estimates range from a 2 to 15 percent increase in annual precipitation or runoff. A National Research Council (NRC) 2003 report on weather modification had limited material on winter orographic cloud seeding, such as is practiced in California and other western states. However, the report did seem to concur that there is considerable evidence that winter orographic weather modification works, up to a 10 percent increase. A 2012 study by the Utah Department of Natural Resources (updating a 2005 study through the 2010 season) showed an average increase in April 1 snowpack water content ranging from 3 to 15 percent from a group of projects that had been operating from seven years (high Uinta Mountains) to 32 years (central/southern Utah). The overall estimated annual runoff increase for Utah was about 180,000 acre-feet, or about 6 percent for the study areas. Estimated costs in 2010 were $2.27 per acre-foot (af) from these ground seeding programs.

Actual increases in annual runoff are probably less in California than in Utah. A new estimate made for Update 2013 by DWR staff is that the combined California precipitation enhancement projects, on average, generate about 400,000 af of runoff annually, which would be an average of about a 4 percent increase in runoff.

Accepting the PG&E estimate for the formerly proposed Pit River-McCloud River cloud-seeding project of 200,000 af for that region (which is one of the most favorable areas for cloud seeding because of more frequent storms and generally colder weather conditions than other parts of the state tend to have), another 200,000 to 300,000 acre-feet per year (af/yr.) may be available in other areas. Thus, a reasonable state estimated total could average 400,000 af/yr. Many of the other best prospects are in the Sacramento River basin, in watersheds that are not seeded now. The North Lahontan and South Lahontan hydrologic regions are already well covered by cloud-seeding projects, except for the Susan River and the Carson River. With the exception of the upper Trinity River watershed, and perhaps the Russian River, there is little new potential in the North Coast Hydrologic Region because limited storage capacity would mean not much extra rainfall could be captured.

There is also potential to increase water production by more effective seeding operations in existing projects. Precipitation enhancement should not be viewed as a remedy for drought, however; cloud-seeding opportunities are generally fewer in dry years. They work better in combination with surface or groundwater storage to increase average supplies. In the very wet years, when sponsors already have enough water, cloud-seeding operations are usually suspended.

Cloud seeding has advantages over many other strategies of providing water. A project can be developed and implemented relatively quickly without multiyear lead times. In areas where it snows, it could offset some of the loss in snowpack expected from climate change. This may benefit mountain meadows and would delay the fire season in forests. As a resource management strategy, precipitation enhancement would qualify as part of integrated regional water management (IRWM). Seeding opportunities tend to be greater in Northern California than in Southern California because Northern California has more frequent storms and cooler temperatures.

Potential Costs

Costs for cloud seeding generally would be less than $30 per af of water supply each year. State law says that water gained from cloud seeding is treated the same as natural supply in regard to water rights. Southern California projects would be more expensive because of fewer seeding opportunities, but imported supplies are also more expensive there.

It is estimated that about $3 to $5 million is being spent now on yearly operations. Realizing the additional 300,000 to 400,000 af of potential new supply could require an initial investment of around $8 million for planning, reports, and initial equipment, plus around $6 million in annual operations costs. Over the next 25 years, that would add up to about $150 million, which would be nearly $22 per af of water supply.

Major Implementation Issues

Reliable Data

No complete and rigorous comprehensive study has been made of all California precipitation enhancement projects. Part of the reason is the natural variability of weather and the difficulty in locating unaffected control basins. Some studies of individual projects have been made in the past years on certain projects, such as the Kings River, which have shown increases in water. A recent evaluation by Dr. Bernard Silverman, published in the journal Atmospheric Research (Silverman 2010), represents the best efforts so far on the longer-running cloud-seeding projects and is generally positive in showing results. Aerial seeding, or combination aerial and ground seeding, showed better results than ground seeding alone.

Operational Precision

It is difficult to target seeding materials to the right place in the clouds at the right time. There is an incomplete understanding of how effective operators are in their targeting practices. Chemical tracer experiments have provided support for targeting practices. New seeding agents, and transport and diffusion studies with some of the new atmospheric measuring tools, like some currently being employed by NOAA in hydrometeorological test bed experiments, would be helpful.

Concern over Potential Impacts

Questions about potential unintended impacts from precipitation enhancement have been raised and addressed over the years. Common concerns relate to downwind effects (enhancing precipitation in one area at the expense of those downwind), long-term toxic effects of silver, and added snow removal costs in mountain counties. The U.S. Bureau of Reclamation (USBR) did extensive studies on these issues. The findings were reported in its Project Skywater programmatic environmental impact statement in 1977 and its Sierra Cooperative Pilot Project environmental assessment in 1981. The available evidence does not show that seeding clouds with silver iodide causes a decrease in downwind precipitation; in fact, at times some of the increase of the target area may extend up to 100 miles downwind (Harris 1981). (A seminar specifically on downwind effects at the end of April, 2012 in Las Vegas at the annual meeting of the Weather Modification Association confirmed earlier findings of no loss to downwind areas; often adjacent downwind areas also showed some increase.)

The potential for eventual toxic effects of silver has not been shown to be a problem. Silver and silver compounds have a rather low order of toxicity. According to the USBR, the small amounts used in cloud seeding do not compare to industry emissions of 100 times as much into the atmosphere in many parts of the country or individual exposure from tooth fillings. Watershed concentrations would be extremely low because only small amounts of seeding agent are used. Accumulations in soil, vegetation, and surface runoff have not been large enough to measure above natural background levels. A 2004 study done for Snowy Hydro Limited (Williams and Denholm 2009) in Australia has confirmed the earlier findings described above.

Some silver accumulation testing by PG&E on the Mokelumne River and Lake Almanor watersheds was presented at the 2007 annual meeting of the Weather Modification Association. Both watersheds have been seeded for more than 50 years. Sampling at Upper Blue Lake and Salt Springs Reservoir showed very low to undetectable concentrations in water and sediment. Similar results were found at Lake Almanor upon testing water, sediment, and fish samples during the 2000-2003 period. Amounts were far below any toxic levels, and there was little to suggest bioaccumulation. Therefore, continued operations should not result in any significant chronic effect on sensitive aquatic organisms.

In regard to snow removal, little direct relationship to increased costs was found for small, incremental changes in storm size, because the amount of equipment and manpower to maintain the roadway is essentially unchanged. In other words, the effort to clear a road of 5.5 inches of snow is practically the same as the effort to clear a road of 5 inches of snow.

All operating projects have suspension criteria designed to stop cloud seeding anytime there is a flood threat. Moreover, the type of storms that produce large floods are naturally quite efficient in processing moisture into rain anyway. In such conditions, seeding is unlikely to make a difference.

Funding

Little federal research funding for weather modification has been available in the past 20 years. The USBR had some funding in 2002 and 2003 in the Weather Damage Mitigation program. Desert Research Institute of Nevada obtained a grant of $318,000 from this source early in 2003 to evaluate its seeding in the eastern Sierra Nevada.

The USBR is also providing some funds to Desert Research Institute for its current Walker River program to augment stream inflow to Walker Lake in Nevada.

Bills introduced in the 110th Congress attempted to reestablish federal support for more weather modification research, some of which would have provided research support on existing operating projects. This legislation was supported by the Western States Water Council, the seven Colorado River basin states, the Colorado River Board of California and others. These bills, Senate Bill 1807 (Hutchison) and House Bill 3445 (Udall) did not pass.

The major research effort in recent years has been funded by the State of Wyoming: an extensive test of cloud seeding in two adjacent mountain regions, the Sierra Madre and the Medicine Bow Mountains. This is a classical randomized statistical experiment in which some storms are seeded and some are not. About 30 cases (testing opportunities) will occur in an average winter season. By the end of 2012, the project had produced 123 cases but needed about 60 more to increase statistical confidence, according to NCAR researchers — which would be at least two more seasons. The Wyoming Legislature in 2012 provided two more years' worth of funding to complete the experiment. Costs are on the order of $1 million per year.

Inadvertent Weather Modification

There is evidence that human activities such as biomass burning, transportation, and agricultural and industrial activities modify local and sometimes regional weather. The effects of aerosols on clouds and precipitation are complex. Studies by Ramanathan, Rosenfeld, Woodley, and others suggest suppressed precipitation formation in affected clouds due to pollution and dust (Ramanathan et al. 2001; Rosenfeld 2000; Rosenfeld and Givati 2006; Rosenfeld and Woodley 2001). Some aerosols can enhance precipitation, and some, especially the very fine aerosols in diesel smoke, can reduce precipitation. Much more research is needed to evaluate the air pollution effects on precipitation processes and the amount of impact, as well as possible effects on cloud-seeding programs. It is possible that some of the California cloud-seeding projects have offset a potential loss in precipitation from air pollution, which may have obscured a more positive effect from the weather modification projects. Research work in Israel has demonstrated such effects (Givati and Rosenfeld 2009).

Recent research by Scripps and the Pacific Northwest National Laboratory has indicated that dust from western China can increase northern Sierra Nevada west slope precipitation (Ault et al. 2011).

Connections to Other Resource Management Strategies

The precipitation enhancement strategy is strongly connected to these strategies:

- Forest Management (see Volume 3, Chapter 23): Much of California's cloud seeding takes place over the forested western side of the Sierra Nevada.
- Watershed Management (see Volume 3, Chapter 27): Upper watersheds in the Sierra Nevada are the catchment for enhanced precipitation from cloud seeding.

Recommendations

1. The State should support the continuation of current projects, as well as the development of new projects, and help in seeking research funds for both old and new projects. Operational funding support for new projects may be available through the IRWM program.

2. DWR should collect base data and project sponsor evaluations of existing California precipitation enhancement projects, and projects of other western states; independently analyze them; and perform research on the effectiveness of this technology to supplement water supplies while minimizing negative impacts.

3. DWR should support efforts to investigate the potential to augment Colorado River supply by cloud seeding, in cooperation with the Colorado River Board of California, the other Colorado River basin states, the USBR, and the Metropolitan Water District of Southern California.

4. DWR, in partnership with the USBR, and seeking cooperation from PG&E, should produce an environmental impact report/environmental impact statement on a Pit River-McCloud River project similar to the one proposed several years ago, because this area has one of the best potential yields. This could benefit both the Central Valley Project and the State Water Project (which share in-basin use north of and in the Sacramento-San Joaquin Delta), and there would appear to be multiple State benefits from augmenting recharge of the huge northeastern California volcanic aquifer.

5. DWR should support research on cloud physics and cloud modeling being done by the NOAA labs and academic institutions. With improvement, these models may become tools to further verify and test the effectiveness of cloud-seeding activities.

6. The State should support research on potential new seeding agents, particularly ones that would work at higher temperatures. Climate change may limit the effectiveness of silver iodide, the most commonly used agent, which requires cloud temperatures well below freezing, around -5 ºC, to be effective. (Additionally, the increasing costs of silver are a detriment to some ongoing projects.)

7. DWR should support efforts by California weather modification project sponsors, such as that proposed in 2002-2003 by Santa Barbara County Water Agency, to obtain federal and State research funds for local research experiments built upon their operating cloud-seeding projects. In this regard, DWR recommends that the CEC Electric Program Investment Charge program include research studies on weather modification.

References

References Cited

American Society of Civil Engineers. 2006. *Guidelines for Cloud Seeding to Augment Precipitation*. Second Edition. Reston (VA): American Society of Civil Engineers. [ASCE Manual No. 81.] 200 pp.

Ault AP, Williams CR, White AB, Neiman PJ, Creamean JM, Gaston CJ, Ralph FM, Prather KA. 2011. "Detection of Asian dust in California Orographic precipitation." Journal of Geophysical Research 116(August, Issue D16).

Givati A, Rosenfeld D. 2009. "Comments on 'Does Air Pollution Really Suppress Precipitation in Israel.'" Journal of Applied Meteorology and Climatology 48(8):1733-1750.

Griffith D, Solak M. 2006. *The Potential Use of Winter Cloud Seeding Programs to Augment the Flow of the Colorado River.* Sandy (UT): North American Weather Consultants. Prepared for the Upper Colorado River Commission. March. 49 pp.

Harris ER. 1981. *Sierra Cooperative Pilot Project Environmental Assessment and Finding of No Significant Impact.* Denver (CO): Office of Atmospheric Resources Research.

Manton M, Warren L. 2011. "A Confirmatory Snowfall Enhancement Project in the Snowy Mountains of Australia — Part II: Primary and Associated Analyses." Journal of Applied Meteorology and Climatology 50(7):1448-1458.

National Research Council. 2003. *Critical Issues in Weather Modification Research*. Washington (D.C.): National Academies Press. December. 144 pp.

Nature. 2008. "Change in the Weather." [Editorial on the need for weather modification research.] Nature 453(June 19):957-958.

Ramanathan V, Crutzen PJ, Kiehl JT, Rosenfeld D. 2001. "Aerosols, Climate, and the Hydrologic Cycle." [Magazine.] Science 294(5549):2119-2124.

Rosenfeld D. 2000. "Suppression of Rain and Snow by Urban and Industrial Air Pollution." Science 287(5459):1793-1796.

Rosenfeld D, Givati A. 2006. "Evidence of orographic precipitation suppression by air pollution-induced aerosols in the western United States." Journal of Applied Meteorology and Climatology 45(7):893-911.

Rosenfeld D, Woodley W. 2001. "Pollution and clouds." Physics World. February. pp 33-37.

Silverman B. 2010. "An Evaluation of Eleven Operational Cloud Seeding Programs in the Watersheds of the Sierra Nevada Mountains." Atmospheric Research 97(4):526-539. September.

Williams BD, Denholm JA. 2009. "Assessment of the Environmental Toxicity of Silver Iodide with Reference to Cloud Seeding Trial in the Snowy Mountain of Australia." Journal of Weather Modification 41(April):71-96.

Additional References

American Meteorological Society. 2013. "AMS Journals Online." Boston (MA): American Meteorological Society. [Web page.] Viewed online at: http://journals.ametsoc.org/. Accessed: April 18, 2013.

American Society of Civil Engineers and Environmental Water Resources Institute. 2004. *Standard Practice for the Design and Operation of Precipitation Enhancement Projects*. Reston (VA): American Society of Civil Engineers. [ASCE/EWRI 42-04.] May. 74 pp.

American Society of Civil Engineers. 2003. "Atmospheric Water Resources Management." Reston (VA): American Society of Civil Engineers. [ASCE Policy Statement No. 275.]

Boe B, Bomar G, Cotton WR, Marler BL, Orville HD, Warburton JA. 2004. "The Weather Modification Association's Response to the National Research Council's Report Titled: 'Critical Issues in Weather Modification Research' Report of a Review Panel." Journal of Weather Modification 36(1):53-82.

Cardno ENTRIX. 2011. *Geochemistry and Impacts of Silver Iodide Use in Cloud Seeding*. Concord (CA): Cardno ENTRIX. May. Prepared for Pacific Gas and Electric Co.

Desert Research Institute. 2011. *Cloud Seeding Operations and Research in the Walker River Basin to Increase Water Delivery to Walker Lake*. [Semi-annual progress report for the period April 1, 2011 through Sept. 30, 2011.] Prepared by Huggins AW, project manager, Division of Atmospheric Sciences, Desert Research Institute.

———. 2011. *Final Report — Cloud Seeding Project for Tahoe and Truckee Basins for WY2011*. Prepared by Huggins AW, project manager, Division of Atmospheric Sciences, Desert Research Institute.

Givati A, Rosenfeld D. 2004. "Quantifying Precipitation Suppression Due to Air Pollution." Journal of Applied Meteorology and Climatology 43(7):1038-1056.

Griffith D, Solak M, Almy R, Gibbs D. 2005. "The Santa Barbara Cloud Seeding Project in Coastal Southern California, Summary of Results and Their Implications." Journal of Weather Modification 37(April):21-27.

Hunter S. 2007. *Optimizing Cloud Seeding for Water and Energy in California*. Denver (CO): U.S. Bureau of Reclamation, Technical Service Center. March. Prepared for the California Energy Commission Public Interest Energy Research Program. 38 pp.

Kings River Conservation District, Kings River Water Association, Pacific Gas & Electric Co., and California Department of Water Resources. 2011. *Summary and Evaluation of 2010-2011 Winter Cloud Seeding Operations for the Kings River Watershed, California*. Sandy (Utah): North American Weather Consultants Inc. Report No. WM 11-2, NAWC Project No. 10-273. Prepared for Kings River Conservation District, Kings River Water Association, Pacific Gas & Electric Co., and California Department of Water Resources. Prepared by Weston TW, Yorty DP, Flanagan T, Solak ME, and Griffith DA of North American Weather Consultants Inc.

List R. "The Serious Flaws of the Academies' Report on Weather Modification Research." Journal of Weather Modification 37(April):67-70.

Manton M, Warren L, Kenyon S, Peace A, Bilish S, Kemsley K. 2011. "A Confirmatory Snowfall Enhancement Project in the Snowy Mountains of Australia — Part I: Project Design and Response Variables." Journal of Applied Meteorology and Climatology 50(7):1432-1447.

Marler B. 2007. "Cloud Seeding Impacts? Water, Sediment and Tissue Studies." [Presentation at the annual meeting of the Weather Modification Association, San Francisco (CA).]

National Oceanic and Atmospheric Administration. 2013. "NOAA in Your State and Territory: 2013 — California." Washington (DC): National Oceanic and Atmospheric Administration. [Word document available through Web page.] 28 pp. Viewed online at: http://www.legislative.noaa.gov/NIYS/. Accessed: April 18, 2013.

New South Wales Department of Environment and Conservation and Sydney Catchment Authority. 2007. Summary from one-day "Workshop on Cloud Seeding." Sydney (Australia). 5 pp.

North American Weather Modification Council. 2013. "Publications." [Web page.] Viewed online at: http://www.nawmc.org/4dcgi/GetCategoryRecord/Publications. Accessed: April 23, 2013.

Ramanathan V, Ramana MV. 2003. "Atmospheric Brown Clouds: Long Range Transport and Climate Impacts." EM (December):28-33. Viewed online at: http://www-abc-asia.ucsd.edu/EM_Paper_20031_final.pdf. Accessed: April 18, 2013.

Ryan T. 2005. "Weather Modification for Precipitation Augmentation and Its Potential Usefulness to the Colorado River Basin States." Los Angeles (CA): Metropolitan Water District of Southern California. October. 34 pp.

Southwest Hydrology. 2007. “Cloud Seeding.” [Magazine; entire issue devoted to cloud seeding.] Tucson (AZ): University of Arizona. Southwest Hydrology 6(2). 44 pp.

United Nations Environment Programme and the Center for Clouds, Chemistry and Climate. 2002. *The Asian Brown Cloud: Climate and Other Environmental Impacts*. Nairobi (Kenya). Prepared for the United Nations Environment Programme.

Utah Department of Natural Resources, Division of Water Resources. 2005. *Utah Cloud Seeding Program, Increased Runoff/Cost Analysis*. Salt Lake City (UT): Utah Department of Natural Resources, Division of Water Resources. May. 15 pp.

———. 2012. *Utah Cloud Seeding Program, Increased Runoff/Cost Analyses*. Salt Lake City (UT): Utah Department of Natural Resources, Division of Water Resources. February. 19 pp.

World Meteorological Organization. 2013. “Archive.” [Web archive of volumes/issues of the journal Bulletin.] Viewed online at: http://www.wmo.int/pages/publications/bulletin_en/archive/index_en.html. Accessed: April 23, 2013.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 12

Municipal Recycled Water


Pittsburg, CA. Recycled water, treated and supplied by the Delta Diablo Sanitation District, is used to irrigate the landscaping along a greenbelt on 8th Street.

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Chapter 12. Municipal Recycled Water

California is increasing its integration of municipal recycled water into its water supply portfolio. In some regions of the state, recycled water meets approximately 7 percent of water supply demands. Although the statewide total is an increase since *California Water Plan Update 2009* (Update 2009) was released, it is still far short of previously established goals. Municipal recycled water benefits the state and individual water users by reducing long-distance water conveyance needs, providing local water supplies, and being a drought-resistant resource. This resource management strategy (RMS) chapter will describe the current status of recycled water in California, what some of the challenges are to its increasing use, and the resources needed to continue to increase municipal recycled water use.

Introduction

The municipal recycled water RMS addresses the recycling of municipal wastewater treated to a specified quality to enable it to be used again. Within this chapter, the term "recycled water" refers to water that originates from a municipal treatment plant. Treated wastewater is primarily from domestic (household) sources, but it can include commercial, industrial, and institutional (CII) wastewater discharged to a sanitary sewer. This RMS does not address other types of water recycling, such as the reuse of:

- Industrial wastewater, either when internally reused or when treated or disposed separately from municipal wastewater.
- Agricultural wastewater.
- Gray water.

These are addressed in other parts of *California Water Plan Update 2013* (Update 2013).

Note that the term "recycled water" is a term indicating a beneficial use after wastewater treatment. It does not indicate a certain level of treatment, such as "tertiary-treatment." Title 22, the regulation overseeing reuse or "recycling" of municipal wastewater, uses level of treatment and bacteriological water quality standards to define what uses are legally allowed, based on the probability of public contact. Title 22 defines uses for water ranging from water that has had secondary wastewater treatment and is not disinfected to water that has undergone tertiary treatment.

Changes in this Strategy Since 2009

The Update 2013 municipal recycled water RMS is extensively changed from the version that appeared in Update 2009. There are new or revised policies (the 2009 Recycled Water Policy adopted by the State Water Resources Control Board [SWRCB]), proposed regulations (the California Department of Public Health's [CDPH's] 2011 draft regulations for groundwater replenishment with recycled water, as part of Senate Bill [SB] 918), and a new statewide survey of recycled water users. In addition, several reports that describe recycled water applications, benefits, and challenges have been prepared. Each of these will be discussed within this chapter.

Affiliations with other Resource Management Strategies

Treating and delivering recycled water, as well as disposing of byproducts that may result from generating recycled water, involve issues that may also be discussed in other RMS chapters within Update 2013. The key affiliations of other RMSs to recycled water are described below, by chapter.

- **Chapter 2, "Agricultural Water Use Efficiency"** — Depending on the level of treatment, recycled water can be used to irrigate any crop.
- **Chapter 3, "Urban Water Use Efficiency"** — Recycled water can be used for landscape irrigation and commercial or industrial applications. This chapter describes gray water applications.
- **Chapter 6, "Conveyance — Regional/Local"** — Distribution of recycled water is planned and implemented on local and regional levels with local conveyance systems.
- **Chapter 15, "Drinking Water Treatment and Distribution"** — In the future, recycled water may be distributed via potable water distribution systems.
- **Chapter 17, "Matching Water Quality to Use"** — Recycled water could replace many instances where potable water is currently being used for non-potable applications.
- **Chapter 19, "Salt and Salinity Management"** — Use of recycled water may have an overall impact on salinity of the underlying groundwater basin. As a result, the Recycled Water Policy includes provisions for preparation of salt and nutrient management plans. Recycled water production also may result in brine generation. Discharges of salts and chemicals into sewers from water softeners can increase wastewater salinity and negatively affect municipal recycling.
- **Chapter 20, "Urban Stormwater Runoff Management"** — Stormwater can be used as a water supply mixing source for projects where recycled water is used for groundwater recharge.
- **Chapter 22, "Ecosystem Restoration"** — Recycled water is often a water supply for ecosystem restoration projects.
- **Chapter 24, "Land Use Planning and Management"** — Use of recycled water can be constrained by the availability of sites suitable for recycled water. Successful local planning can encourage locating potential recycled water users where recycled water is available, as well as planning infrastructure needs to support future growth.
- **Chapter 28, "Economic Incentives** — Loans, Grants, and Water Pricing" — Economic incentives are commonly used to facilitate initiation of recycled water projects, enable infrastructure development, or support the use of lower quality water.
- **Chapter 29, "Outreach and Engagement"** — Introduction of recycled water as a local water supply resource requires extensive public outreach and education regarding its uses, as well as addressing local water quality and health effect concerns.

Definition of Municipal Recycled Water

The California Water Code (CWC) provides the following definition for recycled water: "water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefor [sic] considered a valuable resource" (CWC Section 13050(n)). "Recycled water" and "reclaimed water" have the same meaning and can be used interchangeably. The California Water Plan (CWP) uses the term "recycled water." An illustration of the many paths that municipal recycled water can take for reuse is shown in Figure 12-1. The recycled water pathways shown in this figure do not indicate the level of recycled water treatment. Existing California law specifies required treatment levels for designated uses.

Municipal water recycling is a strategy that increases the usefulness of water by reusing a portion of the existing waste stream that would be discharged to the environment as waste and redirecting the water to another local application. Recycling municipal wastewater increases water supply if it reduces discharges into oceans and inland saline waters and enables conserving higher-quality water for appropriate uses. Additionally, as a local water source, municipal recycled water can:

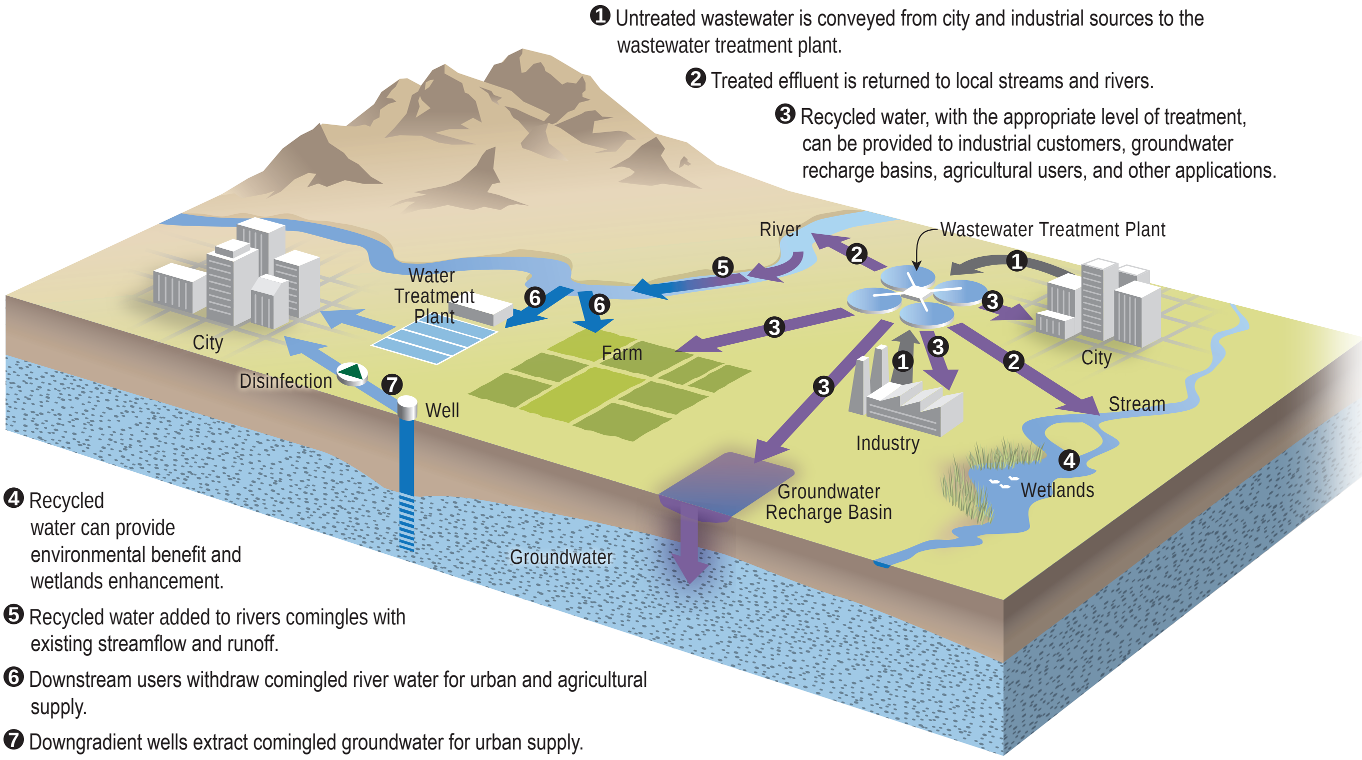
- Be an additional water source, possibly offsetting or delaying obtaining additional freshwater supplies.
- Be a drought-resistant water supply.
- Provide an alternative for treatment and disposal of wastewater.
- Reduce overall energy requirements, especially if it is replacing a higher intensity water source, such as some transferred water.
- Reduce discharge of excess nutrients into surface waters.
- Provide nutrients for crops or landscape plants.
- Support environmental habitats, such as wetlands.
- Be used as the water supply for an injection well barrier to control saltwater intrusion.

Treated municipal wastewater is integrated into California's water supply through both unplanned applications, such as discharge into a stream with a subsequent reuse, or through planned projects. Unplanned reuse occurs when treated wastewater is discharged — usually into a surface water body — and there is no prearranged agreement or intention that the producer would maintain control of the effluent. Discharged treated wastewater supplements river flow and can be a downstream benefit for wetland or aquatic habitat, or withdrawn by a downstream river water user. In the case of the latter, the wastewater discharge is regulated to protect the public health for the downstream beneficial user (Recycled Water Task Force 2003).

Planned recycled water projects are developed by water and wastewater suppliers for potable and non-potable uses (Figure 12-2). Non-potable recycling includes any application not involving drinking water for human consumption, such as landscape or agricultural irrigation, commercial applications like car washes or dual-plumbed office buildings, or industrial process such as oil refineries or cooling towers. Potable reuse results in augmentation to drinking water supplies, and it can be either direct or indirect. Direct potable reuse is treated water conveyed directly from the wastewater treatment plant to a raw or treated drinking water supply lines, a practice which is not currently occurring in California. Indirect potable reuse is treated water from the wastewater treatment plant discharged into recharge basins to infiltrate into groundwater aquifers or into surface water reservoirs used for drinking water supply. Because seawater intrusion barriers typically result in groundwater recharge, they are considered a form of indirect potable reuse.

Water discharged from a wastewater facility may still be reused even if it is not a planned action, as shown in Figure 12-1. Typically, treated wastewater is discharged into rivers and streams as part of permitted disposal practices. Discharged water then commingles with the stream or river that may be a water source for downstream communities or agricultural users. When a

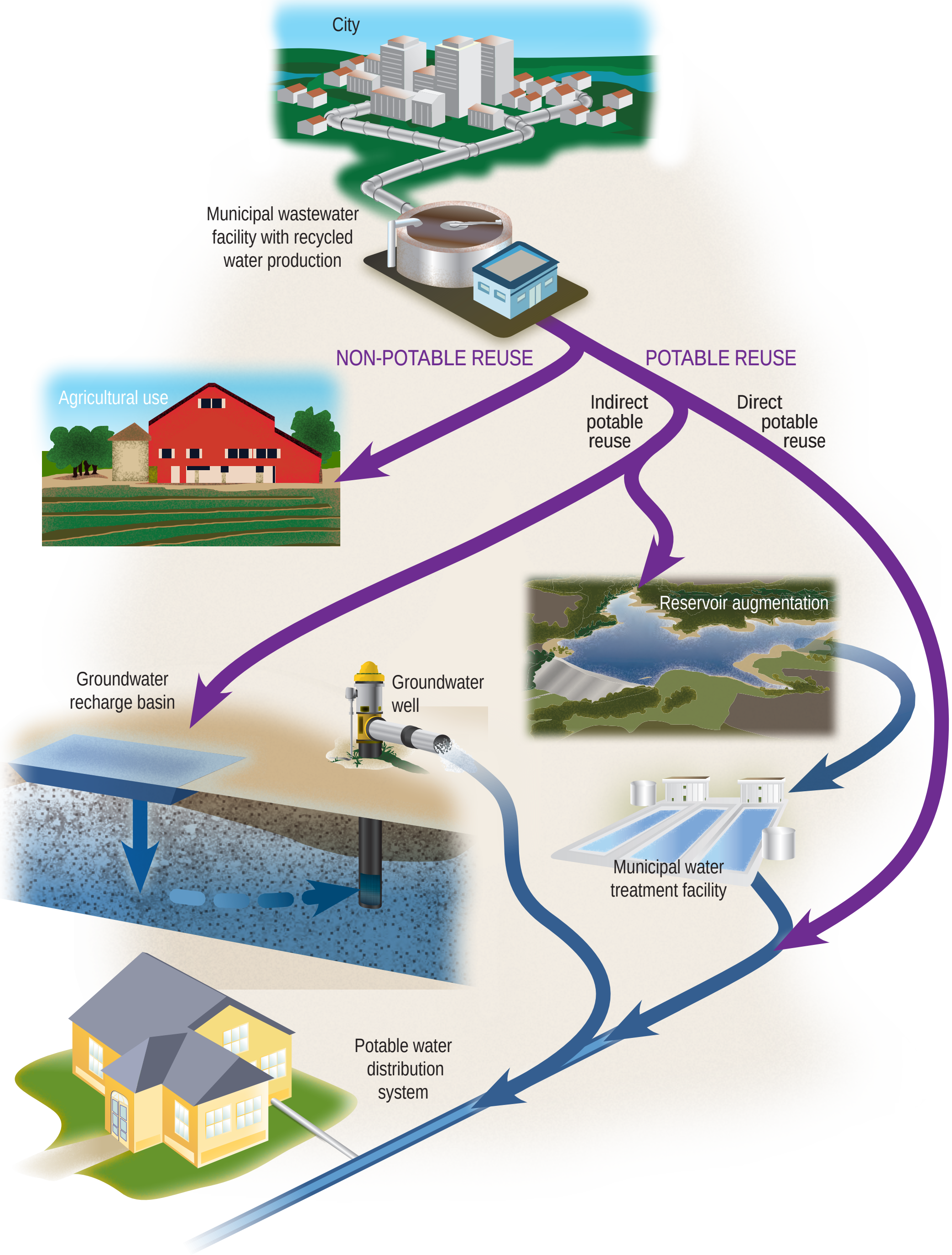
Figure 12-1 Municipal Recycled Water Cycle



downstream entity withdraws water from the stream, a portion of that water is treated wastewater from an upstream discharge that has commingled with the ambient stream flow. Estimates from CWPs prepared in the 1980s indicated that between 86 percent and 100 percent of wastewater discharged in Central Valley hydrologic basins at the time was indirectly reused in this manner. Comingling of recycled water also occurs when it is used to recharge existing groundwater supplies (see Figure 12-1).

Treated wastewater can also be discharged to the ocean or other saline water bodies. This water usually is considered no longer practically available for reuse and is referred to as “irrecoverable water.” The State recognizes recycling projects that capture municipal wastewater in coastal areas that would otherwise become irrecoverable water as providing “new water” supply. An estimated 0.9 million to 1.4 million acre-feet (af) per year (af/yr.) of “new water” could be realized by 2030 through recycling municipal wastewater that is discharged into the ocean or brackish bays (Recycled Water Task Force 2003). Because discharges to the ocean or brackish water bodies support few, if any, downstream beneficial uses, such discharges are prudent sources of wastewater for future recycling efforts (Recycled Water Task Force 2003). These projects may also support energy-efficient water supply strategies because they more fully utilize the energy already expended to treat the water to disposal levels that would otherwise be discharged to irrecoverable sources.

Figure 12-2 Potable and Non-Potable Municipal Recycled Water



An additional consequence of increasing direct municipal recycled water use is that the volume of water discharged into streams may be reduced, potentially adversely affecting downstream water rights or instream beneficial uses. Recognizing this, the CWC requires that prior to making any change in the point of discharge, place of use, or purpose of use of treated wastewater, the SWRCB review potential changes to ensure potential impacts on beneficial uses are considered before authorizing a change in the permitted discharge of municipal wastewater (CWC Section 1211).

Recycled Water Use in California

Continued integration and expansion of recycled water into California's water supply options are necessary to support meeting future demands despite uncertain climactic conditions. Language recognizing the importance of recycled water in meeting future water demands is included in State law: "It is hereby declared that the people of the state have a primary interest in the development of facilities to recycle water containing waste to supplement existing surface and underground water supplies and to assist in meeting the future water requirements of the state" (CWC Section 13510). The state reinforces this declaration by stating in the CWC that under certain conditions the use of potable water for nonpotable purposes is a waste or unreasonable use of water if recycled water is available (CWC Section 13550 et seq.). This has been the basis for the past several decades in California for encouraging recycled water for non-potable uses, especially for industrial and irrigation applications.

Several important actions involving municipal recycled water have occurred (or are in process) since the 2009 update of the CWP. These include:

- Completion of the 2009 Municipal Wastewater Recycling Survey through a joint effort by the SWRCB and the California Department of Water Resources (DWR).
- The SWRCB's adoption of the Recycled Water Policy in 2009.
- CDPH 2011 release of draft regulations for groundwater replenishment with recycled water.
- California Public Utilities Commission (CPUC) release of its Recycled Water Policy Framework for Investor-Owned Utilities.

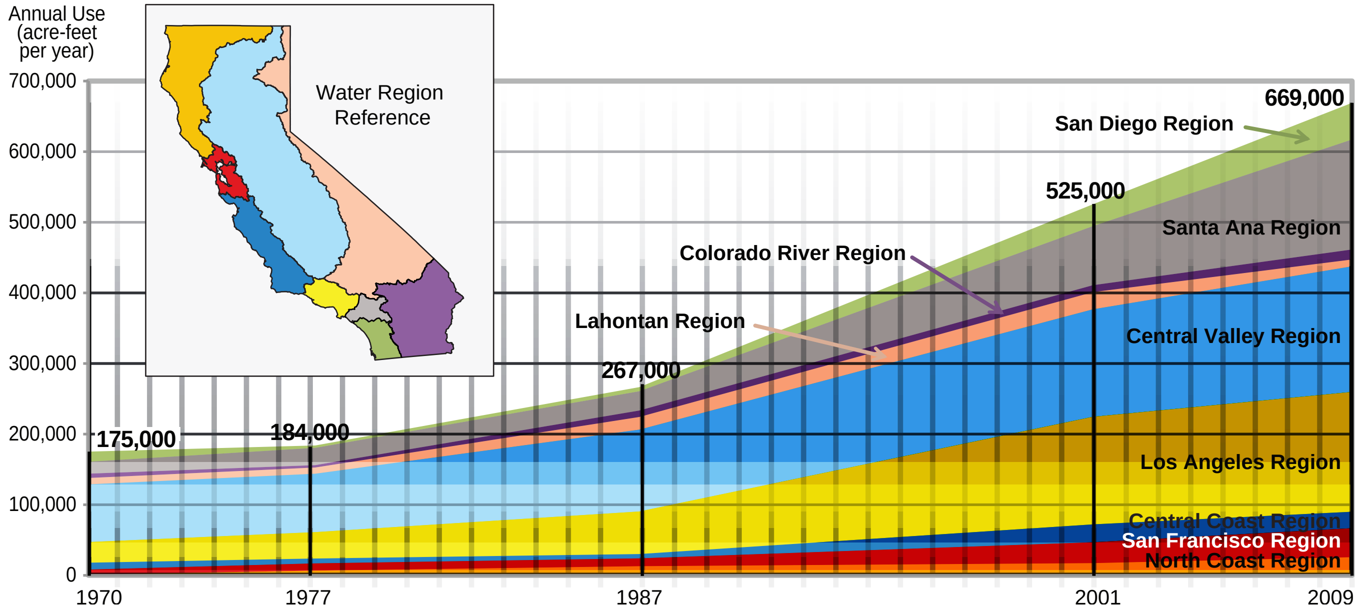
This section addresses past and current water recycling in the state, as well as each of the important actions involving municipal recycled water.

History of Recycled Water in California

Municipal recycled water has been used beneficially in California for more than 100 years. In the earliest applications, farms located near urban areas in this drought-prone state used effluent from municipal wastewater treatment plants. By 1910, 35 sites were using municipal recycled water for agriculture purposes. From 1932 to 1978, San Francisco's McQueen Treatment Plant, the first documented California treatment facility dedicated to treating recycled water (RMC Water and Environment 2009), supplied recycled water for irrigation in Golden Gate Park.

In 1952, 107 California communities were using municipal recycled water for agricultural and landscape irrigation. Following a national initiative to upgrade and improve the level of wastewater treatment in the 1970s, the uses of municipal recycled water applications began to diversify. Beneficial uses of California's recycled water now include landscape, agricultural, and golf course irrigation; commercial and industrial applications; environmental enhancement; groundwater recharge; and lake augmentation.

Figure 12-3 Municipal Recycled Water Use in California Since 1970



Current Recycled Water Use in California — The 2009 Survey

Statewide surveys conducted since 1970 quantified annual volumes of municipal recycled water use and have shown a steady increase in the amount and types of uses (Figure 12-3). These surveys accounted for only planned reuse with recycled water delivered directly to users or to groundwater recharge facilities. For the calendar year 2009, the SWRCB and DWR conducted a survey of agencies involved with the treatment, conveyance, or beneficial reuse of domestic wastewater as recycled water. The survey results identified 669,000 af of treated municipal wastewater that were beneficially reused in California in 2009, classified according to 11 beneficial uses (State Water Resources Control Board 2012). Beneficial uses in the 2001 and 2009 recycled water surveys, as well as historical uses, are shown in Figure 12-4. Indirect potable reuse by adding recycled water to reservoir drinking water supplies and direct potable reuse do not currently occur in California. As part of SB 918 (covered later in the chapter), the California Department of Public Health (CDPH) will investigate the feasibility of developing water recycling criteria for direct potable reuse in California.

Recycling of municipal wastewater occurs throughout California (Figure 12-5). Only seven of the state's 58 counties do not have identified recycling projects. In general, the highest countywide volumes of recycled water occur in parts of the state where local water resources are strained, population densities are high, or wastewater disposal is problematic (Figure 12-6).

The 2009 Municipal Wastewater Recycling Survey identified 210 recycling systems, directly involving almost 300 agencies in some aspect of recycling municipal wastewater in the state. These projects ranged in size from less than 50 af to more than 86,000 af in 2009, and involved many levels of complexity, from direct agricultural reuse to multiple levels of treatment and agency involvement. These projects were funded by local water suppliers, customers, and state

Figure 12-4 Changes in California's Recycled Water Beneficial Uses

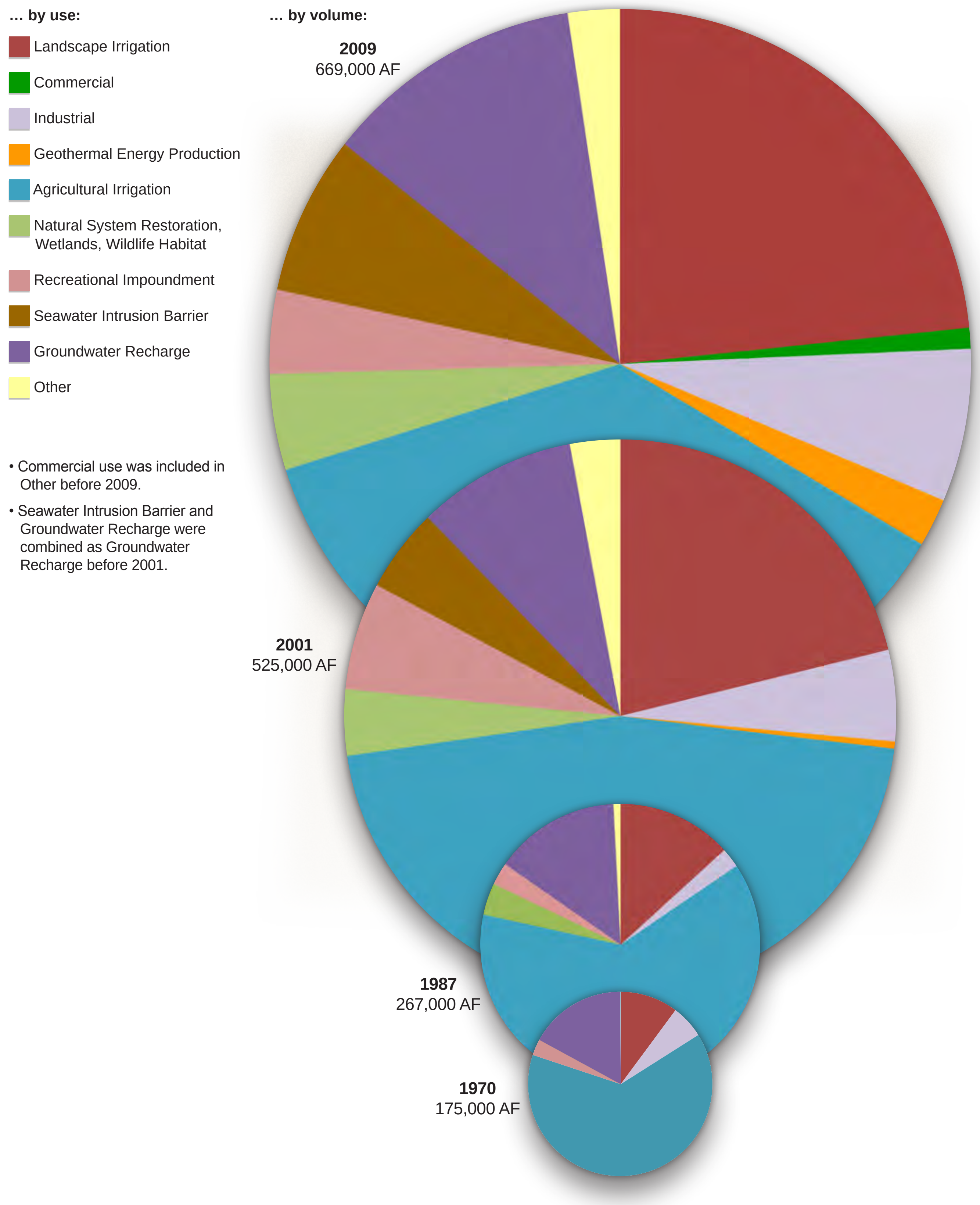
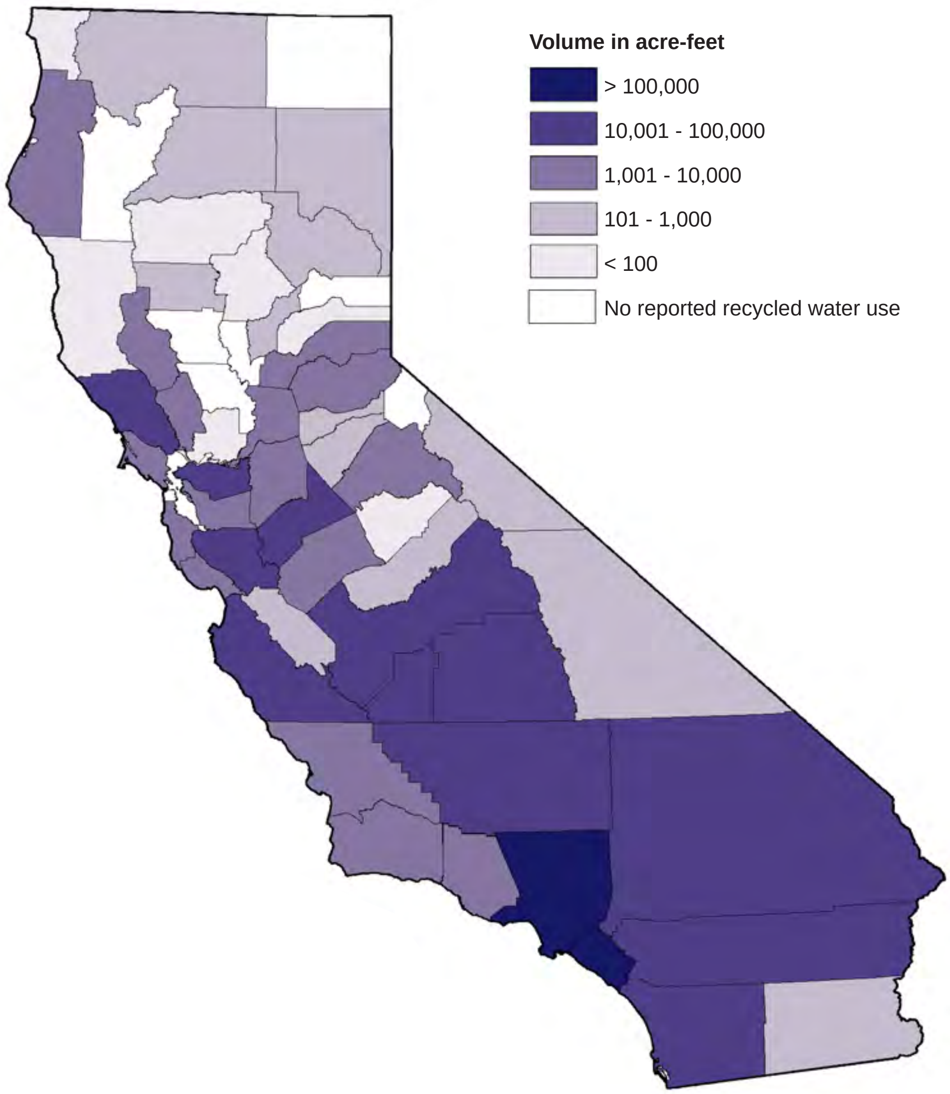


Figure 12-5 Municipal Recycled Water Use by County in 2009

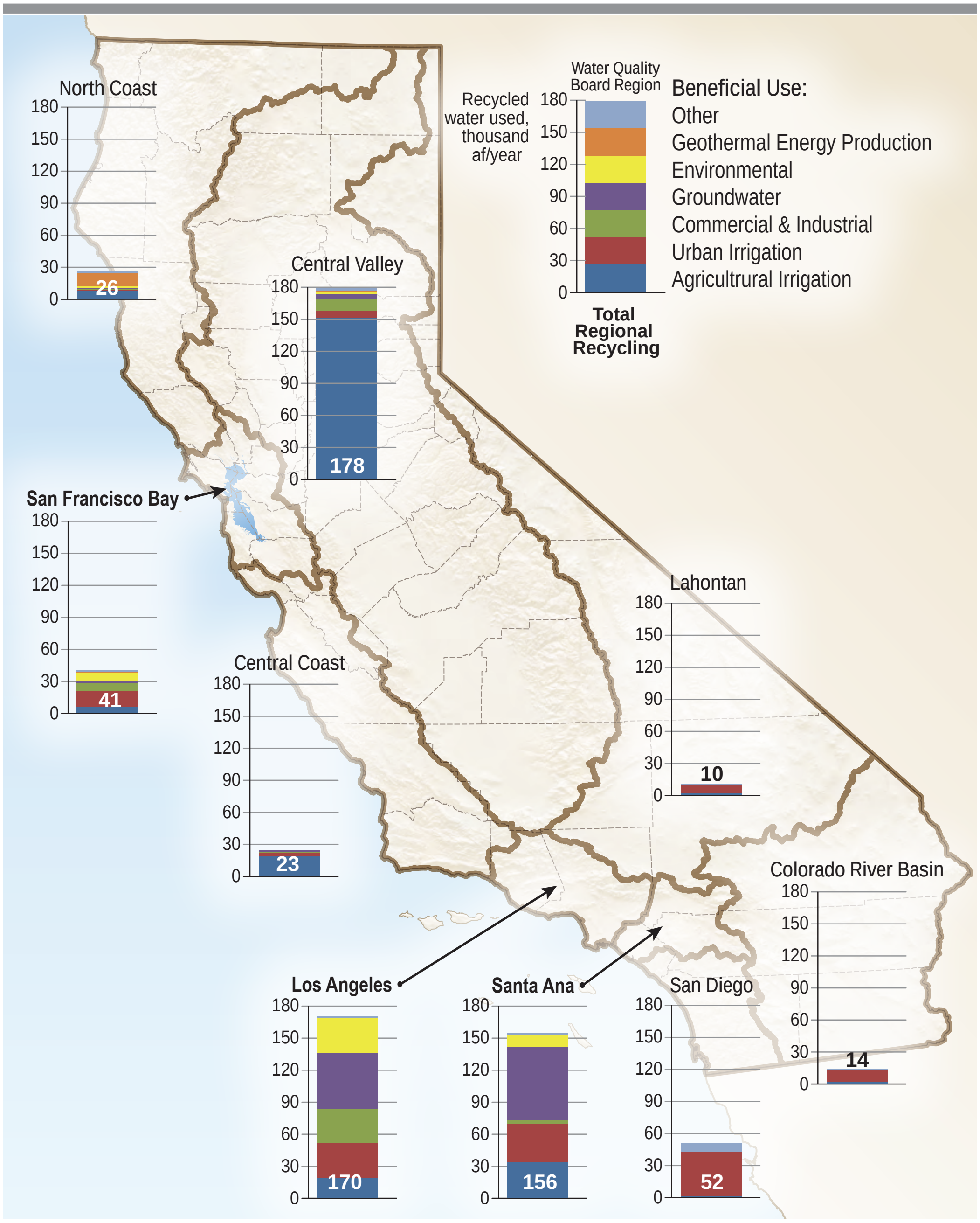


or federal grants and loans obtained through individual or integrated regional water management (IRWM) funding applications.

Potential Recycling in 2020 and 2030

How much water will California be able to recycle in the future? Various future recycled water goals and mandates have been developed by State agencies (Table 12-1), but to date they have not been met. To establish achievable targets, DWR reviewed recycled water use projections included in 2010 urban water management plans (UWMPs), which are required to be prepared by urban water suppliers providing more than 3,000 af annually or having more than 3,000 service connections. UWMPs are discussed more in Chapter 3, "Urban Water Use Efficiency," of this volume. The targets established by DWR, as required by SB X7-7 (2009), do not replace

Figure 12-6 Regional Variations in Beneficial Uses of Municipal Recycled Water in 2009



the existing Recycled Water Policy goals and mandates, but are intended to provide a basis of expectation of actual new capacity. This is an essential function of the CWP and also provides support of local and regional water supply planning efforts.

Using the data from the 2009 Municipal Wastewater Recycling Survey and the UWMPs, DWR estimates that the 2020 and 2030 targets for statewide municipal water recycling should be established at 1,000,000 and 1,300,000 af. No recommendations are made to modify the existing

Table 12-1 Recycled Water Statewide[a] Goals and Mandates

Target Type[b]	Target Volume (in taf)					Notes	Source
	2000	2010	2015	2020	2030		
Potential		1,030			2,050	Midrange of projected potential use increases above 2002 levels	Recycled Water Task Force 2003
Goal	700	1,000					Water Recycling Act of 1991
Goal			1,250				State Water Resources Control Board 2008
Goal				1,525	2,525	1 million af above 2002[c] for 2020 and 2 million af above 2002 for 2030	State Water Resources Control Board 2009[b]
Goal (draft)				1,000	1,300	Based on urban water management plans (UWMPs) and 2009 Municipal Wastewater Recycling Survey data	California Department of Water Resources 2013[b]
Mandate				869	1,169	200,000 af above 2009 for 2020 and an additional 300,000 af for 2030	State Water Resources Control Board 2009[b]

Notes:

af = acre-feet, taf = thousand acre-feet

[a] The actual 2009 statewide volume of beneficially reused municipal recycled water was 669,000 acre-feet.

[b] Potentials, mandates, and goals are terms used in the identified sources. They are developed using various approaches. Mandates are stronger objectives, but in this case they do not carry a defined penalty for non-attainment.

[c] The Recycled Water Policy (State Water Resources Control Board 2009b) indicates that 2020 and 2030 goals are determined relative to the 2002 recycled water levels. The 2001 and 2002 numbers are considered the same because they were based on the same data.

goals or mandates (California Department of Water Resources 2013b). Achieving these new targets would require identifying new opportunities for reusing California's water resources. California's uses of recycled water have diversified over time (see Figure 12-4) and are expected to continue increasing as water resources are more constrained and as people become more knowledgeable about water reuse. Local water suppliers are assessing opportunities for indirect and direct potable reuse of highly treated recycled water as a way of augmenting and "drought-proofing" local supplies, as well as expanding existing irrigation and industrial applications.

The recycled water community is also placing greater emphasis on matching wastewater treatment levels to water quality requirements for the planned reuse, referred to as "fit for purpose" (U.S. Environmental Protection Agency 2012). This concept is where more rigorous treatment (and more energy-intensive processes) is reserved for uses with higher human or food production contact to minimize pathogen or chemical of emerging concern contact. Conversely, less-treated wastewater has been safely used for decades in many agricultural reuse applications, which is the largest category of recycled water use in California. Greater reuse of secondary-treated wastewater in agriculture and environmental settings, where additional "natural treatment" can augment wastewater plant treatment, may provide additional opportunities for meeting the newly established 2020 and 2030 recycled water targets. Finally, water suppliers may determine that having available multiple levels of treated wastewater may support increased integration of recycled water use into their water supply portfolio. West Basin Municipal Water District is very successfully providing multiple water quality levels of recycled water to its customers to meet specific needs of its diverse customer base.

Tracking the State's success in increasing use of recycled water and achieving identified goals, targets, and mandates would require conducting future recycled water surveys. Collection of actual recycled water use data in a manner consistent with approaches used in previous recycled water surveys will facilitate monitoring progress. However, completing a voluntary recycled water use survey using the existing methodologies is a labor-intensive effort. Efforts are under way to identify more efficient data collection approaches using mandatory, electronic reporting. Because of the complexity of recycled water producers, wholesale and retail agency, and end user relationships, any electronic reporting mechanism will have to be coupled with expert review and compilation of data to avoid missing or duplicating data in surveys.

Recycled Water Use Policies, Regulations, Responsibilities, and Funding

As the treatment level of municipal wastewater increases from primary to secondary, tertiary, or advanced, the permitted uses of recycled water increase. State policies and regulations are in place to increase the use of recycled water in a manner that is protective of human and environmental health. State regulations mandate that producers and users of recycled water comply with treatment and use restrictions to protect public health and water quality.

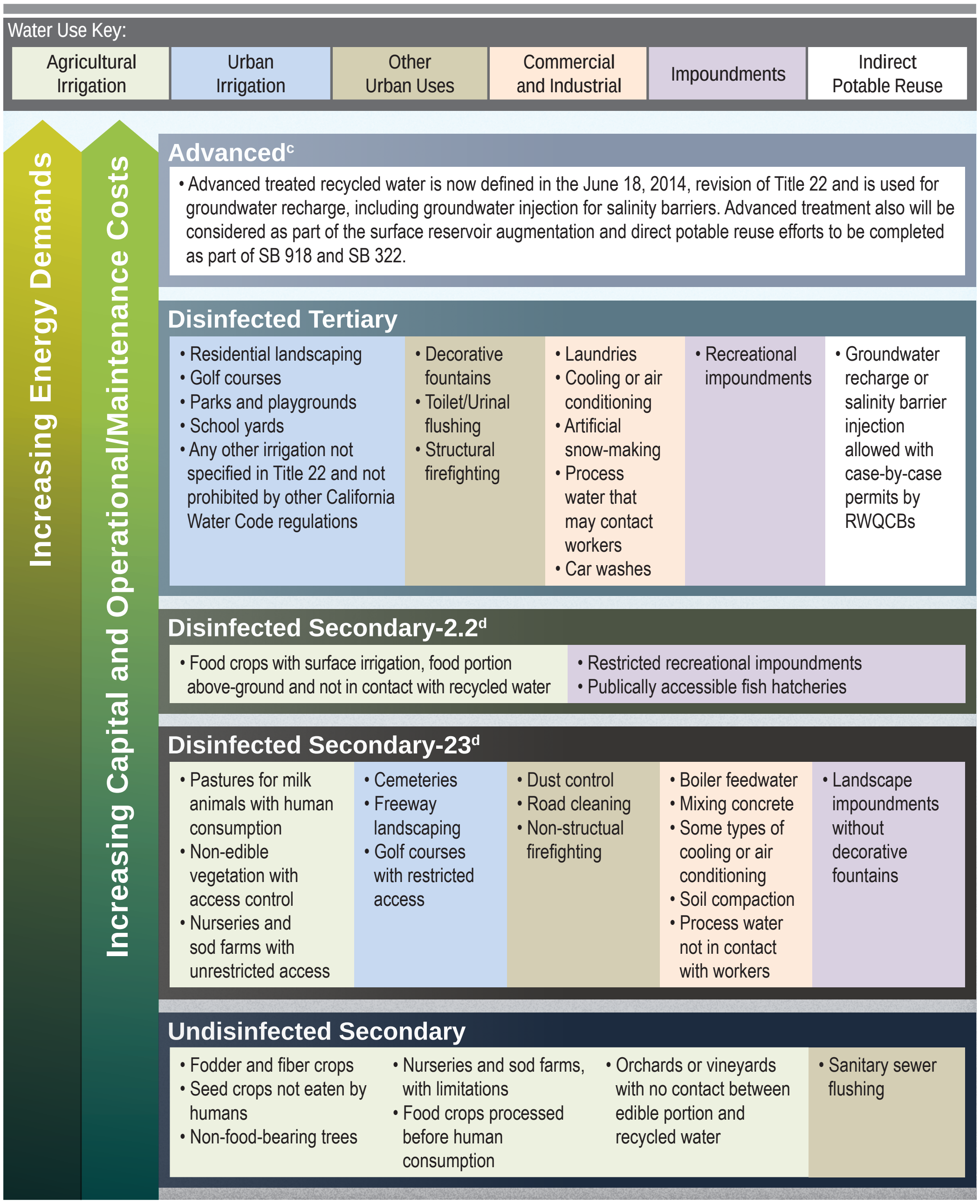
In general, the levels of treatment for recycled water use are based on levels of human exposure and pathways of exposure leading to infection. The required levels of treatment are specified in Title 22 of the California Code of Regulations (CCR) (Division 4, Chapter 3, Section 60301 et seq.), as shown in Figure 12-7. The Title 22 regulations also specify monitoring and reporting requirements and on-site use area requirements. For example, municipal wastewater that has completed tertiary treatment can be used to irrigate school yards, parks, residential landscape, and food crops for human consumption that do not require further processing or washing, as well as industrial applications, or toilet and urinal flushing in office and institutional buildings. Wastewater that has been treated to secondary levels is generally suitable for uses that do not include contact with people or unprocessed food crops, such as agricultural irrigation of animal feed crops.

Aside from the need to protect human health, there are special water quality needs for uses in agriculture or industry to grow crops or manufacture products. Higher levels of treatment may be needed for some industrial applications. Some agencies are able to provide multiple levels of recycled water treatment for various customer uses.

Recycled Water Roles

The current framework for regulating municipal recycled water has been in place since the 1970s. As established in State law, primary authority for overseeing municipal recycled water is divided between the SWRCB, including the nine regional water quality control boards (RWQCBs), and the CDPH. A memorandum of agreement between the two agencies documents this arrangement

Figure 12-7 Title 22 Water Uses and Treatment Issues



a: Based on California Code of Regulations Title 22, Section 60001 et seq.

b: Uses for increasing levels of treatment also include all uses for lower treatment levels.

c: Wastewater treated with reverse osmosis and advanced oxidation processes.

d: Recycled water with a median concentration of total coliform bacteria not exceeding a most probable number of 2.2 or 23 per 100 milliliters (see California Code of Regulations, Title 22).

and clarifies the roles of the agencies. The CDPH regulates public water systems and sets standards for wastewater reuse to protect public health by adopting water recycling criteria based on water source and quality and by specifying sufficient treatment based on intended use and human exposure. The treatment objective is to remove pathogens and other constituents, making the water clean and safe for the intended uses. The SWRCB, through the RWQCBs, has the roles of permitting and providing ongoing oversight authority for water recycling projects. The permits incorporate applicable CDPH Title 22 requirements and specify approved uses of recycled water and performance standards.

It is possible that CDPH's Drinking Water Program may be moved to the SWRCB in 2014. The details of how this transition would be accomplished if it occurs, as well as how various responsibilities for managing recycled water would change, are still being addressed as of the publication of Update 2013.

Four other state agencies are directly involved with municipal recycled water issues in California and implement various sections of State law: DWR, the CPUC, the California Department of Housing and Community Development (HCD), and the California Building Standards Commission (CBSC). Statutes governing municipal recycled water are currently contained within the CWC, the California Health and Safety Code, the California Government Code, the Public Resources Code, and the Public Utilities Code, and regulations are in various subdivisions (titles) of the CCR. State agency roles and responsibilities are summarized in Table 12-2.

In addition to the statewide agencies, local city and county officials also have a regulatory role affecting municipal recycled water projects. In some cases, the CDPH can delegate responsibilities to local officials if local sponsors of municipal recycled water projects agree with the delegation.

Recycled Water Use Statutes, Regulations, and Policies

Since the 1970s, various statutes, regulations, and policies have been enacted and developed to address recycled water generation and use. Table 12-3 highlights some of them. Additionally, there are several new and pending regulations, which are discussed here. The following discussion is based on conditions in early 2013. Some revisions to State statutes have been introduced into the Legislature to consolidate and streamline existing recycled water laws to facilitate uniform implementation.

Recycled Water Policy of 2009

In 2009, the SWRCB adopted the Recycled Water Policy to address issues of concern for permitting recycled water and protecting water quality, including salinity management, regulation of incidental runoff, and monitoring and regulation of chemicals of emerging concern. The policy (State Water Resources Control Board 2009b) calls for managing basins or subbasins through stakeholder involvement and implementation of salt and nutrient management plans and regulating incidental runoff through waste discharge requirements and best management practices. It also prioritizes approval of groundwater recharge projects utilizing municipal recycled water treated by reverse osmosis.

The policy was modified in 2013 to incorporate science advisory panel recommendations (State Water Resources Control Board 2010) on monitoring chemicals of emerging concern. Chemicals of emerging concern are classes of chemicals in the environment — such as pharmaceuticals, currently used pesticides, and industrial chemicals — that could have adverse aquatic and human health effects. These could be existing chemicals which new information indicates potential toxicity concerns or chemicals for which new information suggests possible hazards. These chemicals have the potential to be present in recycled water, which is why the SWRCB convened the scientific panel and modified the Recycled Water Policy to address monitoring requirements for chemicals of emerging concern in certain types of recycled water projects.

Senate Bills 918 and 322

SB 918, enacted in 2010 and modified by SB 322 in 2013, focuses on the issues of indirect and direct potable reuse. It requires CDPH adoption of uniform water recycling criteria for indirect potable reuse for groundwater recharge in 2013 and surface water augmentation in 2016. It also requires the CDPH, by the end of 2016, to investigate and report to the Legislature on the feasibility of developing uniform water recycling criteria for direct potable reuse. The CDPH is required to convene both advisory and expert panels to advise it on the development of criteria for surface water augmentation and the feasibility of direct potable reuse.

In June 2013, the CDPH released draft regulations addressing groundwater replenishment using recycled water from domestic wastewater sources, for aquifers designated as a source of drinking water. The proposed regulations would replace the existing Title 22 regulations that provide the requirements for groundwater recharge projects using recycled water to be determined on a case-by-case basis. Through SB 918 (2010) and SB 322 (2013), CWC Section 13562 et seq. requires the CDPH to adopt revised groundwater replenishment regulations by Dec. 31, 2013. Although the rulemaking was not completed by this deadline, proposed groundwater replenishment and surface water augmentation projects continue to move forward.

The proposed groundwater recharge regulations seek to protect public health for projects utilizing indirect reuse of recycled water to replenish drinking water basins, by establishing criteria that cover:

- Source water control.
- Potential risks associated with pathogenic microorganisms, regulated contaminants, and unregulated contaminants.
- Effective natural barriers and multiple treatment barriers.
- Ongoing monitoring of recycled water and groundwater.
- Effective treatment processes.
- Time to identify and respond to failures.
- Review, reporting, and notification processes.

Recycled Water Policy Framework for Investor-Owned Utilities

The CPUC is in the process of developing a comprehensive policy framework to cover recycled water projects, production, and recycled water use for the investor-owned water and sewer utilities that it regulates. This action, required under the CPUC's Order Instituting Rulemaking 10-11-014, applies to investor-owned utilities with a customer base of 2,000 or more connections. The goal of the policy framework is to facilitate the cost-effective use of recycled water where it is available or can be made available and to reduce the barriers to collaboration between wholesalers and retail recycled water purveyors. The policy framework is expected to provide guidance to investor-owned water and sewer utilities that are in a position to identify, evaluate, and pursue opportunities to add recycled water to water supply portfolios. The policy framework will take into account the most recent State policy and legislation for the production, delivery, and use of recycled water and will encourage interagency coordination and collaboration in the implementation of these policies.

Table 12-2 Regulatory Agency Roles and Responsibilities for the Regulation and Use of Municipal Recycled Water

Agency	Role	Responsibility	California Code of Regulations Title Number
California Department of Public Health	Protects public health	• Adopts uniform recycled water criteria for non-potable and potable recycled water projects[a] • Provides recommendations for recycled water project permits • Reviews and makes recommendations on sites proposed for recycled water use • Oversees cross-connection prevention[b] • Oversees protection of drinking water sources • Regulates public drinking water systems	Titles 17 and 22
State Water Resources Control Board	Protects water quality and water rights	• Establishes general policies governing recycled water project permitting. • Oversees regional water quality control boards. • Provides financial assistance to local agencies for recycled water projects. • Allocates surface water rights	Title 23
Regional water quality control boards (nine)	Protect water quality	• Issue and enforce permits for recycled water projects, incorporating California Code of Regulations Title 22 requirements and California Department of Public Health recommendations • Protect surface water and groundwater quality from recycled water impacts	Title 23
California Department of Water Resources	Manages statewide water supply	• Evaluates use of and plans for potential future recycled water uses through the preparation of the *California Water Plan* • Provides financial assistance to local agencies for recycled water projects • Adopts standards for recycled water indoor plumbing	Title 24 (California Plumbing Code, Chapter 16A, Part II)
California Public Utilities Commission	Oversees rates and revenues of investor-owned utilities	• Approves rates and terms of service for the use of recycled water by investor-owned utilities	Title 20
California Department of Housing and Community Development	Oversees building standards for dwellings, including institutions and temporary lodgings	• Adopts standards for gray water systems in residential structures • Adopts standards for non-potable water systems within buildings over which it has jurisdiction	Title 24 (California Plumbing Code, Chapter 16A, Part I; Chapter 6)
California Building Standards Commission	Oversees adoption of standards for buildings	• Adopted standards for gray water systems in non-residential structures in 2011 cycle of California Building Standards Code • Oversees the adoption of the California Plumbing Code, including provisions added by other State agencies	Title 24 (California Building Standards)

Agency	Role	Responsibility	California Code of Regulations Title Number
Local building officials	Oversee building design, including plumbing	• Enforce building standards, including the California Plumbing Code	Title 24
County environmental health departments	Protect drinking water systems	• Enforce cross-connection control • Review and make recommendations on proposed recycled water use sites	Titles 17 and 22

Notes:

[a] As of November 2011, the California Department of Public Health has adopted regulations in Title 22 for non-potable use of recycled water, but not for potable reuse projects. Senate Bill 918 requires the department to adopt uniform water recycling criteria for indirect potable reuse projects involving groundwater recharge and surface water augmentation.

[b] The California Department of Public Health may delegate some responsibilities for review of new sites and cross-connection control to the local county health departments with the permission of the local recycled water provider.

Recycled Water Use Funding

Recycled water projects are funded directly by local water agencies and water users through rates, bonds, or rebates. Individual water users may also pay for projects that directly benefit them, such as an industrial facility installing on-site or off-site infrastructure to receive recycled water or implementing a process modification. Local agencies take the lead in identifying, analyzing, and prioritizing the water resource projects in their jurisdictions to help achieve their identified goals. They then proceed with the best option to implement their identified projects. Once projects are constructed, revenue from the sale of recycled water, revenue from the sale of potable water, and tax assessments are options for operation, maintenance, and debt service financing.

Other funding options include obtaining grants or loans from both State and federal sources, including the sources listed below.

- **IRWM Grant Program,** administered by DWR. The IRWM grants (funded by Proposition 84) are used by communities in IRWM regions to implement water supply and management projects. Water recycling is one of many strategies that may be considered by IRWM regions in developing their water resource management portfolios.
- **Water Recycling Funding Program,** administered by the SWRCB. This program provides low-interest financing and grants to local agencies (funded by a variety of sources, including Proposition 13). Water recycling is a key objective in the SWRCB's *Strategic Plan Update 2008-2012* (State Water Resources Control Board 2008), which identifies priorities and direction for the SWRCB and its nine RWQCBs.
- **Clean Water State Revolving Fund,** administered by the SWRCB (and funded by the federal Clean Water Act and State bonds). This program provides low-interest financing primarily for wastewater collection, treatment, and disposal, but it also funds recycling projects.
- **Title XVI,** administered by the U.S. Bureau of Reclamation. This federal program (authorized by Title XVI of Public Law 102-575) funds water reclamation and reuse projects throughout the western United States.

Table 12-3 **Important Recycled Water Policies and Regulations**

Year	Action	Organization	Summary
1984	Water Quality Order 84-7	State Water Resources Control Board	Pursuant to California Water Code, Section 13142.5(e), in cases where discharges of wastewater to the ocean are proposed in "water-short" areas, the report of waste discharge should include an explanation as to why the effluent is not being recycled for further beneficial use.
2001	Assembly Bill 331, Recycled Water Task Force	California Assembly	This bill established a 40-member Recycled Water Task Force to evaluate the current framework of State and local rules, regulations, ordinances, and permits to identify the opportunities for, and obstacles or disincentives to, increasing the safe use of recycled water. The task force was composed of individuals representing federal, State, and local government; public health professionals; private sector entities; environmental organizations; the University of California; internationally recognized researchers; and public interest groups. The task force was a cooperative effort of DWR, the State Water Resources Control Board, and the California Department of Health Services (now the California Department of Public Health).
2003	Recycled Water Task Force	California Department of Water Resources	The Recycled Water Task Force presented its findings and recommendations in a final report titled Water Recycling 2030: Recommendations of California's Recycled Water Task Force. The task force estimated the future potential and costs of water recycling and made a wide variety of findings, many of which are reflected in this chapter. The task force issued 26 recommendations to increase water recycling. The recommendations are broad, are not limited to legislative actions or statutory changes, and as of this update are still worthy recommendations in need of being fully implemented. Work has been accomplished on many of the recommendations.
2003	Assembly Bill 334, Water Softening and Conditioning Appliances	California Assembly	This bill authorized local agencies to adopt regulations governing water softeners or conditioning appliances that discharge salt into the community sewer system. The Water Softening and Conditioning Appliances bill specifically authorizes local agencies, by ordinance, to limit the availability or use, or prohibit the installation, of water softening or conditioning appliances that discharge to the community sewer system.
2004	Incidental Runoff of Recycled Water memorandum	State Water Resources Control Board	This memorandum reviewed the legal requirements of federal and State statutes and regulations that relate to the regulation of incidental runoff and, to determine the available regulatory and enforcement options, conducted legal analysis and conducted stakeholder meeting to arrive at the decisions in the memorandum.
2006	Uniform Analytical Method for Economic Analysis framework	State Water Resources Control Board	This was a partially funded research project to develop a Uniform Analytical Method for Economic Analysis framework for evaluating the benefits and costs of water reuse by the WateReuse Foundation (August 2006). The State Water Resources Control Board convened the Economic Analysis Task Force with participation from State, federal and university members in fall 2008.
2006	Climate Action Team, created in response to Assembly Bill 32	California Environmental Protection Agency	The Climate Action Team was created to formulate measures to mitigate the effects of climate change. Water recycling can contribute to the reduction of greenhouse gas emissions by replacing energy-intensive imported water with local recycled water. To that end, the Climate Action Team formulated a water recycling measure to require the development and implementation of wastewater recycling plans. The water recycling CAT measure is identified in Climate Change Scoping Plan: A Framework for Change prepared by the California Air Resources Board in 2008.

Year	Action	Organization	Summary
2007	Assembly Bill 1481, Landscape Irrigation	California Assembly	This bill required the regional water quality control boards to prescribe general waste discharge requirements (a general permit) for landscape irrigation that uses recycled water for which the California Department of Public Health has established uniform statewide recycling criteria. The State Water Resources Control Board adopted the General Permit for Landscape Irrigation of Municipal Recycled Water, which further supports the use of recycled water in California while protecting the water quality.
2009	Recycled Water Policy	State Water Resources Control Board	This action was for implementing state statutes, regulations, and policies for recycled water projects to establish more uniform interpretation (State Water Resources Control Board 2009a, 2009b). This policy aims to increase the use of recycled water from municipal wastewater sources (as defined in California Water Code Section 13050(n)), in a manner that implements State and federal water quality laws.
2009	California Plumbing Code	California Department of Water Resources	This action addressed plumbing within buildings with both potable and recycled water systems. The California version of these provisions was adopted in 2009 and became effective in 2010. This section of the plumbing code will provide guidance throughout the state to safely plumb buildings for indoor use of recycled water for toilet and urinal flushing.
2009	Recycled water symbol change in code	California Department of Housing and Community Development	The department adopted a recycled water symbol change to remove the requirement for the skull-and-crossbones symbol in sections 601.2.2 and 601.2.3 of the California Plumbing Code. Now the symbol is a picture of a glass containing liquid, encircled, and with a line slashed through, indicating the liquid should not be ingested.

With State budget constraints, it is likely that additional sources of funding will be limited in the future. This is a challenge, because implementation of recycled water projects often requires significant capital outlay, which many water suppliers are not able to fund without outside resources. However, given the importance of a reliable water supply to the state's economy, legislative support of providing additional funding for recycled water projects is a critical component of continued recycled water development.

Later in this chapter, the subsection "Affordability" describes sharing costs, regional approaches, planning considerations, and actions that could support implementation costs.

Potential Benefits

Water recycling provides many benefits to local and statewide water supply reliability. Municipal recycled water increases local supplies, supports drought preparedness, supports climate change mitigation and adaptation strategies, provides environmental benefits, and can reduce energy consumption by lowering dependence on imported supplies.

Local Supply

Municipal recycled water has the advantage of being locally generated and reused. The availability of additional local supplies can provide resource-limited communities with additional options for meeting water supply demands. Areas with constrained or declining groundwater supplies or heavy dependence on imported water may realize significant benefit from appropriate reuse of treated municipal wastewater. Recycled water may provide more cost-effective water self-sufficiency options than other resource development alternatives. It can also provide additional water resources to address increased demands from population growth.

Drought Preparedness

Establishing recycled water capacity provides a more reliable water supply resource for water managers to access during drought cycles. Municipal recycled water as a water supply has less variability than traditional resources because domestic water disposal continues even during droughts. Wastewater production will decrease during a drought as households and commercial and industrial facilities conserve, but some wastewater generation will still occur.

Climate Change

Climate change is expected to increase atmospheric temperatures, resulting in a more variable precipitation regime and declining snowpack (California Department of Water Resources 2008). Consequences of the warming climate are anticipated to increase water demand for urban, agricultural, and environmental uses, with a concurrent reduction in water supply availability and reliability.

Municipal recycled water can support climate change adaptation by contributing to sustainability for urban water supplies facing changing climate conditions, particularly where local water supplies are limited. Recycled water can support climate change planning as a source of water for groundwater recharge, surface reservoir augmentation (not currently occurring in California, but occurring in other parts of the country), and salinity barriers for coastal aquifers. Although recycled water supplies can be affected by drought and increased conservation, the fluctuation is usually lower than other resources and is considered to be less sensitive to temperature and precipitation variation expected with climate change.

Energy Savings

Wastewater treatment serves two functions — it makes the water suitable for discharge to the environment and then makes it suitable for beneficial use. When projects are analyzed, treatment energy is allocated to the two functions. Wastewater treatment — and its required energy and GHG emissions — to protect the environment are allocated to pollution control. Any additional treatment necessary to enable the water to be used beneficially is allocated to water supply. When recycled water is used as a water supply source, the energy required above that required for discharge plus the energy for distribution, is the allocation that would be compared for evaluation and comparison of alternative water supply options.

Implementing municipal water recycling could reduce energy consumption, which may also support California's climate change mitigation efforts. The water sector uses a significant amount of energy to convey water from its source to its use. The State Water Project uses two-three percent of the energy consumed in the state and is the single largest user of energy in California (Natural Resources Defense Council 2004). Water recycling can provide a lower-energy source of local water compared with importing water from other regions and desalination of ocean water or brackish waters. Energy savings are greatest when recycled water is used in close proximity to wastewater treatment sources and when additional treatment is not required beyond the treatment needed for wastewater disposal.

Wastewater generally is required to be treated to at least a secondary treatment level before it can be released to the environment. However, in many cases, tertiary treatment of wastewater discharge is required to protect public health or the environment. Recycled water used for most urban applications requires tertiary treatment, which requires a greater amount of energy to produce and, therefore, produces more greenhouse gases (GHG). GHG savings can be realized in two ways — first, not overtreating water that can be beneficially reused at lower levels of treatment, and second, reusing water beneficially that does not have downstream flow requirements. When tertiary treatment is already required for discharge, to take the further step to recycle the wastewater for urban uses, it is necessary only to install infrastructure to convey the recycled water to end users.

Energy savings realized by implementing a recycled water project depend on multiple factors, including the source of the water offset by the recycled water, the amount of increased treatment above that already required for disposal needed to reuse the water, and distance to the point of recycled water use. Research is also ongoing to develop lower-energy recycling methods, which would in turn reduce the GHG generation during the water recycling process. Overall, it is assumed that implementing recycled water would provide an energy use benefit by developing local resources versus importing fresh water. This energy use benefit would also be realized by considering “fit for purpose” in recycled water use planning and by avoiding treating water to a higher level than is necessary for its planned reuse, thus improving energy resource efficiency.

Potential Costs

Augmenting statewide municipal recycled water funding, even in light of current statewide budget issues, is a long-term benefit because it develops local, reliable water supplies. The costs to implement recycled water projects vary based on the amount of water to be treated, treatment requirements, infrastructure needs, project planning, permitting, and financing. As a result, project costs can vary widely, as described further below.

Overall Costs

California’s Recycled Water Task Force (2003) estimated that between 2003 and 2030, an additional 1.4 million to 1.7 million af of additional wastewater could be recycled annually in California, based on growth in available wastewater and increased percentage of wastewater recycling. Of this, 0.9 million to 1.4 million af (62 percent to 82 percent) of the additional recycled water would be from discharges that would otherwise be lost to the ocean, saline bays, or brackish bodies of water (Recycled Water Task Force 2003). To add 1.4 million to 1.7 million af per year of recycled water, the task force estimated that a capital investment of between $9 billion and $11 billion would be required (in 2003 dollars) (Recycled Water Task Force 2003). This amount would be the incremental capital cost above the cost of wastewater treatment for discharge to a water body.

Given the variability of local conditions and their effect on treatment and distribution costs, the current estimated range of capital and operational costs of water recycling range from $300 to $1,300 per af of recycled water, but in some instances costs are above this range. The upper end of the current unit costs for recycled water projects comes from cost estimates recently prepared for two Southern California projects, in San Diego and Oxnard. Costs per af for those projects are estimated to be between $1,191 and $1,900 (Fikes 2012; Wenner 2012). These are urban projects and are reflective of higher-end projects, as well as the increasing costs of implementing recycled water projects. Therefore, for planning purposes, the State should consider that overall costs to reach the Recycled Water Task Force (RWTF) potential estimate will be at the higher end of the estimate range, if not beyond this.

Increased focus on matching water use to water quality is an approach to implement more cost-effective projects while attempting to lessen ratepayer impacts for these projects. In a state where between 70 percent and 80 percent of developed water is used for agriculture, projects that can convey secondary effluent to agricultural users and develop cooperative solutions could be a cost-effective way to meet water resource needs. Overall, the actual cost of recycled water projects will depend on the quality of the wastewater, the level of treatment required, the proximity of potential users to the sources of recycled water, and user costs associated with required upgrades or operational modifications. Uses that require higher water quality or have greater public health concerns, or both, will incur higher costs.

The cost to install new distribution systems is a major obstacle to the expansion of water recycling. Assessing costs of implementing recycled water programs should consider not only the cost of municipal infrastructure and its operation and maintenance, but also the cost to users. In particular, larger industrial, agricultural, or commercial users that may need on-site modifications to maintain a separate water system, including physical barriers for backflow prevention, or process modification to utilize a different water quality. In addition, a user may have additional operating costs for recycled water use as that user integrates recycled water into its water supplies.

Because recycled water is not classified as potable, regulatory constraints prohibit conveying recycled water and potable water in the same pipelines. Under current regulations, recycled water must be conveyed in a separate purple pipe distribution system that is labeled and readily distinguished from potable water lines. The cost to install new purple pipe distribution mains from treatment plants to users can exceed the costs of obtaining alternate water sources or projects — including, in some cases, the cost of potable reuse projects. As a consequence, extension of purple pipe systems to areas near treatment plants can be more cost-effective than extending infrastructure and service to more distant users. Distribution system cost can be an obstacle when evaluating the feasibility of supplying recycled water to large numbers of users or users more distant from urban wastewater treatment plants. Some agencies have constructed satellite water recycling facilities to provide recycled water at locations near large concentrations of use.

How cost is a potential issue to increasing recycled water use in California is discussed further in the next section.

Individual User Costs

Additional costs that individual recycled water users may need to incur to receive recycled water include installing dual plumbing, modifying facility processes to use water of a different quality, and implementing cross-connection prevention. These can be significant cost components to potential recycled water customers using both potable and non-potable water.

Cross-connections, the accidental direct contact between potable and non-potable water systems, can contaminate potable water systems. Air gaps, valves, or other controls are installed to prevent cross-connections because of inadvertent pipe connections, pressure loss, or other failures. Specific requirements vary by the water supplier or governmental agency. State regulations to protect public potable water systems from contamination by non-potable water are in CCR Title 17 adopted by the CDPH.

The California Plumbing Code specifies protections to prevent potable water lines on the property of users from contamination. Its provisions governing dual plumbing in buildings were adopted in California in 2009. These codes established statewide standards to install both potable and recycled water plumbing systems in commercial, retail, and office buildings; theaters; auditoriums; condominiums; schools; hotels; apartments; barracks; dormitories; jails; prisons; reformatories; or other structures as determined by the CDPH. Some potential recycled water customers have faced challenges working with local inspectors to implement dual-plumbed systems, but these issues are expected to decrease as the systems become more common.

Major Issues

There are many issues involved in planning and implementing recycled water projects. However, based on the many successful projects in California, potential obstacles are not insurmountable. Awareness of potential issues and sound planning practices to address or prevent negative impacts are key components of successful project development. Successfully implemented projects have also included early involvement of affected agencies, potential recycled water customers, other stakeholders, and representatives of public interests.

Identifying and planning successful approaches to issues that could hinder the implementation of increasing recycled water use both locally and statewide is critical for continued growth. The Recycled Water Task Force (2003) identified 26 recycled water “issues, constraints, and impediments” and provided recommendations to address them. More recently, three efforts conducted since Update 2009 addressed issues (also referred to as barriers or challenges) facing increased municipal recycled water use. These efforts were:

- *Integrated Water Resources Plan: 2010 Update* (Metropolitan Water District of Southern California 2010).
- *Draft Commercial, Institutional and Industrial Task Force Water Use Best Management Practices Report to the Legislature* (California Department of Water Resources 2013a).
- *Water Reuse: Potential for Expanding the Nation’s Water Supply Through Reuse of Municipal Wastewater* (National Research Council 2012).

Input from these documents supported development of the issue discussions included in this section. However, continued discussion regarding sometimes opposing recycling issues, such as how to finance projects, higher costs for higher treatment, matching water quality to use, chemicals of emerging concern, regulatory requirements, and public acceptance continue to challenge expansion of recycled water use. As part of future recycled water planning, it is recommended to reconvene the RWTF to provide a forum to discuss these issues and develop implementable solutions. It is recommended that the reconvened RWTF work in cooperation with the Advisory Panel being established by CDPH and to assess direct potable reuse and indirect potable reuse issues.

The issues addressed below are commonly confronted in planning and developing local and regional recycled water projects. DWR and other State agencies directly involved with recycled water will support local efforts by preparing applicable statewide recycled water planning documents. This will include reviewing the National Research Council's recommendations (2012) and other applicable documents (e.g., National Water Research Institute 2012) and integrating those that are applicable to California.

Affordability

The affordability of recycled water has to be viewed from various perspectives, such as those of agencies implementing recycled water projects, users of recycled water, suppliers of potable water whose revenue may be affected by recycled water use, and sewer and potable water ratepayers who may see their rates affected by recycled water use. The costs of recycled water projects may include: additional treatment above current wastewater treatment, disposal of treatment byproducts, storage and pump facilities, and recycled water pipeline distribution systems. In addition, there may be on-site costs at user sites for specialized treatment of the recycled water, including on-site plumbing, cross-connection control devices, and potential modification of commercial or industrial processes to accommodate recycled water. The responsibility for payment of these costs depends on sources of revenue or financial assistance and how agencies agree to share costs based on the perceived beneficiaries.

The common reference point for water suppliers and users is what they currently pay for alternative water sources, such as potable water, or what agencies will have to pay in the future for new water supplies. Water suppliers in California are often dependent on other wholesale suppliers for their water supply. Prices for water often are set to recover costs from past projects and do not reflect the more expensive costs of new water supplies. Thus, prices are not a good benchmark for the true economic cost of new water supplies. New freshwater supplies are often developed at the regional or state level, whereas recycled water projects are often developed at the sub-regional or local level. It is difficult for any one water supplier or user to see the total water supply picture from the standpoint of costs.

Much of the water provided by federally funded projects is provided at discounted prices. Artificially low rates discourage adoption of water recycling and similar conservation programs. Consequently, there is growing recognition that pricing should more closely reflect the true costs to provide water and thus encourage more efficient use of existing water supplies. As stated in the National Research Council's 2012 report on national water recycling, "Current reclaimed water rates do not typically return the full cost of treating and delivering reclaimed water to customers." Water pricing issues need to be considered early in the planning process for recycled water and thoroughly vetted with potential customers.

Some benefits or costs can be difficult to quantify and, even though real, are accrued indirectly such that they are not reflected in project costs. Recycled water has a benefit of reliability during droughts, but the monetary benefit accrues to the general economy and not to water suppliers.

Economic tools can provide a quantification of many indirect costs and benefits, and an economic analysis can be used to compare recycled water and other water projects on an equal basis by looking at total costs and benefits to society as a whole. When economic analysis finds recycled water to be cost-effective compared with alternative water supplies, the challenge should then be to allocate costs according to beneficiaries and to use financial incentives, such as regional rebates or State and federal loans and grants, to encourage local water suppliers to build recycled water projects.

Interagency cooperation can be a way to allocate costs according to beneficiaries and to achieve multiple objectives. Recycled water can improve regional water reliability and offset potable water that can be used in other areas. Regional water supplier partners can help local recycled water projects by contributing to construction and operation costs reflecting the regional benefits. Because of high initial infrastructure costs, many California communities are developing cooperative recycled water projects. These projects are developed and implemented locally to best serve the local needs. Projects have been developed where one community provides wastewater to another that then treats it to recycled water standards and distributes it. Another institutional arrangement involves a wastewater agency producing recycled water and a partnering water agency distributing it. Yet another option is for large wholesale water purveyors to finance, construct, and operate regional distribution systems within their service area to serve multiple small retail purveyors that may not have the resources to pursue individual projects or may not be proximate to the source of recycled water.

Advancements in water recycling treatment technology may bring down costs in the future, especially for indirect and, potentially, direct potable reuse, where high levels of treatment are often required. Another way of reducing costs is to incorporate purple recycled water pipelines in new developments at the same time as potable water lines are being installed. Long-range planning can anticipate where future recycled water users should be.

Nevertheless, dedicated recycled water distribution systems are costly. Adding recycled water to sources of drinking water (e.g., aquifers or surface reservoirs) eliminates the need for dual distribution systems. Introducing highly treated recycled water directly into potable water pipelines could also eliminate the need for separate recycled water lines. Groundwater recharge is widely practiced in California, but suitable aquifers are not available everywhere. Indirect potable reuse by augmenting surface drinking water reservoirs with recycled water and direct potable reuse currently does not occur in California, but such practices would give communities more flexibility in how recycled water could be used at potentially lower cost than non-potable reuse through separate recycled water pipelines. SB 918 and SB 322 established a schedule for the CDPH to evaluate surface water augmentation and adopt regulations and to evaluate direct potable reuse and report to the Legislature.

The availability of local funding sources continues to challenge the implementation of new projects or the expansion of existing projects. Where a recycled water project is found to be cost-effective from an evaluation of all costs and benefits from society's perspective, but more expensive than alternatives from a local perspective, there is a role for regional, State, and federal financial assistance to encourage the optimum water resource solution. As discussed earlier, a key source of State funding has been the Water Recycling Funding Program administered by the SWRCB, which provides low-interest loans and grants to local agencies. DWR administers the IRWM Grant Program. Water recycling is an RMS that must be considered by an integrated regional water management plan (IRWMP) and may be utilized as an active component of the plans to help a region meet water management goals and objectives. Inclusion of wastewater agencies in the IRWM process has occurred in some regions. Continued and expanded inclusion facilitates the identification of municipal recycled water projects as viable water supply projects and facilitates the interaction of water and wastewater agencies to identify mutually beneficial solutions to common issues. Water recycling projects identified in IRWMPs to be a key strategy may qualify for IRWM grant funding. The federal government, through the U.S. Bureau of

Reclamation, has been a major contributor of grants and loans to recycling projects in California, primarily through the Title XVI program, but like State programs, has had availability and accessibility challenges.

Water Quality

Water quality criteria for recycled water, established by the CDPH, define water quality and treatment requirements to protect public health for most expected uses of recycled water. RWQCBs establish water quality requirements to protect the beneficial uses of surface and groundwater bodies. Under current regulations, RWQCBs issue the waste discharge or water reclamation permits to recycled water producers, distributors, and users. These permits incorporate water quality and monitoring requirements for recycled water projects, including health department criteria to protect public health and any site-specific requirements for protecting water quality.

Recycled water quality is to protect environmental and human health in order to support current uses and long-term sustainability. Recycled water quality issues include:

- Pathogen content (primarily bacteria and viruses).
- Salinity.
- Nitrogen compounds.
- Heavy metals.
- Organic and inorganic substances (often of commercial and industrial origin, but also pharmaceuticals and personal care products, household chemicals and detergents, fertilizers, pesticides, fungicides, and hormones), including chemicals of emerging concern.

Chemicals of emerging concern, described earlier in this chapter within the section about the Recycled Water Policy, are found in wastewater and may occur in recycled water at very low concentrations. Research is ongoing regarding potential impacts of chemicals of emerging concern in recycled water, particularly with respect to effects on human health or the environment. Currently, there are no established regulatory limits for chemicals of emerging concern, but some monitoring is required by the CDPH and the SWRCB as a precaution for protection of human health and the aquatic environment.

The SWRCB's expert panel on chemicals of emerging concern (State Water Resources Control Board 2010) provided recommendations, based on available information, for constituents to be included in required monitoring of various types of recycled water projects. These recommendations have been incorporated into the Recycled Water Policy. As additional information becomes available, future changes can be made to regulations and policies to protect California's water resources while supporting implementation of new projects.

The Recycled Water Policy encourages the development of salinity and nutrient management plans. These plans address salinity and nitrogen issues, including changes that may occur with the use of recycled water. Therefore, implementation of a recycled water program may be enhanced by the parallel development of a salinity and nutrient management plan. In addition to water quality being protective of human and environmental health, aligning water quality to end use is a key component of recycled water planning and implementation (see Chapter 17 within this volume, "Matching Water Quality to Use"). The planned end uses and commercial/industrial application compatibilities are crucial recycled water considerations. In many cases, recycled water is integrated into existing processes. Most commercial and industrial applications are sensitive to water quality, and recycled water typically has more minerals and organic content than many available alternative supplies. Subtle changes in water quality, such as increases or decreases of certain minerals or chemical species, can dramatically change the suitability of recycled water or the treatment requirements for use in an industrial process. Many water quality concerns associated with recycled water can be and are addressed with additional treatment by the water utility, on-site treatment, or other water management practices. These additional efforts have to be considered during recycled water planning, along with financial impacts and responsibilities.

Public Acceptance

Public acceptance of recycled water projects is critical for their success. Water quality and cost factors are two issues often raised by the public. Integrating public input into the project planning phase has been a successful approach for many agencies.

In general, there is public acceptance and support for most non-potable recycled water applications, such as agricultural and landscape irrigation, where there is a lower degree of direct human exposure. Public acceptance can be lower for projects with more direct links between recycled water and human consumption or contact. In addition, the public expects assurances that recycled water is safe and regulations protect the public from misuse. Outreach, education programs, and involvement during project planning can provide public reassurance that recycled water is adequately regulated to protect public health.

Environmental buffers — natural processes separating treated recycled water from human end uses — frequently enhance public acceptance of recycled water projects and differentiate indirect and direct potable reuse, as explained earlier. For example, public concern about mixing recycled water with groundwater appears to be partly alleviated when infiltration, percolation, and underground residence time expose the water to natural cleansing processes after engineered treatment. The actual benefit of environmental barriers versus engineered treatment with system controls has not been fully quantified. Additional research and planning may support how environmental buffers and engineered controls are perceived by the public and implemented in future projects.

Impacts on Downstream Users

Communities that discharge wastewater to rivers and streams contribute to the ambient water available for use by downstream users. The implementation of water recycling in upstream communities would reduce the volume of such discharges, potentially reducing the volume of ambient water available for downstream reuse or fulfillment of environmental needs. In some circumstances, downstream users may have rights to the use of discharged wastewater, potentially preventing upstream communities from implementing recycling.

In the case of groundwater recharge with recycled water, the availability of groundwater downgradient may be increased, but there may be water quality impacts. Whether for storage or planned indirect use, the discharge of recycled water to wells, infiltration sites, or other locations underlain by permeable soil and geologic materials has the potential to introduce contaminants, including salts, into potable groundwater sources and aquifers. Modern microfiltration, reverse osmosis, and disinfection practices produce exceedingly high-quality recycled water, but concerns about pathogens, emerging contaminants, or other potentially unknown contaminants warrant continued research to advance the science and technology in this area. Presently, California does not approve direct potable reuse projects, that is, where recycled water is piped directly from a treatment plant into a drinking water supply.

Recommendations

1. **Reconvene the Recycled Water Task Force.** The RWTF presented 26 recommendations to increase water recycling in its 2003 report, *Water Recycling 2030: Recommendations of California's Recycled Water Task Force*. Since completion of the RWTF report, significant accomplishments have resulted from implementing the task force's recommendations. Additional statewide and local issues associated with specific approaches to increasing recycled water use continue to be discussed. Because of the wide range of issues and sometimes differing approaches, reconvening the RWTF would provide the forum for meaningful discussion, development of consensus, and guidelines for future statewide actions.

2. **Develop approaches to facilitate increasing statewide use of recycled water for agricultural and environmental uses.** DWR, in cooperation with the SWRCB and the RWQCBs, will identify obstacles to increasing agricultural and environmental reuse of recycled water, with an emphasis on applications using secondary-treated wastewater to avoid the additional treatment cost and GHG emissions of higher levels of treatment. The focus of this effort is to implement "fit for purpose" and matching wastewater treatment levels to water quality requirements for the planned reuse to support meeting the State's 2020 and 2030 targets for recycled water use.

3. **Develop a uniform interpretation of State standards for recycled water.** State agencies including the SWRCB, the RWQCBs, the CDPH, DWR, and the CPUC should develop a uniform interpretation of State standards for inclusion in regulatory programs and IRWMPs and should clarify regulations pertaining to water recycling, including permitting procedures, health regulations and the impact on water quality. It is important to recognize that uniformity in State standards does not mean uniformity in permit terms and conditions, however, as implementation should account for the variability in local conditions and local needs. Implementing this recommendation could also streamline existing regulations about recycled water. Internal and cross-training of agency staff could be a key method of accomplishing this.

4. **Continue to review opportunities for recycled water development.** DWR will continue to identify opportunities to increase statewide planning, development, and implementation of recycled water. It is intended that this will be accomplished with comprehensive statewide planning documents and regional interactions over the next few years.

5. **Incorporate wastewater agencies into regional IRWM processes.** Inclusion of wastewater agencies into regional IRWM processes has been initiated in some regions. Increasing this integration will facilitate the integration of recycled water into the water supply planning process. In addition, potential recycled water customers should be involved in the IRWM and recycled water project planning process to identify potential partnerships, assess the viability of recycled water projects, and consider future CII water quantity and quality planning.

6. **Provide dedicated recycled water funding.** The State Legislature is urged to provide additional funding dedicated to planning and implementing recycled water projects in California. Although some funds are available through IRWM grants and loans, the cost of implementing these projects can make them difficult to put forth in the existing grant processes, especially with so many water suppliers facing financial challenges. If California intends to reach its water recycling mandates and goals and support future water supply reliability to support economic growth, then additional funds dedicated to recycled water implementation will need to be provided. Additional funding sources will be needed when Proposition 84 funds are no longer available.

7. **Develop reliable electronic reporting methods for recycled water data.** To be able to monitor progress in meeting targets or achieving progress in beneficially using recycled water, there is a need for reliable and periodic data collection. Voluntary surveys have been the historic method of data collection. Mandating standardized data collection integrated with electronic reporting could facilitate the collection of data and the availability of the data for use. DWR, the SWRCB, and the CDPH should work together to accomplish this objective.

References

References Cited

California Air Resources Board. 2008. *Climate Change Scoping Plan: A Framework for Change.* Sacramento (CA): California Air Resources Board. Viewed online at: http://www.arb.ca.gov/cc/scopingplan/document/scopingplandocument.htm. Accessed: Nov. 20, 2012.

California Department of Public Health. 2011. *Draft regulations for the replenishment of groundwater with recycled water*. Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Documents/Recharge/DraftRechargeReg-2011-11-21.pdf. Accessed: March 13, 2013.

California Department of Water Resources. 2008. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water*. Sacramento (CA): California Department of Water Resources. 30 pp. [White paper.] Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf. Accessed: Nov. 19, 2012.

———. 2013a. *Draft Commercial, Institutional and Industrial Task Force Water Use Best Management Practices Report to the Legislature*. Sacramento (CA): California Department of Water Resources. Volumes I and II. [Report to the Legislature.] Viewed online at: http://www.water.ca.gov/calendar/index.cfm?meeting=20142. Accessed: Nov. 14, 2012.

——— 2013b. *Determination of Revised Statewide 2020 and 2030 Municipal Recycled Water Use Goals*. In preparation.

Fikes BJ. 2012. "Recycling sewage to drinking water could save city of San Diego money: Study." Escondido (CA): North County Times. [Newspaper article.] Viewed online at: http://www.nctimes.com/business/recycling-sewage-to-drinking-water-could-save-city-of-san/article_9a5540f2-1383-5186-8a42-8e5959dc8a3b.html. Accessed: Nov. 19, 2012. Last updated: June 2, 2012.

Metropolitan Water District of Southern California. 2010. *Integrated Water Resources Plan: 2010 Update.* Los Angeles (CA): Metropolitan Water District of Southern California. Report No. 1373. Technical Appendix A-10. Viewed online at: http://www.mwdh2o.com/mwdh2o/pages/yourwater/irp/IRP2010Report.pdf. Accessed: Nov. 14, 2012.

National Research Council. 2012. *Water Reuse: Potential for Expanding the Nation's Water Supply Through Reuse of Municipal Wastewater*. Washington (DC): National Academies Press. 262 pp. [Book.] Viewed online at: http://www.nap.edu/catalog.php?record_id=13303. Accessed: Nov. 14, 2012.

National Water Research Institute. 2012. *Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation*. Fountain Valley (CA): National Water Research Institute. 14 pp. [White paper.] Prepared by Schroeder E, Tchobanoglous G, Leverenz HL, and Asano T, Department of Civil and Environmental Engineering at the University of California, Davis. Viewed online at: http://www.nwri-usa.org/documents/NWRIWhitePaperDPRBenefitsJan2012.pdf. Accessed: Nov. 19, 2012.

Natural Resources Defense Council. 2004. *Energy Down the Drain The Hidden Costs of California's Water Supply*. 78 pp. [Report.] Prepared by Cohen R, Nelson E, and Wolff G. Viewed online at: http://www.nrdc.org/water/conservation/edrain/edrain.pdf. Accessed: Dec. 16, 2013.

Recycled Water Task Force. 2003. *Water Recycling 2030: Recommendations of California's Recycled Water Task Force*. Sacramento (CA): California Department of Water Resources, State Water Resources Control Board, and California Department of Health Services. 300 pp. [Report.] Viewed online at: http://www.water.ca.gov/pubs/use/water_recycling_2030/recycled_water_tf_report_2003.pdf. Accessed: Nov. 19, 2012.

RMC Water and Environment. 2009. *Final Technical Memorandum, Eastside Non-Potable Water Use Study*. Prepared for: San Francisco Public Utilities Company. November 17.

State Water Resources Control Board. 1990. *California Municipal Wastewater Reclamation in 1987*. June.

———. 2004. *Incidental Runoff of Recycled Water*. [Memorandum.] Sacramento (CA): State Water Resources Control Board. Feb. 24, 2004.

———. 2008. *Strategic Plan Update 2008-2012*. Sacramento (CA): State Water Resources Control Board. 45 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/hot_topics/strategic_plan/docs/final_draft_strategic_plan_update_090208.pdf. Accessed: Nov. 19, 2012.

———. 2009a. *Resolution No. 2009-0011: Adoption of a Policy for Water Quality Control for Recycled Water*. Sacramento (CA): State Water Resources Control Board. 3 pp. Viewed online at: http://www.swrcb.ca.gov/board_decisions/adopted_orders/resolutions/2009/rs2009_0011.pdf. Accessed: Nov. 19, 2012.

———. 2009b. Recycled Water Policy. Sacramento (CA): State Water Resources Control Board. 14 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/recycledwaterpolicy_approved.pdf. Accessed: Nov. 19, 2012.

———. 2009c. *Resolution No. 2009-0059: Approval of Certification Pursuant to the California Environmental Quality Act of the Mitigated Negative Declaration Covering General Waste Discharge Requirements for Landscape Irrigation Uses of Municipal Recycled Water 2009-0006-DWQ*. Sacramento (CA): State Water Resources Control Board. 2 pp. Viewed online at: http://www.swrcb.ca.gov/board_decisions/adopted_orders/resolutions/2009/rs2009_0059.pdf. Accessed: Nov. 19, 2012.

———. 2010. *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in Recycled Water: Recommendations of a Science Advisory Panel*. [Final report.] Sacramento (CA): State Water Resources Control Board. 220 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/water_recycling_policy/docs/cec_monitoring_rpt.pdf. Accessed Nov. 19, 2012.

———. 2012. "Municipal Wastewater Recycling Survey." [Results of 2009 survey.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/grants_loans/water_recycling/munirec.shtml. [Also on the Web site is a link to the article "Results, Challenges, and Future Approaches to California's Municipal Wastewater Recycling Survey," which was written by DWR and SWRCB staff.]

U.S. Environmental Protection Agency. 2012. *2012 Guidelines for Water Reuse*. EPA/600/R-12/618. Viewed online at: http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf.

Wenner G. 2012. "Oxnard's water recycling plant moving forward." Camarillo (CA): Ventura County Star. June 21. Viewed online at: http://www.vcstar.com/news/2012/jun/21/oxnards-water-recycling-plant-moving-forward/. Accessed: Nov. 19, 2012.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 13

Surface Storage — CALFED

Glenn and Colusa Counties. The proposed Sites Reservoir, a North-of-the-Delta Offstream Storage alternative, would divert Sacramento River water through existing canals and a new pipeline to this offstream reservoir location. The reservoir is designed to provide additional water to improve water quality as well as urban, agricultural, and refuge water supply; it also will provide ecosystem restoration and other benefits.

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Surface Storage in California

California remains significantly dependent upon surface water. A review of the California Water Balance Summary, 2001-2010 (Volume 1, Chapter 3, Table 3-2), indicates that in an average year like 2010, about 65 maf (million acre-feet) (more than 80 percent) of 80 maf total dedicated and developed water supply is associated with surface water. Surface storage is an essential element of managing the state's surface water resources.

The naturally arid conditions found in much of California, coupled with seasonal variations of too much or too little water prompted water planners of the past to implement conveyance and storage projects to support land development, population, and economic growth. After construction, these dams captured seasonal runoff and stored it for beneficial uses during drier times. Today, these projects facilitate a larger set of water management objectives including reliable water supplies, water quality and ecosystem maintenance, flood management, and hydropower generation. In many areas of the state, surface water and groundwater are used conjunctively. Coordinated surface water and groundwater management can be either formal or informal. For example, a managed groundwater recharge program where surface water is infiltrated to an aquifer for later use is formal; excess applied surface water in agricultural areas during wetter years that increases the availability of groundwater in drier years is often more informal.

Dams and surface water storage continue to be a critical tool for providing water management flexibility in California. The amount of surface water in California, as noted above, often make it a foundational integration element of more diverse local and regional water management portfolios. In addition to storing water for use by residents, businesses, and industries, these facilities provide vital supplies during warm and dry periods for growing crops and maintaining the state's managed wildlife refuges.

CALFED Surface Storage in California

The CALFED Record of Decision (2000) identified five potential surface storage reservoirs that are being investigated by the California Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), and local water interests:

- Shasta Lake Water Resources Investigation (SLWRI) — Draft Feasibility Report released February 2012/Draft EIS released June 2013.
- North-of-the-Delta Offstream Storage (NODOS) — administrative draft feasibility report and Administrative Draft EIR released May 2014.
- In-Delta Storage Project (IDSP) — Delta Wetlands Project — Draft EIR 4/2010.
- Los Vaqueros Reservoir Expansion (LVE).
- Upper San Joaquin River Basin Storage Investigation (USJRBSI) — Draft Feasibility Report released January 2014; Draft EIS released August 2014.

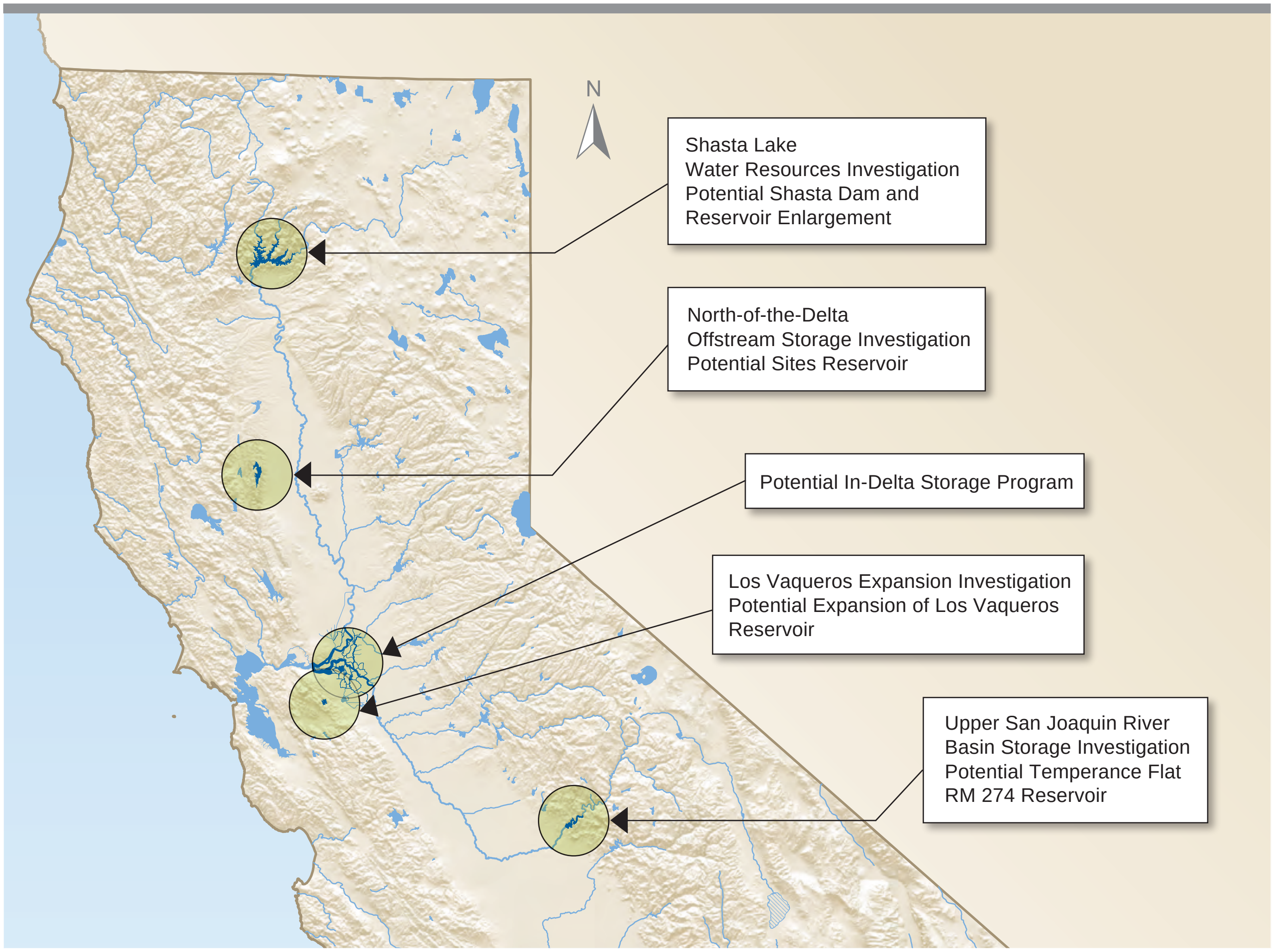
These five investigations were recommended after the CALFED Program evaluated and considered 52 sites. An initial screening identified and eliminated those reservoir sites that were clearly impracticable for the CALFED Program. The following summary provides a snapshot of the current status of the five CALFED Surface Storage Investigations. Additional information is at http://www.water.ca.gov/storage/index.cfm. The general locations of the initial alternatives reflected in the summary below are shown in Figure 13-1, "General Location of CALFED Surface Storage Initial Alternatives."

The proposed water bond, "Funding for Water Quality, Supply, Treatment, and Storage Projects," if approved by voters, would provide $2.7 billion for new water storage. CALFED surface storage is one type of eligible storage. This public money would be used to invest in public benefits including ecosystem restoration, flood management, water quality, emergency response, and recreation. According to the bond proposal, water supply reliability benefits for urban or agricultural users would be paid for by those beneficiaries. The California Water Commission, consistent with direction in this legislation, has begun developing methods for the quantification and management of these potential public benefits.

Water resources planning has changed significantly over the past several decades. New approaches to planning for CALFED surface storage has resulted in a new era of project formulations designed to address a new era of water resources needs. The State and federal governments have funded the five surface storage investigations, which were explicitly conceived to support at least three of CALFED's program objectives: water supply reliability, water quality, and ecosystem restoration. From the outset, investigation planners acknowledged that the dam building model of the past (i.e., onstream reservoirs built primarily for agricultural and urban users and flood protection) would not be helpful in solving California's current water challenges. In fact, these approaches would likely exacerbate many of the state's water resources problems, especially perceptions about winning and losing in California's water battles. Consequently, CALFED considered new onstream storage untenable. However, offstream storage or expansion of existing onstream reservoirs were considered to be consistent with CALFED solution principles. For example, of the initial investigation formulations described in this status summary, Los Vaqueros, Sites Reservoir (North-of-the-Delta Offstream Storage), and In-Delta Storage are considered offstream; Shasta Lake enlargement and Temperance Flat (Upper San Joaquin River Basin Storage) are considered expansions of existing onstream reservoirs. In addition, formulations would emphasize effective mitigation of impacts and would not limit consideration of environmental effects to mitigation, but instead would be designed to improve environmental conditions. Project purposes emphasize multi-objective storage, combining newer objectives associated with ecosystem restoration and water quality with more traditional purposes of water supply reliability, hydropower, and flood control. More specifically, these new projects would support aquatic ecosystem restoration focused on the Delta and its tributaries, improved drinking and habitat water quality, and water supply reliability improvements that ultimately support California's growing population and diverse economy.

The CALFED surface storage project formulations have dedicated significant project resources to public benefits including ecosystem restoration, water quality, and water supply reliability for environmental uses (e.g., refuge water supply) (see Table 13-1, "CALFED Surface Storage 2010 Progress Report Benefits Summary") that would be paid for by the State and/or federal governments. Contributions to a reliable water supply are also explicitly included. Urban and agricultural water supply reliability is considered a non-public benefit that would be paid for by water users. In addition, tribes could be potential beneficiaries of the projects. Note that this

Figure 13-1 General Location of CALFED Surface Storage Initial Alternatives



summary includes information from the 2010 Progress Report and does not reflect changes now included in the more recent environmental and feasibility documents.

California's water resources future has become increasingly uncertain. Consequently, these projects will need to perform well under a number of potential future conditions including climate change, alternative Delta conveyance and management, and disaster/emergency response. The investigations should consider a project's effectiveness as precipitation and runoff patterns change and sea level rises, with either existing or new Delta conveyance and management and potential implementation of multiple storage facilities. Storage should also support adaptively managed restoration approaches based on new or improved science, changes in the viability of species, and modified restoration priorities. While flexibility may be challenging to value, a robust response to various future scenarios will help ensure that projects would remain "no-regrets" investments.

The continuing CALFED Surface Storage Investigations are in their final phase of planning. Funding for In-Delta Storage ended in 2005; the four remaining investigations are ongoing. State funding for State agencies to participate in the Shasta Lake investigation also ended

Table 13-1 CALFED Surface Storage 2010 Progress Report Benefit Summary

Investigation (Reservoir Initial Formulation Shown)[a]	New Storage Capacity (taf)	Average Annual Yield (taf / year)	Drought Yield[b]	Yield Estimate Includes	Benefits Not Included in Yield Estimate
Los Vaqueros Expansion	115	13 147	3 86	Water Supply[c] Ecosystem (diversion through new fish screens)	Emergency Water Supply Water Quality
North-of-the-Delta Offstream Storage (Sites Reservoir)	1,800	560 183 197 180	387 209 112 66	Total Water Supply Water Quality Ecosystem Restoration	Flexible Hydropower Generation Recreation Flood Damage Reduction
Shasta Lake Water Resources	634	74	71	Total to be distributed to water supply, ecosystem restoration, and water quality	Dedicated storage for anadromous fish Hydropower Recreation
Upper San Joaquin River Basin Storage (Temperance Flat RM 274)	1,260	140	86	Total to be distributed to water supply, ecosystem restoration, and water quality	Flood Damage Reduction Hydropower Recreation Ecosystem Restoration Water Quality Emergency Water Supply
In-Delta Storage[d]	217	107 30 18 13 2 44		Total Urban + Ag Groundwater Banking Ecosystem Restoration Refuge Water Quality	Ecosystem Restoration (non flow-related)

Notes:

taf = thousand acre-feet

[a] Initial Investigation Formulations are from the 2010 CALFED Surface Storage Investigations Progress Report, unless noted, and are not feasibility or environmental document alternatives.

[b] Drought yield is the average annual yield associated with the driest periods, which include 1928-1934, 1976-1977, and 1986-1992.

[c] Water supply may include municipal and industrial, agricultural, and refuge water supply reliability improvements.

[d] In-Delta Storage information was compiled from the 2004 Draft – State Feasibility Study and 2006 Supplemental Report of the In-Delta Storage Project.

in 2005. DWR and the USBR are coordinating planning assumptions and documents with the Bay Delta Conservation Plan (BDCP) and Delta Habitat Conservation and Conveyance Program (DHCCP) so that potential future changes to Delta conveyance can be considered in surface storage planning. DWR and USBR plan significant outreach and stakeholder input throughout this final phase, especially during the comment period of the environmental documents. Planning requirements for large surface storage projects are extensive. A more comprehensive listing of regulatory permits and compliances that would likely be required, as compiled by one of the investigations is shown in Tables 13-2 and 13-3.

Potential Benefits

The size and location of these surface storage projects facilitates accomplishing water resources benefits in two distinct ways. First, many benefits are achieved directly by releases from new storage. Second, additional storage can provide significant system flexibility such that other facilities' operations can be modified without reducing current benefits to support additional benefits within the system. Additional water in storage can be used either to improve ecosystem functions and conditions for targeted species, or to improve water quality or supply reliability for water users. Another important characteristic of these proposals is the geographic location of the benefits. A number of the environmental benefits occur within the Sacramento-San Joaquin Delta. Other environmental benefits are targeted at the Delta's tributaries including the Sacramento River and the San Joaquin River and other rivers downstream of existing reservoirs, recognizing the direct connections between tributary and estuarine health. Water supply reliability improvements are generally for State Water Project (SWP) and Central Valley Project (CVP) contractors or environmental uses (i.e., refuges). However, these reliability improvements could be directed to other beneficiaries, including other users such as local and regional water suppliers, tribes, or contractors of other systems if those entities become project participants.

Performance of the CALFED surface storage projects is measured using an operations simulation of the CVP and SWP systems, using the historic hydrologic sequence 1922-2003 run through a simulation model of the water projects (CALSIM II). CALSIM II provides detailed information related to operations of the system under with and without project conditions. Results are often reported with both average annual values and driest periods average annual values, reflecting the importance of performance under dry and drought conditions. Drought performance has become increasingly important, as water managers and decision-makers acknowledge challenges California will face with future drought conditions. This type of comprehensive analysis allows investigators to determine how much water from a proposed project will be used to meet needs that would not be met without the project. In addition, DWR and USBR have developed a suite of analytical tools that are used in a coordinated manner with the operations simulation to assess other important characteristics including Delta water quality, Sacramento River temperature, water quality, fishery effects, river meander, sediment transport, riparian success, and water resources economics. DWR, USBR, and other agencies have developed a Common Assumptions process that establishes a common set of analytical tools, operations, planning assumptions, and reporting metrics so that projects are evaluated with a common foundation.

In 2010, DWR, in coordination with Reclamation and Contra Costa Water District, published the CALFED Surface Storage Investigations Progress Report. Some detail associated with specific benefits is shown in Table 13-1, "CALFED Surface Storage 2010 Progress Report Benefits Summary." An initial alternative from each investigation is described here and in Table 13-4, "CALFED Surface Storage 2010 Progress Report Cost Summary." These initial alternatives are

Table 13-2 Primary Environmental Permits/Compliance Issues

State
DEPARTMENT OF FISH AND WILDLIFE CODE SECTIONS:
5937-Water Diversions and Fish
3511-Fully Protected Birds
4700-Fully Protected Mammals
3503-Specified Birds
3505-Eggs and Nests
3503.5-Birds of Prey
Department of Fish and Wildlife Streambed Alteration Agreement
California Environmental Quality Act
California Endangered Species Act
California Water Rights
Executive Order 12898—Environmental Justice
Executive Order 11990—Wetlands Protection
Natural Community Conservation Planning Act
Native Plant Protection Act
Regional Water Quality Control Board Storm-water Permit
Federal
1899 Rivers and Harbors Act
Energy Regulatory Commission License
Fish and Wildlife Coordination Act
Migratory Bird Treaty Act
National Environmental Policy Act
Clean Water Act Sections 404 and 401
Other
Local Permits and Compliances
Public Trust Doctrine

not feasibility or environmental documentation alternatives and are not necessarily the preferred alternative. However, the initial alternatives described here are being and have been used to inform the formulation of alternatives for feasibility and environmental documents that are now in development. The Progress Report did not evaluate an In-Delta Storage initial formulation. Consequently, a 2004 DWR State feasibility study report for the In-Delta Storage Program and a 2006 draft supplemental report is used for In-Delta information shown in the tables. No additional State or federal funding for the program has been received since 2006. Consequently,

Table 13-3 Primary Cultural Resource Permits/Compliance Issues

Federal	
	American Indian Religious Freedom Act of 1978 (42 USC 1996)
	Archaeological and Historic Preservation Act of 1974 (16 USC 469)
	Archaeological Resource Protection Act of 1979 (16 USC. 470)
	Archeology and Historic Preservation: Secretary of the Interior's Standards and Guidelines (48 CFR 44716)
	Determination of Eligibility for Inclusions in the National Register of Historic Places (36 CFR Part 63)
	National Historic Preservation Act of 1966(16 USC 470, Section 106)
	National Register of Historic Places (36 CFR Part 60)
	Native American Graves Protection and Repatriation Act of 1990 (25 USC 3001)
	Protection of Archaeological Resources: Uniform Regulations (43 CFR 7)
	Protection of Cultural and Historic Properties (36 CFR Part 800)
	Reclamation Cultural Resources Directives and Standards LND 02-01
	Reclamation Cultural Resources Management Policy LND-P01
State	
	California Environmental Quality Act (Public Resources Code Sections 21083.2 and 21084.1, and Section 15064.5 of the CEQA Guidelines)
	California Health and Safety Code (Section 7070.5(b))

study results are not consistent with the Common Assumptions being used by the other CALFED Surface Storage Investigations. The In-Delta storage reports are available at http://www.water.ca.gov/storage/indelta/index.cfm.

Potential Costs

Costs have been estimated for an initial alternative for each of the CALFED Surface Storage Investigations. The costs shown in Table 13-4 reflect the same initial formulation as described in the Potential Benefits section above so that benefits and costs can be considered together. As noted previously, the initial formulations shown here are not necessarily the preferred alternative, but will be used to inform the alternatives that will be selected and analyzed in the environmental and feasibility planning documents. The investigations are also considering several cost-saving measures that have been identified in value engineering studies that may be incorporated into final formulations that are included in the feasibility and environmental documents. Costs and benefits are shown as they are reported in the 2010 Progress Report or the In-Delta reports. The older In-Delta studies have not been updated to reflect same date comparisons of the four investigations reported on in the Progress Report. Table 13-4 shows the storage capacity and capital cost. Costs of the initial formulations shown range from $789 million to $3.6 billion. Costs would be allocated to benefits based upon the amount of project resources necessary to

Table 13-4 CALFED Surface Storage 2010 Progress Report[a] Cost Summary

Investigation (Reservoir Initial Formulation Shown Here)	New Storage Capacity of Initial Project Formulation (taf)	Cost ($ Million)
Los Vaqueros Expansion	115	N/A[b]
North-of-the-Delta Offstream Storage (Sites Reservoir)	1,800	$3,620
Shasta Lake Water Resources	634	$942
Upper San Joaquin Basin Storage (Temperance Flat RM 274)	1,260	$3,360
In-Delta Storage[c]	217	$789

Notes:

taf = thousand acre-feet

[a] Initial Investigation Formulations are from the 2010 CALFED Surface Storage Investigations Progress Report, unless noted, and are not feasibility or environmental document alternatives.

[b] Not available.

[c] In-Delta Storage information was compiled from 2004 Draft – State Feasibility Study and 2006 Supplemental Report of the In-Delta Storage Project.

support each benefit type and the value of the benefits. Benefits provided to the public would be paid for by federal and/or State funding sources. The remaining portion of the cost of each project would then need to be paid for by local and regional water interests. In these initial formulations, the local and regional water interests are primarily considered to be the contractors of the CVP and SWP.

Major Implementation Issues

Climate Change

Climate models project that average temperatures are expected to continue to rise by the end of this century. With warmer temperatures, it is anticipated that a higher percentage of precipitation will fall as rain as snow levels rise, and snowpack is reduced. In the past few years, there has been a gradual shift in snowpack and runoff timing in California; runoff is now occurring earlier in the year than it has historically.

Climate temperature models have a higher degree of certainty than precipitation models. Climate precipitation models project little change in precipitation in California before 2050 and projections past 2050 suggest even more uncertainty with either more or less precipitation. SWP and CVP operations are sensitive to precipitation changes and sea level rise, with projected effects to reservoir carryover storage levels, in-basin reliability for water management purposes, and Delta exports. Existing system vulnerabilities intensified by a changing climate will potentially reduce water management flexibility, supply, and delivery capability, including reduced Delta exports.

Adaptation

Much of the state's infrastructure was built to capture relatively slow spring runoff and deliver water during the summer and fall months. With anticipated changes to the snowpack, runoff timing, and sea level rise, increased surface storage would improve management flexibility by capturing more runoff as it occurs. Stored runoff would supplement existing storage by providing a buffer to meet water demand under drier or wetter future climate conditions. While surface storage has the potential to immediately address vulnerabilities such as water quality, ecosystem health, and supply reliability, additional surface storage will also allow the system to respond to future climate scenarios such as extreme drought periods and sea level rise. While uncertainties of the state's hydrologic future exist in current climate science, the current framework of understanding demonstrates the need for adaptive capacity and to address system vulnerabilities with additional surface storage.

Mitigation

Energy intensity of surface storage could be different depending on net energy input or energy used for construction and maintenance. Surface storage projects could also have some climate change impacts on watershed ecosystems and water quality related to greenhouse gas (GHG) emissions; however, these impacts are not well defined due to project-related uncertainty. Energy use and generation should be defined to evaluate energy benefit with hydropower and net energy production.

Management strategies discussed in this chapter can be used to avoid and minimize adverse impacts on climate change related to energy use and GHG emissions:

1. CALFED surface storage projects have the potential to reduce GHG emissions by maximizing the use of renewable energy sources and displacing the least efficient/highest emissions power plants. This can be done by using intermittent renewable energy sources (e.g., wind and solar) to pump water into storage when excess renewable energy is available and releasing stored water to generate electricity when renewable generation drops (e.g., night, calm wind conditions) or when energy demands peak.

2. Prioritizing future surface storage by assessing energy use and GHG emissions in the feasibility and environmental studies for three CALFED Surface Storage Investigations (NODOS, LVE, 10 and USJRBSI).

3. Evaluating potential project effects and related alternatives (upgrading existing projects or developing new projects) by using climate change mitigation and reducing GHG emissions as one of the project option selection criteria.

4. Identifying public benefits in surface storage for the State and federal investment in ecosystem service including carbon offset from riparian and wetland environments could have mitigation potential related to GHG emissions reduction.

5. Performing integrated planning with the Delta Plan, the California Water Plan (CWP) updates, and the BDCP as well as IRWM with watershed management could provide long-term public benefits with water quality control, vegetation improvement, and ecosystem service, which could have mitigation potential related to carbon sequestration and reducing energy use and GHG emissions.

6. Planning project operations to achieve primary purposes of ecosystem restoration could provide potential benefits related to carbon sequestration and reducing energy use and GHG emissions.

7. Evaluating energy efficiency and GHG emissions with other water management options such as water use efficiency, water transfers, conjunctive management, desalination, and recycling could provide opportunities for climate change mitigation.

Effects

Implementation of new CALFED surface storage would affect environmental and human conditions, including economic effects to surrounding communities, as well as flow upstream and downstream of diversions and throughout California's water resources system. Some potential effects will be positive and some will be negative. Regulatory and permitting requirements, as listed previously, will require surface storage investigations to consider, for example, potential effects to streamflow regimes, water quality, stream geomorphology, fish and wildlife habitat, and risk of failure during seismic and operational events. In addition, agencies are developing analytical methodologies to determine GHG emissions and their contribution to climate change associated with project construction and operations. Mitigation of significant effects is required under State and federal environmental laws and is accomplished through implementation strategies that avoid, minimize, rectify, reduce over time, or compensate for negative effects. Significant input from tribes, the public, and agencies have already been received by DWR and USBR related to effects associated with potential implementation. Additional input is anticipated as feasibility and National Environmental Policy Act/California Environmental Quality Act alternatives are developed and evaluated during the final phase of the investigations.

State and Federal Interests

A continuing essential task is the identification of State and federal interests in each of the investigations. DWR will identify public benefits (consistent with the description in the bond proposal) that warrant investment by the State. Similarly, USBR will continue to determine federal interest in projects as the federal feasibility studies are developed. In addition, DWR and USBR are working with stakeholders to identify which projects have the greatest local interest and possible willingness to pay for project costs. The CALFED Surface Storage Investigations will then use results of all these evaluations to develop federal-State-local partnerships with local and regional interests to continue refining alternatives development and plan formulations. Local and regional water entities have indicated a preference that the State and federal governments express some commitment to potential State and federal investments in the projects prior to their commitment. If partnerships are not formed (demonstrating lack of interest in advancing a project) and/or the outcome of technical and economic studies indicate any of the five projects are not feasible, then the State and/or federal governments may decide to defer future studies of specific projects.

Financing

Implementation of one or more CALFED surface storage projects would likely require multiple types of financing. The Safe, Clean, and Reliable Drinking Water Supply Act, scheduled for vote in 2014, could provide general obligation bonds to pay for the public benefits portion of

CALFED surface storage projects. Repayment bonds could facilitate contractor (i.e., local agencies) participation in benefits to specific water users, as has been provided in the past. Local agencies may also develop their own financing. Federal participation in the projects would potentially make them much more effective. State and federal investment in developed water supplies dedicated to the restoration of the Delta and tributary ecosystems would give fish and wildlife managers new tools to revitalize these ecosystems proactively. Managers could then use these environmental water supplies to support water-required actions that would improve conditions for aquatic ecosystems and species that depend on them. These dedicated restoration supplies may prove an essential element in recovery of the Delta, its tributaries, and dependent species. State and federal fish and wildlife management agencies would have the task to manage restoration water supply assets proactively and adaptively. DWR and USBR understand that these agencies and the public will want assurances that projects will be operated in a manner to protect these potential public investments. The federal government may also invest in refuge water supplies or make a capital investment in water supplies for CVP contractors.

Recommendations to Facilitate CALFED Surface Storage Decision-Making

1. CALFED signatories and stakeholders should continue to prioritize work efforts to complete the feasibility and environmental studies of the surface storage investigations.
    - A. As indicated in the funding discussion above, DWR is prioritizing future surface storage work to complete environmental documentation and feasibility analyses for three CALFED Surface Storage Investigations (NODOS, LVE, and USJRBSI). USBR is prioritizing work on four investigations (SLWRI, NODOS, LVE, and USJRBSI). Prioritization criteria include reviewing conclusions and recommendations from ongoing State and federal planning studies; determining federal, State, and local interest including willingness to pay; evaluating benefits in light of the bond proposal; and assessing legal and logistical issues related to specific projects.
    - B. Engage more stakeholders and potential project participants in the process. The investigations should continue to work with tribes, the public, and agencies in identifying, evaluating, and quantifying potential project effects (i.e., both beneficial and negative effects).
    - C. Develop information on costs, effects, and how the projects could be operated for a variety of purposes.
    - D. Consider uncertain potential futures including alternative Delta conveyance and operations and climate change effects that allow potential participants to assess their interest in specific projects more fully.
    - E. Develop mechanisms to provide assurances that these projects should be operated in a manner consistent with the objectives.
    - F. Assess tribal, federal, State, and local interest in the investigations, including opportunities for State and federal investment in public benefits.
    - G. The investigations should coordinate with IRWM efforts.
2. DWR, USBR, other State and federal agencies, and local interests should continue coordination with related planning efforts including Delta Vision, the CWP Update, and the BDCP.

3. DWR and USBR should continue their development of conceptual finance plans that include descriptions of relevant State and federal financial policies and a determination of the potential for State and federal investment in benefits to the general public. The scenarios and finance plans may help facilitate potential investment discussions and then decisions by the public as well as local, regional, State and federal decision-makers.

Linkages to Other Strategies

The CALFED Surface Storage Investigations are inclusive of a number of other strategies in their formulations. As stated previously, ecosystem restoration and water quality are explicitly included as primary purposes of several investigations. Accomplishments related to ecosystem restoration and water quality are achieved by dedication of developed water to these purposes. Other strategies are included as secondary purposes of the surface storage investigations such as flood management and water-dependent recreation. A major conceptual component of these investigations is related to how these new facilities would be integrated into the existing water resources systems, especially the CVP and SWP systems. In each investigation, new storage integrated into these systems provides unique opportunities to provide benefits associated with system re-operation. In many cases, the existing facilities can be operated in a more efficient manner with additional storage. These re-operative approaches are described in greater detail in each investigation's most recent planning documents.

The CALFED Surface Storage Investigations are also incorporating many other strategies into their planning. For example, a cooperative and collaborative Common Assumptions process has led to agreed-upon assumptions associated with future strategy implementations including agricultural and urban water use efficiency, Delta conveyance, water transfers, conjunctive management, desalination, and recycled municipal water. The CALFED Surface Storage Investigations is one of just a few strategies that assume increased implementation of other strategies in its planning estimates shown in CWP. For example, the common assumptions include increased water use efficiency, water transfers, conjunctive management, desalination, and recycling. All of these strategies are assumed to be implemented in an integrated manner with the potential CALFED surface storage projects. The Common Assumptions process and assumptions are described in each investigation's current planning documents.

California Water Plan Update 2005 and California Water Plan Update 2009 provided a planning roadmap with two initiatives for achieving sustainable and reliable water supplies for California through 2030. The CALFED Surface Storage Investigations fall naturally in the Improve Statewide Water Management Systems initiative since the investigations seek to integrate with the CVP and the SWP, California's largest water systems. The second initiative, implementation of IRWM, is also essential to the future of California's water resources. Many purposes of the surface storage investigations need to be integrated with local and regional planning efforts. Ecosystem restoration, water quality, and improved regional and local supplies all need to be incorporated into local and regional planning. The new era approach by the CALFED Surface Storage Investigations is very similar to the approach now being promoted through IRWM.

References

References Cited

CALFED Bay-Delta Program. 2000. Programmatic Record of Decision. Sacramento (CA): CALFED Bay-Delta Program. Conveyance Program. Three volumes. 846 pp. Viewed online at: http://bibpurl.oclc.org/web/752.

Additional References

California Department of Water Resources. 2004. *Draft - State Feasibility Study, In-Delta Storage Project.* Sacramento (CA): California Department of Water Resources. 156 pp. Viewed online at: http://www.calwater.ca.gov/calfed/library/Archive_IDS_2004.html.

California Department of Water Resources. 2006. *2006 Supplemental Report to 2004 Draft State Feasibility Study, In-Delta Storage Project*. Sacramento (CA): California Department of Water Resources. 88 pp. Viewed online at: http://www.calwater.ca.gov/calfed/library/Archive_Storage_FSR_Update.html.

California Department of Water Resources. *CALFED Surface Storage Investigations Progress Report, November 2010*. Viewed online at: http://www.water.ca.gov/storage/CALFED%20Progress%20Report%202010/index.cfm.

U.S. Bureau of Reclamation. 2006. *Initial Economic Evaluation for Plan Formulation, Los Vaqueros Expansion Investigation*. Sacramento (CA): U.S. Bureau of Reclamation. 104 pp. Viewed online at: http://www.usbr.gov/mp/vaqueros/docs/init_econ_eval/full_report.pdf.

———. 2013. *Draft Shasta Lake Water Resources Investigation Environmental Impact Statement*. Sacramento (CA): U.S. Bureau of Reclamation. Viewed online at: www.usbr.gov/mp/slwri/documents.html.

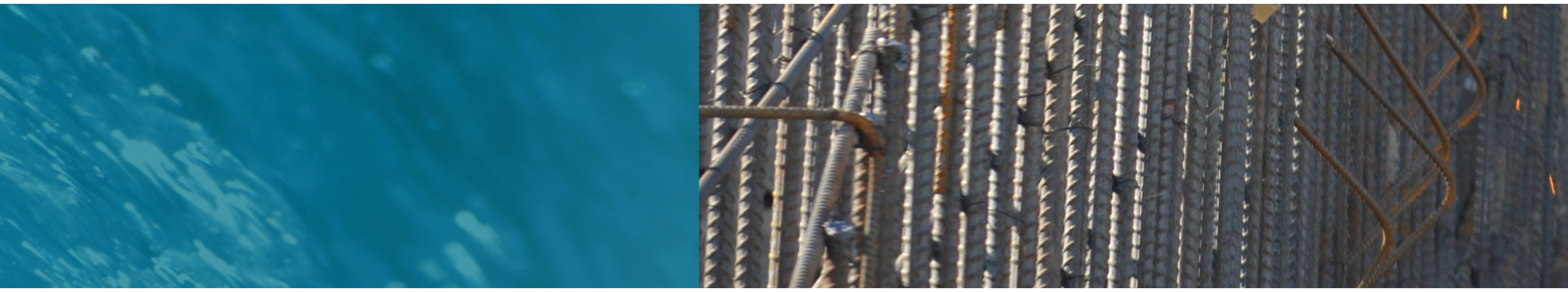
U.S. Bureau of Reclamation, California Department of Water Resources. 2008a. *Final Plan Formulation Report, Upper San Joaquin River Basin Storage Investigation*. Sacramento (CA): U.S. Bureau of Reclamation and California Department of Water Resources. 298 pp. Viewed online at: http://www.usbr.gov/mp/sccao/storage/docs/usjrbsi_pfr/index.html.

———. 2008b. *Plan Formulation Report, North-of-the-Delta Offstream Storage Investigation*. Sacramento (CA): U.S. Bureau of Reclamation and California Department of Water Resources. 353 pp. Viewed online at: http://www.usbr.gov/mp/nodos/docs/index.html.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 14

Surface Storage — Regional/Local



Los Vaqueros Reservoir, Byron, CA. Workers trim rebar for the Los Vaqueros Reservoir Expansion Project. The reservoir's capacity grew from 100,000 acre-feet to 160,000 acre-feet, and the dam increased in height by 34 feet, to 226 feet high. Photo courtesy of Contra Costa Water District.

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Chapter 14. Surface Storage — Regional/Local

Surface storage is the term for the use of human-made, above-ground reservoirs to collect water for later release when needed. Surface storage has played a key role in California where the quantity, timing, and location of water demand frequently does not match the natural water supply availability. Many California water agencies rely on surface storage as a part of their water distribution systems. Reservoirs also play an important role in flood control and hydropower generation throughout California.

In addition, surface storage is often necessary to implement, or can maximize the benefits from, other water management strategies, such as water transfers, conjunctive water management of surface and groundwater (see Chapter 9, "Conjunctive Management and Groundwater"), and conveyance improvements. Some reservoirs contribute to water deliveries across several regions of the state while others provide only relatively local water deliveries. There are two general categories of surface storage reservoirs: (1) those formed by damming an active, natural river; and (2) those called offstream reservoirs, which require a human-made diversion or pumping of water from a river into storage.

Additional surface storage benefits can be developed by enlarging a dam and releasing the water it stores behind it, reoperating the releases from a dam (see Chapter 7, "System Reoperation"), or modifying existing reservoirs. Smaller reservoirs typically store water only annually in the winter for supply use in summer, while larger reservoirs hold extra water over several years (known as carryover storage) as a reserve for droughts or other emergency supplies. In recent decades, reservoir operations have been most affected by the need to meet environmental regulations for the protection of affected fish species. Today, multiple-purpose surface storage projects balancing water supply, flood protection, hydropower production, water quality, recreation, and ecosystem needs are the norm.

The information in this chapter focuses on regional and local surface storage alternatives but does not include the major surface storage investigations of the State and federal CALFED Bay-Delta Program (CALFED), which are described separately in Chapter 13, "Surface Storage — CALFED."

Surface Storage in California

California has nearly 200 surface storage reservoirs greater than 10,000 acre-feet (af) with a combined storage capacity of more than 41 million af. These were tabulated in chronological order within Volume 4 of *California Water Plan Update 2009,* "Reference Guide," under the topic "Infrastructure" (California Department of Water Resources 2009). In addition, there are many more reservoirs smaller than 10,000 af that are used to provide for a wide range of water uses, such as stabilizing water delivery to customers or providing a backup supply for emergency needs.

Most of California's reservoirs were constructed more than 40 years ago; the number of new reservoirs built has steadily declined since the 1960s. Only six new water supply reservoirs were constructed in California in the 1980s and 1990s, and only three have been completed since 2000. Examples of recently completed surface storage projects servicing local or regional areas include:

- The U.S. Bureau of Reclamation's Warren H. Brock Storage Reservoir, located on the north side of the All-American Canal in Imperial County and completed in 2010.
- San Diego County Water Authority's Olivenhain Reservoir, completed in 2003.
- Metropolitan Water District of Southern California's Diamond Valley Reservoir, completed in 2000.
- The U.S. Army Corps of Engineers' and Orange County Flood Control District's Seven Oaks Reservoir, completed in 1999.
- Contra Costa Water District's Los Vaqueros Reservoir, completed in 1998.

The primary benefits of these new reservoirs include water supply reliability against catastrophic events and droughts, operational flexibility to meet peak summer water demands, water quality improvement, flood control, hydropower, and capturing excess flows.

A few enlargements of existing surface storage reservoirs have been completed since 2000 to meet anticipated future needs. Examples include the 60,000 af expansion of Los Vaqueros Reservoir by Contra Costa Water District completed in 2012; the 24,000 af expansion of Topaz Lake Reservoir on the California-Nevada border in 2008 to increase flood control; the 152,000 af enlargement of San Vicente Reservoir in San Diego County in 2006; and the 42,000 af expansion of Lake Kaweah reservoir in 2004 for flood protection and agricultural water supply.

Some surface storage is used to provide flood control benefits and to facilitate capture of stormwater for recharge of downstream groundwater basin(s) used for local water supply. Water conservation pools have been established by U.S. Army Corps of Engineers (USACE) at Seven Oaks Dam and Prado Dam on the Santa Ana River. Captured water is released slowly for groundwater recharge and use by downstream water managers. The Los Angeles County Flood Control District also holds water behind many local dams for subsequent release and spreading to recharge groundwater. The Southern California Water Committee Stormwater Task Force has initiated discussions with USACE to determine if additional stormwater could be captured at the federal flood control reservoirs for water supply purposes. Some water agencies also use their surface storage for imported water deliveries for groundwater recharge. Accumulation of sediment in flood control reservoirs has reduced capacity for both flood management and stormwater conservation. (See Chapter 26, "Sediment Management," for more information on sediment management.)

Some surface storage has decreased across the state due to the removal of smaller, older, obsolete dams, primarily for the purpose of improving fish habitat and passage upstream. The California Department of Water Resources' (DWR's) Fish Passage Improvement Program, within the FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO), maintains a list of dams removed for fish passage purposes. DWR's June 2005 Bulletin 250, *Fish Passage Improvement: An Element of CALFED's Ecosystem Restoration Program*, describes structures removed to improve fish passage in California. One of the reasons that removal of existing dams is feasible is that newer, more efficient alternatives now serve the projects' original purposes for water deliveries or hydropower generation. In early 2010, a package of agreements was signed by many local stakeholder groups, three tribes, PacifiCorp (an electric power company), California, Oregon, and the federal government. This is leading to the removal of four hydroelectric dams on the Klamath River in Oregon and California. The removal will improve fish passage and possibly bring about a major fisheries restoration.

Throughout the past three decades, new regulations and legislation have required many reservoirs to be operated in a more environmentally friendly manner to improve downstream riverine habitats and fisheries. Specifically, many existing reservoirs have been reoperated to achieve ecosystem and river recreation benefits beyond the original project objectives.

As the competing water demands for agricultural, urban, and environmental needs have increased, the operational flexibility of California's various surface water systems has decreased. Today's water system managers face a complex array of competing demands on the use of limited reservoir storage, which potentially results in more water reductions during droughts.

The relative need for additional local surface storage development may be greatest in California's interior mountainous areas, such as the Cascades and the Sierra Nevada. Although much of the water used throughout the state originates in the mountains, these locations generally possess limited groundwater supplies, are particularly vulnerable to the impacts of climate change on hydrology, and have a shorter list of water management strategies available to meet local needs. This is largely due to geographic, hydrogeologic, or hydrologic limitations. Of these few strategies, new surface storage or enlargement of existing reservoir storage may hold the greatest potential for achieving local supply reliability objectives. Local surface storage development options also could include the reoperation of existing reservoirs through the development of water sharing or purchasing agreements with the downstream owners of existing reservoirs.

Potential Benefits

Many of California's reservoirs were originally built for one or two primary purposes, such as agricultural and municipal consumptive water use, flood control, or hydropower. However, over time the number of benefits asked of surface storage has generally expanded to include the following:

- Water quality management.
- Ecosystem management.
- Sediment transport management.
- River and lake recreation.
- Emergency water supply.
- System operational flexibility.
- Flexible hydropower — the conversion and storage of wind and solar energy as hydropower.

The presence of new surface storage allows water managers the flexibility to implement water management strategies more easily and more efficiently or to implement strategies simply not available without storage. Storage helps solve the temporal problem that occurs when the availability of water and the demand for water do not occur at the same time. Often regional conservation efforts are ineffective if any water conserved cannot be stored for later use. For example taking into consideration percolation rates and geology, surface reservoir capacity can store and carry over stormwater captured in wet years for gradual release into spreading grounds or retention basins to help replenish groundwater.

Storage allows water transfers between regions to occur at any time, not just when the water is needed for immediate use. In addition, water transfers early in the water year are generally less expensive, because of less demand, than transfers later in the water year. Surface storage is needed to enable and improve the effectiveness of conjunctive water management strategies by controlling the timing and volume of water ultimately conveyed for storage in groundwater basins.

Dealing with climate change impacts is a key concern for California's water purveyors. Climate change projections foresee more extreme weather, such as floods and droughts. More importantly, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall and creating larger and earlier runoff events. In addition, several million acre-feet (maf) of natural snowpack storage could be lost. By expanding surface storage capacity, water supply systems would have greater flexibility to capture the increased winter runoff and help control larger anticipated flood flows. Additional reserve storage would also allow water to be held over for all uses in dry years and droughts.

Potential Costs

Cost estimates for potential surface storage alternatives are not specified in this narrative because they vary extensively by region and specific project design. In most cases, the costs of multipurpose storage projects are shared by many beneficiaries and often include a State or federal cost-share component. The magnitude of individual project benefits and corresponding costs for new water supply, hydropower, flood management, and water quality, as examples, can be expected to vary significantly from project to project such that average cost information is not accurate.

Major Implementation Issues

Climate Change

Climate change projections indicate that California will experience more extreme weather, such as floods and droughts. At the same time, warming temperatures are expected to raise the snowfall elevation, causing more winter precipitation in the Sierra Nevada to occur as rainfall. This will lead to larger and earlier runoff events. As a result of these changes, several maf of natural snowpack storage could be lost annually, reducing available water supply. In addition, the increasing severity of storms and increased runoff could overwhelm existing reservoir flood protection capacity and increase flood risks downstream.

Adaptation

Expansion of surface storage capacity can be an effective climate change adaptation strategy because increasing local and regional surface storage can provide greater flexibility for capturing runoff and managing supplies to meet increasingly variable future conditions. The ability to store water from wet years for use in dry years is critical to addressing increasing climate variability. Additional surface storage allows water to be held over from year to year as a hedge against dry years and droughts. Surface storage facilities south of the Sacramento-San Joaquin Delta

(Delta) allow water to be moved through the Delta when conditions allow it. Even if the water isn't needed immediately, the water can be stored for later use, providing additional protection from Delta supply interruptions and cutbacks. Surface storage provides unique climate change adaptation characteristics that are difficult to achieve with other management strategies: the ability to quickly detain and retain flood flows to protect downstream assets, and the ability to quickly release large quantities of water when demands increase or to meet instream temperature requirements. Reservoirs also allow storage of water that can be released slowly at rates that match groundwater basin percolation rates and facilitate recharge of downstream groundwater basins.

Mitigation

Increases in greenhouse gas (GHG) concentrations in Earth's atmosphere are thought to be the main cause of current climate warming. Human activities, such as the burning of fossil fuels and deforestation, have been identified as the origin of higher GHG concentrations. Construction of surface storage reservoirs typically requires substantial construction and heavy equipment activity, which can emit large quantities of GHGs. In addition, offstream surface storage projects often require water to be pumped into the reservoir for storage, requiring electricity to run pumps (most electricity generation emits GHGs). In this way, development of new or expanded surface storage projects can work against efforts to mitigate the effects of climate change through GHG emission reduction efforts.

Conversely, depending on how individual surface storage projects are operated, they can provide substantial climate change mitigation benefits that in some cases more than offset emissions from construction. Enhancing the surface storage capacity of local water supplies near water users may reduce the need for energy intensive water conveyance and pumping. Surface storage reservoirs with hydroelectric generating capacity provide effective backup power supplies to be operated in tandem with intermittent renewable energy resources, such as wind and solar energy. Excess wind or solar energy can be used to run pumps to move water into offstream reservoirs, and water can be released from surface storage facilities to generate electricity when clouds obscure solar generation or when winds die down and reduce wind generation. Onstream reservoirs can produce substantial quantities of renewable, GHG-free hydroelectric energy.

Funding and Identifying Project Beneficiaries

Construction usually requires a substantial amount of money in a short time — millions to hundreds of millions of dollars. Included in the long-term capital outlay are planning costs, such as administrative, engineering, legal, financing, environmental documentation, permitting, and mitigation costs. Some new-storage options, such as raising existing reservoirs, reoperating them, or constructing small local reservoirs, may require significantly less capital but may require local funding through revenue or general obligation bonds.

There are concerns related to how the beneficiaries will be determined, who will actually pay, and who will control a storage operation. One financing concept assumes that only the direct beneficiaries of a proposed storage project should pay for the construction and operation costs. However, many of the beneficiary groups do not have adequate financial resources to build large projects without outside financial assistance.

Another general financing concept relies on a large percentage of State and federal funding support to assist in the construction of new projects. With this method, the project beneficiaries would have a smaller, more affordable project cost component to fund. However, the process of obtaining funding approval from either federal or State government agencies generally requires substantially more time and justification documents. The challenge is to develop financial and operations agreements that have the best possibility for successful allocation of project costs corresponding directly to the beneficiaries and uses of a given project.

Impacts

New storage can affect environmental and human conditions and can create economic impacts for the surrounding community and flow impacts both upstream and downstream of diversions. New reservoirs may result in the loss of property tax revenue to local governments in the area where they are located, due to inundated developed land or land suitable for development, or may result in an increase of local property values by firming up a water supply. Regulatory and permitting requirements mean that surface storage investigations must consider potential impacts on streamflow regimes, potential adverse effects on designated wild and scenic rivers, potential water quality issues, potential changes in stream geomorphology, loss of fish and wildlife habitat, and risk of failure during seismic or operational events. Existing environmental laws require that these effects be addressed and potentially mitigated. Mitigation of environmental effects is normally accomplished through implementation strategies that avoid, minimize, rectify, reduce over time, or compensate for negative impacts. New surface storage projects are required to address impacts under the application of various laws, regulatory processes, and statutes, such as public trust doctrine, State dam safety standards, area-of-origin statutes, the California Environmental Quality Act, the National Environmental Policy Act, the Clean Water Act, California's Porter-Cologne Act, the federal Migratory Bird Treaty Act, and the California Endangered Species Act and federal Endangered Species Act.

Suitable Sites

Most of the best natural reservoir sites in California have already been developed, and environmental regulations and mitigation requirements impose significant constraints on development of new surface storage in California's mountainous areas. In some areas, the development of new offstream storage is a feasible alternative if the geographic terrain provides suitable locations. Another option that has received consideration in recent years is the rehabilitation and enlargement of existing reservoirs. This has the advantage of using an established reservoir site, but the feasibility and costs for rehabilitation of an older facility must be carefully evaluated.

Project Funding

The range of surface storage development options is generally more limited for smaller local agencies than for the State and federal governments, because limited agency funding and staff resources affect their capability to complete complex feasibility studies, design documents, environmental impact studies, and related project planning needs. These circumstances severely constrain the ability of local governments and agencies to finance and implement the projects necessary to sustain the local economy, preserve or restore riparian habitats, and provide water supplies for regional population growth. Traditionally, small local agencies have been unwilling to fund projects outside their service areas. However, recently, local partnerships through integrated regional water management plans (IRWMPs) have pooled resources and collaborated on local shared storage projects aimed at benefiting all regional participants.

Recommendations

1. Local agencies seeking to implement storage projects should develop a comprehensive methodology for analyzing all project benefits and costs. DWR should provide guidance, technical expertise, and planning process assistance to local agencies if requested.

2. Reservoir operators and stakeholders should continue to adaptively manage operations of existing facilities in response to increased understanding of system complexities and demands, as well as changes in natural and human considerations, such as social values, hydrology, and climate change.

3. DWR and other State, federal, and local resource management agencies should continue studies, research, and dialogue focused on a common set of tools that would help determine the full range of benefits and impacts, as well as the costs and complexities of surface storage projects.

4. Water resources scientists, engineers, and planners, including those at DWR, should recognize the potential long development time required for new surface storage in securing funding needed for continuity of planning, environmental studies, permitting, design, construction, and operation and maintenance.

5. Rehabilitation and possible enlargement of existing older dams and infrastructure should be given full consideration as an alternative to new reservoir storage.

6. As an alternative to new storage, agencies should consider the potential to develop water purchasing agreements to buy water from other agencies that own storage reservoirs with substantial water supplies.

7. Local agencies should investigate integrating existing surface storage with groundwater management or other water supply options (e.g., water use efficiency).

8. Local agencies should team with other regional agencies through the IRWMP process on new regional storage projects.

9. Surface storage can be the centerpiece of a comprehensive IRWMP offering multiple benefits and the flexibility to fully implement many other resource management strategies. Shared local or regional surface storage can enhance water user ability to implement conjunctive groundwater storage, integrate flood management practices, take full advantage of water transfers, assist in ecosystem restoration, and offer recreation benefits — all by augmenting consumptive water use.

10. The California Air Resources Board, California Public Utilities Commission, and California Energy Commission should consider developing policies to support the use of pumped energy storage to increase the development of solar and wind energy in a cost-effective manner.

References

References Cited

California Department of Water Resources. 2009. *California Water Plan Update 2009*. Volume 4, "Reference Guide." Topic: "Infrastructure." Section 2, "California Reservoir Summary." Viewed online at: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c13a02_cwp2009.pdf. Accessed: March 27, 2013.

California Department of Water Resources. 2005. *Fish Passage Improvement: An Element of CALFED's Ecosystem Restoration Program.* Bulletin 250.

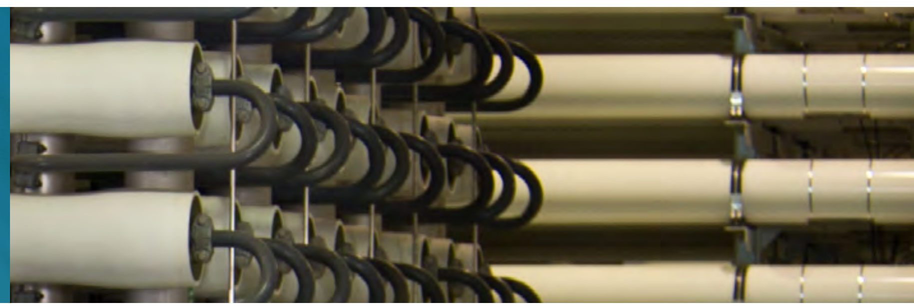
Additional References

U.S. Department of the Interior, U.S. Department of Agriculture, U.S. Department of Commerce, California Department of Fish and Game, et al. 2013. "Klamath Basin Water Issues." [Web site.] Viewed online at: http://klamathrestoration.gov/. Accessed: March 27, 2013.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 15

Drinking Water Treatment and Distribution



Fremont, CA. Assistant General Manager Robert Shaver and District Board President Jim Gunther inspect Alameda County Water District's Newark Desalination Facility. (July 16, 2013)

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Chapter 15. Drinking Water Treatment and Distribution

Providing a reliable supply of safe drinking water is the primary goal of public water systems in California. To achieve this goal, public water systems must develop and maintain adequate water treatment and distribution facilities. In addition, the reliability, quality, and safety of the raw water supply are critical to achieving this goal. In general, public water systems depend greatly on the work of other entities to help protect and maintain the quality of the raw water supply. Many agencies and organizations have a role in protecting water supplies in California. For example, the basin plans developed by the regional water quality control boards recognize the importance of this goal and emphasize protecting water supplies — both groundwater and surface water.

A public water system is defined as a system for the provision of water for human consumption, through pipes or other constructed conveyances, which has 15 or more service connections or regularly serves at least 25 individuals daily at least 60 days of the year (Health and Safety Code Section 116275[h]).

Public water systems are divided into three principle classifications: community water systems (CWS), non-transient non-community (NTNC) water systems, and transient non-community (TNC) water systems. As the name indicates, CWS serve cities, towns, and other residential facilities occupied by year-round users. Examples include everything from apartment complexes served by their own wells to systems serving California's largest cities. NTNC systems are public water systems that are not CWS and provide water to the same non-residential users daily for at least 180 days of the year. Examples include schools, places of employment, and institutions. TNC systems are places that provide water for a population that mostly comes and goes. Examples include campgrounds, parks, ski resorts, rest stops, gas stations, and motels. Table 15-1 shows the number of public water systems in California by class. CWS serve approximately 36.6 million of the estimated 37.7 million people throughout the state, or 97 percent of the state's population. The remaining estimated 1.1 million people in the state (3 percent of the population) receive their drinking water from private wells serving their individual residences or from other sources. Virtually every Californian and visitor to the state will use drinking water from a regulated public water system through their work, while on vacation, or while traveling through the state. Figure 15-1 shows water system class by percentage of total number of public water systems in California.

Under the California Safe Drinking Water Act and Toxic Enforcement Act, the California Department of Public Health (CDPH) or CDPH Drinking Water Program has adopted regulations to ensure high-quality drinking water is provided by public water systems at all times. In developing drinking water regulations and carrying out the public water system regulatory program, CDPH recognizes that healthy individuals and communities cannot exist without safe, reliable water supplies. These actions are necessary not only for drinking water, but also to meet basic sanitary and public safety needs.

Drinking water regulations mandated by the California Safe Drinking Water and Toxic Enforcement Act apply to all public water systems, regardless of ownership. There are two basic water system ownership types — publicly owned and privately owned. Publicly owned systems

Table 15-1 Public Water Systems in California by Class

Public Water System Classification	Number
Community	2,973
Non-transient non-community	1,490
Transient non-community	3,111
Total number of public water systems	7,574

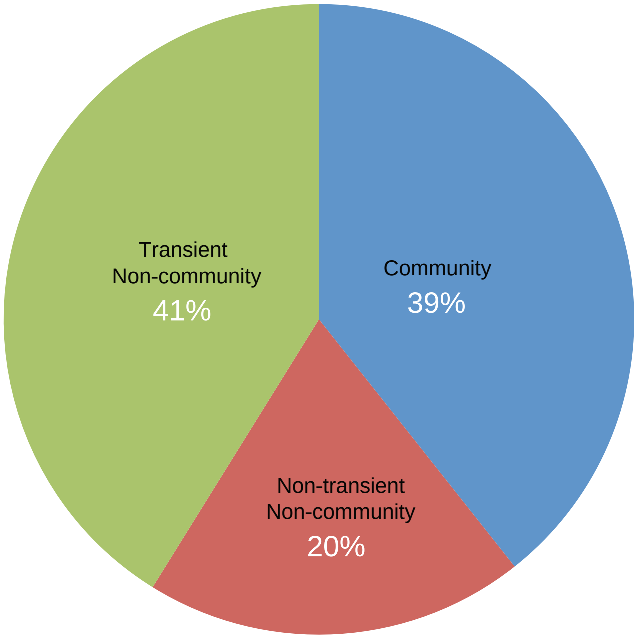
Source: California Department of Public Health records, August 2012. Does not include water systems serving Native American tribes or on tribal lands.

include municipalities, special districts, and federal or State government systems. Privately owned systems include investor-owned utilities, mutual water companies, mobile home parks, and water associations, and may include various commercial enterprises, such as restaurants, hotels, resorts, employee housing, or other similar businesses that have their own water supply. While CDPH regulates all public water systems for all aspects that may affect water quality regardless of ownership, the California Public Utilities Commission (CPUC) regulates privately owned, for-profit systems serving communities for the purposes of establishing appropriate water rates. The CPUC regulates sole proprietorships, partnerships, and corporations that provide water service to the public for profit. Mutually owned systems and homeowners associations are exempt from CPUC oversight if they provide water only to their stockholders or members. In addition, systems serving privately owned mobile home parks are also exempt except that CPUC may conduct an investigation into water rate abuses when they receive complaints from residents. Table 15-2 provides a summary of the type, number, and size of the CPUC-regulated water systems.

At the federal level, the U.S. Environmental Protection Agency (EPA) is responsible for ensuring implementation of the federal Safe Drinking Water Act and related regulations. The State has primacy for the public water system regulatory program in California and works closely with the EPA to implement the program. In addition, local primacy agencies (typically the county environmental health departments) are responsible for regulating many small public water systems (typically those serving fewer than 200 homes) in 32 of the 58 California counties. EPA directly provides regulatory oversight for tribal water systems.

Public water systems rely on groundwater, surface water, or a combination of both as their source of supply. Groundwater wells used for drinking water are constructed in a manner to intercept high-quality groundwater. Therefore, many groundwater wells require little to no treatment. However, some groundwater wells are affected by anthropogenic (human-made) and/or naturally occurring contaminants that require treatment to achieve the high level of quality mandated by State and federal regulations for a safe, reliable water supply. All surface water supplies used for drinking water must receive a high level of treatment to remove pathogens, sediment, and other contaminants before being suitable for consumption. Once the water is treated to drinking water standards, this high level of water quality must be maintained as the water passes through the distribution system to customer taps. Water treatment and distribution issues are discussed in detail later in this chapter. There is an increasing effort aimed at preventing pollution and matching water quality to water use. This is described in this volume in Chapter 17, “Matching Water Quality to Use,” and Chapter 18, “Pollution Prevention.”

Figure 15-1 Public Water System Class by Percentage of Systems



The use of bottled water in the United States has been an increasing trend; however, recently that trend appears to have flattened from 2007 through 2011. The Beverage Marketing Corporation and International Bottled Water Association report that U.S. consumption of bottled water was 29.2 gallons per person in 2011 and 29.0 gallons per capita in 2007. In 2005, California ranked Number 1 in the nation for percentage of the bottled water share (23.9 percent) and was ranked Number 3 behind Arizona and Louisiana for per-capita consumption at 51.2 gallons (Donoho 2007). Some of the reasons that individuals choose bottled water include convenience, image, taste, and perceived health benefits. On the other hand, many consumers are becoming aware of the environmental impact associated with the production, transportation, and waste disposal of bottled water, including the contributions to greenhouse gas (GHG) emissions. While tap water and bottled water are regulated differently, both are generally safe. Tap water provided by a public water system yields public health and fire protection among its other advantages to a modern quality of life. Bottled water costs significantly more than tap water for the volume consumed in cooking and drinking.

Bottled water is regulated by the U.S. Food and Drug Administration under the 1938 Food, Drug, and Cosmetic Act. California regulates bottled and vended water to a much greater degree than provided in the act. The California Sherman Food, Drug, and Cosmetic Law is the basic statute that authorizes such regulation and is implemented by the CDPH Food and Drug Branch.

Drinking Water Treatment in California

Public Health

Water treatment includes processes that treat, blend, or condition the water supply of a public water system for the purpose of meeting primary and secondary drinking water standards. These processes include a wide range of facilities to treat surface water and groundwater. Common surface water treatment facilities include basic chlorine disinfection; sedimentation basins; filtration; and more recent technical advances, such as membrane filtration, ultraviolet light, and ozonation to meet pathogen removal and/or inactivation as well as disinfection requirements while controlling the formation of disinfection byproducts. Common facilities for groundwater sources that require treatment are chemical removal and/or blending facilities. Blending treatment

Table 15-2 Number and Type of CPUC-Regulated Water Agencies

CPUC class	Number of Connections Served	Number of Agencies in Class
A	>10,000	10[a]
B	2,000-10,000	6[a]
C	500-2,000	22
D	<500	85

Source: California Public Utilities Commission Web site, June 2012.

Notes:

[a] Many of the private agencies included in the number shown operate multiple water systems throughout California.

is an acceptable practice for meeting chemical water quality standards and is a process of reducing the contaminant concentration in one water source by blending or dilution with water that has a lower contaminant concentration. Many water systems must also buffer or adjust the pH of the water to ensure that the delivered water is not corrosive in the distribution system and customers' piping. Fluoridation treatment, now commonly practiced in California, may be used to add fluoride to an optimal level that provides dental health benefits.

Widespread treatment of drinking water, especially disinfection, filtration, and fluoridation, was a great public health advancement of the 20th century. The 21st century promises to bring additional advances in water treatment technologies to improve the removal of contaminants, reduce the cost per gallon of treated water, improve water use efficiency (increase water recovery and reduce waste streams), and manage energy consumption. Water recovery — or recycling of water containing treatment process wastes (i.e., filter backwash water, filter rinse water) that would otherwise be disposed — begins with treatment of the recovered or recycled water so it may be blended with raw untreated water at the start of the treatment plant process. This enables a larger percentage of a water supply to be converted to potable water and concentrates the solids generated at the treatment plant. It is important for treatment processes in water-short areas to maximize the amount of a water supply that can be converted to potable water by reducing the amount of water that is discharged as waste.

California public water systems use an estimated 17,983 groundwater wells and surface water supplies to meet the water supply needs of consumers. Some of these sources need treatment to remove or inactivate harmful contaminants or to meet aesthetic quality prior to consumption. These could include minerals, metals, chemicals from industry or agriculture, pathogens, and radiological constituents. Currently, there are an estimated 8,560 water treatment facilities in California. Most of these are disinfection facilities provided at sources, treated water storage tanks, or within the distribution system. The remaining systems provide more extensive treatment summarized in Table 15-3.

Fluoridation

Fluoridation of community drinking water has been practiced in the United States for more than 60 years. It is accepted as a safe and effective public health practice for people of all ages. The

Table 15-3 Treatment Plants on California Public Water System Sources

Type of Contaminant	Approximate Number of Major Treatment Plants
Surface water[a]	699
Nitrate	150[b]
Arsenic	79[b]
Perchlorate	40
Radiological	10[b]
Volatile and synthetic organic chemicals	220[b]
Aesthetic water quality	350

Source: These estimates are based on a survey of California Department of Public Health offices and from California Department of Public Health records.

Notes:

[a] Surface water, defined under the California Surface Water Treatment Rule (California Code of Regulations, Title 22, Section 64651.83) means "all water open to the atmosphere and subject to surface runoff..." and hence would include all lakes, rivers, streams, and other water bodies. Surface water includes all groundwater sources that are deemed to be under the influence of surface water (i.e., springs, shallow wells, wells close to rivers), which must comply with the same level of treatment as surface water.

[b] Includes only chemical removal treatment facilities. Blending facilities are not included.

previous five U.S. Surgeons General have recommended that communities fluoridate their water to prevent tooth decay, the major form of preventable dental disease in America. California's fluoridated drinking water act, Assembly Bill (AB) 733, became law in 1995 and required water systems with 10,000 or more service connections to fluoridate once money from an outside source is provided for both installation and operation and maintenance costs. CDPH is also responsible for identifying funds to purchase and install fluoridation equipment for public water systems.

During fluoridation treatment of public water system supplies, water systems adjust fluoride in drinking water to an optimal level shown to reduce the instances of tooth decay. Optimal fluoridation means that the water treatment facility and distribution system is closely managed to provide a consistent level of fluoride at the appropriate prophylactic level to reduce dental disease. Other water systems, that purchase water from a wholesale provider that fluoridates, provide variable fluoridation at levels up to the optimal level. The level of fluoride in these systems depends on many factors, including time of year, water demand, and the use of sources that may not have fluoridation treatment facilities. Additional information on water systems that provide fluoridated water is available at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Fluoridation.aspx.

Regulation

Both EPA and CDPH have ongoing programs for improving public health through new or more stringent drinking water regulations. These regulations include monitoring requirements, maximum contaminant levels (MCLs) in the water provided to the customer, multi-barrier treatment requirements, permitting requirements, public notification, and more. These regulations include specific MCLs for constituents of health concern that are present in drinking water sources. In California, new drinking water standards — the MCLs — are adopted only after development of a Public Health Goal (PHG), which is the level of a contaminant in drinking water below which there is no known or expected risk to health. PHGs are set by the Office of Environmental Health Hazards Assessment, an agency under the California Environmental Protection Agency (Cal/EPA). MCLs take into account not only chemicals' health risks, but also such factors as their detectability and treatability, as well as costs of treatment. The Health and Safety Code requires CDPH to establish a contaminant's MCL at a level as close to its PHG as is technically and economically feasible, placing primary emphasis on the protection of public health.

In some cases, California adopted MCLs in advance of the federal adoption of an MCL. For example, CDPH adopted a perchlorate MCL of 6 micrograms per liter (µg/L) in 2007. This MCL is based primarily on potential adverse effects on the thyroid. In 2008, EPA indicated that it did not intend to adopt an MCL for perchlorate. However, in 2011 EPA reversed its earlier decision and now plans to propose a formal rule for perchlorate (U.S. Environmental Protection Agency 2011). In September 2012, EPA posted a Federal Register notice of a public meeting regarding its intent to regulate perchlorate levels in drinking water through adoption of an MCL and anticipated that a draft rule would be available for public comment in 2013.

CDPH is currently in the regulation process to establish an MCL for chromium-6. On July 1, 2011, Cal/EPA's Office of Environmental Health Hazard Assessment completed the setting of a PHG for chromium-6 at a concentration of 0.02 µg/L, a necessary prerequisite to adopt an MCL. In August 2013, CDPH released a proposed MCL for chromium-6 of 10 µg/L and accepted public comments on this proposed MCL during a 45-day comment period. It is anticipated that in the absence of any major delays, an enforceable MCL will be established in 2014.

In addition, if the adoption of a specific MCL is not practical, EPA and CDPH have adopted specific treatment performance standards that essentially take the place of an MCL. An example of this is in the various rules for surface water treatment that are intended to provide protection against *Giardia* and *Cryptosporidium*, two microbial contaminants found in surface waters where direct testing is impractical, costly, or lacks the level of reliability necessary for setting an MCL.

New Technology

New or innovative treatment technologies are often developed to address new or more stringent drinking water standards, improve the contaminant removal efficiency, reduce treatment plant footprint, reduce energy consumption, or reduce/eliminate waste streams from the treatment process. Innovative environmental technologies hold the promise of being more effective than traditional methods and can address today's far more complex environmental problems. Technologies increasingly used in California as a result of new regulations include:

- Ultraviolet (UV) disinfection treatment to comply with disinfection byproducts under the Stage 2 Disinfection Byproducts Rule and requirements for the treatment of surface waters under the Long Term 2 Enhanced Surface Water Treatment Rule.
- Arsenic removal technologies including adsorptive (disposable) media to increase affordability of small water system compliance with the arsenic MCL.

- Membrane filtration to comply with requirements of the Long Term 1 and Long Term 2 Enhanced Surface Water Treatment Rules.
- Biological treatment in the form of fixed bed, fluidized bed, and membrane bioreactors to treat for perchlorate and now being demonstrated for nitrate and other contaminants.

As a result of both increases in demand and the relative scarcity of new water supplies, many water providers are now shifting toward treating sources formerly considered unsuitable for domestic use. Treatment processes such as reverse osmosis are used to desalt brackish shallow groundwater for potable uses and are discussed in greater detail in Chapter 10, "Desalination (Brackish and Sea Water)" in this volume.

Drinking Water Distribution in California

Treated and/or conditioned water that meets drinking water standards is considered to be "finished water," suitable for distribution to consumers for all potable water uses. Water distribution systems consist of pipes, storage tanks, pumps, and other physical features that deliver water from the source or the water treatment plant to the customer's connection. Even high-quality drinking water is subject to degradation as it moves through the distribution system to the tap. For example, contaminants can enter the distribution system via backflow from a cross-connection, permeation and leaching during water main repair or replacement activities, and contamination via finished water storage facilities. Within the distribution system, water quality may deteriorate as a result of microbial growth and biofilm, nitrification, corrosion, water age, effects of treatment on nutrient availability contributing to microbial growth and biofilm, and sediments and scale within the distribution system (U.S. Environmental Protection Agency 2006).

CDPH has established laws and regulations for the design, construction, operation, and maintenance of distribution systems primarily through the California Waterworks Standards (California Department of Public Health 2008a). Regulations mandate monitoring distribution system water quality for coliform bacteria, chlorine residual, lead, copper, physical water-quality parameters, and disinfection byproducts. California has also adopted cross-connection control and backflow prevention regulations to protect water quality within a water distribution system.

In 2000, a federal advisory committee working to develop more stringent EPA regulations for disinfection byproducts and microbial contamination noted the following factors as part of its key considerations to develop further regulations.

- Finished water storage and distribution systems may have an impact on water quality and may pose risks to public health.
- Cross-connections and backflow in distribution systems represent a significant public health risk.
- Water quality problems can be related to infrastructure problems, and the aging of distribution systems may increase risks of infrastructure problems.
- Distribution systems are highly complex, and there is a significant need for additional information and analysis on the nature and magnitude of risk associated with them.

The maintenance of water quality within the distribution system has received considerable attention in recent years, especially as systems have modified treatment methods. Changes to the methods and levels of disinfectants can create the potential for reduced control of microbial contaminants that may be present in the distribution system.

Water utilities are also constantly making improvements to their distribution systems, including increasing the reliability of their water supply. One example is the installation of emergency water interties between neighboring water utilities. These interties provide a backup source, with the neighboring water system, in case of an outage resulting from an unforeseen emergency or a potential disaster. The intertie also allows a water utility to shut down a part of its system to do necessary maintenance without interrupting service to customers.

For example, a number of San Francisco Bay Area water systems have constructed emergency interties with neighboring water systems. There is an emergency intertie between the East Bay Municipal Utility District (EBMUD), the City of Hayward, and the San Francisco Public Utilities Commission (SFPUC) to supply treated water among the three water systems and is intended to be used during planned outages, for needed maintenance, and to avoid service interruptions. EBMUD has two small interties, each able to carry 4 million gallons per day, with the City of Hayward which adjoins its service area. SFPUC, the agency in charge of the Hetch Hetchy water used by many Bay Area water districts and residents, has also constructed an intertie with the Santa Clara Valley Water District and has been considering constructing another intertie. These interties may also play a role in the security of the water distribution system by creating a backup source should a terrorist act or disaster disrupt the source of supply from any single water provider.

In other cases, interties can provide untreated water between utilities in an emergency. For example, Contra Costa Water District (CCWD), whose service area is crossed by EBMUD Mokelumne pipeline, has an intertie that can be used to transfer untreated water between EBMUD and CCWD in an emergency.

Interties are one of the strategies for improving water supply reliability and quality, and were recommended by the CALFED August 28, 2000, Record of Decision.

Potential Benefits

Improved water quality can directly improve the health of Californians, thereby improving the state's standard of living and reducing the burden and costs on the state's healthcare system.

Since 1989, a number of rules have been adopted by the EPA and CDPH that are aimed at controlling both microbial pathogens and disinfection byproducts. The first of these rules were the Surface Water Treatment Rule (1989) and the Total Coliform Rule (1989). Both rules are intended to reduce the occurrence of both viral and microbial pathogens in drinking water. As the regulatory community became more aware of the risks posed by organisms such as *Giardia*, *Cryptosporidium*, and certain enteric viruses present in surface water supplies, rules were adopted to address these risks and increase the degree of protection for consumers. These rules included:

- Interim Enhanced Surface Water Treatment Rule (1998).
- Filter Backwash Rule (2001).
- Long Term 1 Enhanced Surface Water Treatment Rule (2002).
- Long Term 2 Enhanced Surface Water Treatment Rule (2005).

Concurrently, rules were adopted to improve the disinfection process while at the same time providing protection against two groups of disinfection byproducts: trihalomethanes (TTHM) and haloacetic acids (HAA5). The following disinfection byproduct rules were adopted:

- Stage 1 Disinfection Byproducts Rule (1998).
- Stage 2 Disinfection Byproducts Rule (2006).

In addition to the surface water rules, EPA adopted the Groundwater Rule (2006) to increase the level of protection primarily from enteric viruses.

The perchlorate MCL and the arsenic MCL reduce the permissible level of these contaminants and result in direct benefits. Perchlorate exposure is a public health concern because it interferes with the thyroid gland's ability to produce hormones. In the very young, hormones are needed for normal prenatal and postnatal growth and development, particularly for normal brain development. Therefore, a reduction in thyroid hormones is a serious concern. In adults, thyroid hormones are needed for normal body metabolism. About 515,000 people in California will avoid exposure to perchlorate at levels above the MCL annually as a direct result of the perchlorate regulation (California Department of Public Health 2007). The arsenic MCL of 10 ug/L will result in an exposure reduction for more than 790,000 people and a theoretical reduction of 57 lung and bladder cancer cases per year in California (California Department of Public Health 2004).

Adequate operation and maintenance of the distribution system network will reduce delivery problems (main or tank ruptures, water outages) and ensure delivery of high-quality water. Operators of drinking water distribution systems in California must be certified at the appropriate level, depending on the size and complexity of the distribution system. This certification requirement helps to ensure a competent level of operation of distribution systems. Similarly for water treatment facilities, proper operation and maintenance is essential for achieving optimum water treatment plant performance.

Water fluoridation ranks as one of 10 great public health achievements of the 20th century according to the U.S. Surgeon General in 2000. Fluoridation of public water supplies targets the group that would benefit the most from its addition, namely infants and children under 12, by decreasing cavities and improving dental health. Studies have shown that fluoridation, at the optimal concentration, reduces the incidence of dental cavities by 50-70 percent. It has also been demonstrated that tooth decay will increase if water fluoridation is discontinued in a community for an extended period. For example, the City of Antigo, Wisconsin, started fluoridating its community water supplies in 1949 and discontinued it in 1960. Five and one-half years later, second graders had more than 200 percent more tooth decay, fourth graders had 70 percent more, and sixth graders had 91 percent more tooth decay than children of the same age in 1960 (California Department of Public Health Community Water Fluoridation Program 2009).

Potential Costs

The cost of providing drinking water in compliance with all drinking water standards is steadily increasing as a result of increasing costs for energy and materials and increasing regulations requiring higher levels of treatment. Water bills reflect the costs of pumping, treating, and delivery of water, as well as the operation and maintenance of the system, water quality testing, and debt repayment. Water treatment costs may include the cost of chemicals, energy, and operation and maintenance of the treatment facilities. Drinking water treatment costs will vary widely from plant to plant. Many different factors can affect the cost of water treatment, including the choice of which water treatment technology to use.

Table 15-4 summarizes the past and future estimated costs of treated full-service water provided by the Metropolitan Water District of Southern California (MWD), which treats a blend of surface water from the Colorado River and the California Aqueduct. The table shows an increase of approximately 65 percent from 2007 to 2012 in the cost to provide treated water in an area serving a large rate base. The additional cost reflects improvements to the treatment provided, increased cost for chemicals and energy, and reduced availability of new water supplies. The primary cost factors causing the rate increase included increased conservation efforts, the quagga mussel control program, litigation, and the higher cost for State Water Project deliveries. MWD may not capture the true cost of service with these rates and must cover some costs through the use of reserves.

The increase in cost to provide safe drinking water for smaller systems may be significantly greater on a per-capita basis. These systems lack the economy of scale necessary to achieve savings in their day-to-day operations. In addition, most small systems have not set up any asset management plans or capital improvement accounts to fund infrastructure replacement.

Per household costs for compliance with new regulations for small water systems can be more than four-fold higher than those for medium-to-large water systems (U.S. Environmental Protection Agency 2006). Where substantial areas are affected by contamination, such as the nitrate contamination in the Tulare Lake basin and Salinas Valley, the cost to consumers can be significant. According to a recent University of California, Davis study, titled “Addressing Nitrates in California’s Drinking Water – Technical Report 7: Alternative Water Supply Options” (Honeycutt et al. 2012), about 2.4 million people receiving groundwater supplies from community water systems and state small water systems are potentially affected by nitrate in the Tulare Lake basin and Salinas Valley study areas. In addition, about 245,490 persons in these areas obtain water from unregulated private water supplies that may also be subject to nitrate contamination. According to the study, the estimated cost per person to provide safe water (water that meets nitrate standards) is estimated to be between $80 and $142 per year. For a typical public water system customer, this cost represents an estimated increase in the monthly water bill from $23 to $42 per month (based on $80 to $142 per year times 3.5 persons per household).

The most prevalent groundwater contaminant is arsenic, a naturally occurring contaminant, affecting an estimated 287 community drinking water system statewide (State Water Resources Control Board 2012). The average annual cost per household to comply with the arsenic MCL is estimated to range from $140 to $1,870 per residence, depending on the size of the water system (California Department of Public Health 2008b). These costs are in addition to current costs for drinking water.

Up to one-third of the operations and maintenance costs for some water utilities are energy related, including energy used for water treatment and pumping. One factor in water-related energy consumption is using new technologies that are more energy intensive than most previous treatment technologies (e.g., UV treatment and high-pressure membranes).

Desalination will play an increasing role in California’s water supply, both for brackish groundwater desalination and seawater desalination. Historically, the high cost and energy

Table 15-4 Metropolitan Water District of Southern California Treated Water Rate History

Year	Cost of Treated Water ($/af)	
HISTORICAL AND CURRENT WATER RATES		
1994	412	
1995-1996	426	
1997-2002	431	
	Tier 1[a]	**Tier 2[b]**
2003	408	489
2004	418	499
2005	443	524
2006	453	549
2007	478	574
2008	508	606
2009	579	695
2010	701	811
2011	744	869
2012	794	920
2013	847	997
2014	890	1,032

Source: Metropolitan Water District of Southern California 2014.

Notes:

af = acre-feet

[a] Tier 1 supply rate – recovers the cost of maintaining a reliable amount of supply.

[b] Tier 2 supply rate – set at Metropolitan Water District cost of developing additional supply and to encourage efficient use of local resources.

requirements of desalination have confined its use to places where energy is inexpensive and fresh water is scarce. Recent advances in technology, especially improvements in membranes, are making desalination a realistic water supply option. The cost of desalinating sea water is now competitive with other alternatives in some locations and for some high-valued uses. However, although process costs have been reduced as a result of the newer membranes that allow for lower energy consumption, the total costs of desalination, including the costs of planning, permitting, and waste salt brine concentrate management, remain relatively high, both in absolute terms and in comparison with the costs of other alternatives (National Resource Council 2008). Since development of other traditional sources of supply is limited and may require substantial capital investment, such as new storage or canal systems, the expanded development of brackish water and seawater desalination may become more cost competitive.

The condition of infrastructure is a growing concern in California and throughout the country. In the *2013 Report Card for America's Infrastructure*, the American Society of Civil Engineers gave drinking water infrastructure across the country a D (American Society of Civil Engineers 2013). The EPA conducted a Drinking Water Infrastructure Needs Survey and Assessment in 1995, 1999, 2003, 2007, and 2011. The 2011 survey (U.S. Environmental Protection Agency 2012) shows a total investment need of $384.2 billion over the next 20 years nationwide. It identified a total investment need of $44.5 billion for California. This is more than 11 percent of the national need. The majority of the California need was for transmission and distribution systems (60 percent or $26.7 billion). The second highest need category was for treatment (19 percent or $8.4 billion), followed by water storage (14 percent or $6.4 billion), and water source (5.6 percent or $2.5 billion). (All amounts are in January 2011 dollars.) This does not include the infrastructure needs of tribal water systems that are regulated directly by the EPA. (See the following link for information about these systems: http://water.epa.gov/grants_funding/dwsrf/upload/epa816r13006.pdf.) California's investment needs may not include all cost associated with changes in the Colorado River water resources, recent or evolving drought issues, or changes to groundwater basins.

Funding for drinking water projects on tribal lands is provided by the federal government as part of the Drinking Water Infrastructure Grants: Tribal Set-aside Program, which was established by the federal Safe Drinking Water Act reauthorization of 1996. The program allows the EPA to award federal grants for infrastructure improvements for public drinking water systems that serve tribes.

Major Implementation Issues

Based on a review of issues discussed within the water supply industry and regulatory agencies, the following topics represent some of the most significant challenges for public water suppliers and the regulatory agencies today.

Deteriorating Infrastructure

With the aging of the nation's infrastructure and the growing investment needed to replace deteriorated facilities, the water industry has a significant challenge to sustain and advance its achievements in protecting public health and the environment (Grumbles 2007). During the last several decades, the public investment has been toward expanding and upgrading service levels, such as providing higher levels of treatment.

New solutions are needed for critical drinking water investments over the next two decades. Many utilities are moving to the concept of asset management to better manage and maintain their water facilities and infrastructure (Cromwell et al. 2007) for greater operational efficiency and effective use of limited funds. However, addressing the replacement of deteriorating infrastructure will add to the cost of water.

Asset management alone will not fix the basic problem. Particularly in smaller systems, inadequate funding for capital improvement plans for infrastructure replacement has created a serious problem. From the post-war period of the late 1940s and into the early 1980s, a proliferation of small community water systems occurred in rural areas, some far from the nearest city. In the past, such systems could often fund major maintenance and needed infrastructure replacement with informal assessments from the rate payers. However, the magnitude of the current infrastructure needs makes it very difficult to finance without creating an inordinate burden on rate payers.

CDPH has funding “set-asides” from the Safe Drinking Water State Revolving Fund (SDWSRF) program for technical assistance to small water system operators and managers to develop technical, managerial, and financial capacity. Additional funding would allow the expansion of this program into more detailed areas of asset management and rate setting.

Source Water Protection

There is an increasing need to protect source water quality as the first critical barrier in the multiple barrier approach to provide safe drinking water. A key issue is the increasing difficulty of protecting source water quality as the state population increases, which results in increased wastewater discharge and urban runoff into surface water supplies. Another major issue is that some drinking water contaminants (organic carbon, nutrients, and pathogens such as *Giardia* and *Cryptosporidium*) are not currently regulated by the regional water quality control boards in basin plans. Thus, there are generally no requirements for dischargers to control these contaminants.

Inadequate Financial Assistance to Address Both Water Treatment and Infrastructure Issues of Public Water Systems

The four major funding programs for California public water systems are SDWSRF, Proposition 50, Proposition 84, and the American Recovery and Reinvestment Act of 2009 (ARRA). Combined, these programs have provided more than $1.87 billion to 441 public water systems to solve health risk problems and Safe Drinking Water Act violations, resulting in an overall risk reduction for consumers. However, this funding has not been adequate to address all of California’s identified needs. The combined project priority list for these funding programs includes more than 4,000 projects, many of which have been on the list since its inception in 1997 and have not received funding. The estimated value of unfunded need on the combined project priority list exceeds $12 billion is shown in Table 15-5.

The CDPH Drinking Water Program administers multiple funding programs to assist water systems to achieve and maintain compliance with safe drinking water standards. These programs use federal funds and State funds to address the highest priorities of the total infrastructure need.

Safe Drinking Water State Revolving Fund

The largest funding program CDPH administers is the SDWSRF . The EPA provides SDWSRF funds to states in the form of annual capitalization grants. States, in turn, provide low interest rate loans and other assistance to public water systems for infrastructure improvements. In order to receive a federal SDWSRF Capitalization Grant, states must have statutory authority for the program and must provide a State match equal to 20 percent of each annual capitalization grant. Pursuant to State statutes (Health and Safety Code, Division 104, Part 12, Chapter 4.5 commencing with Section 116760, Safe Drinking Water State Revolving Fund Law of 1997), CDPH is authorized to receive the federal capitalization grants and administer the SDWSRF program in California. California’s SDWSRF program began in 1998 and issued its first loans in

Table 15-5 California Department of Public Health Summary of Funded and Unfunded Projects

	Funded Projects		Unfunded Projects
Funding Source	Number of Systems	Funded Amount (million $)	Unfunded Need (million $)
SDWSRF	224	1,351	11,700[a]
ARRA	51	150	
Proposition 50	78	295	366
Proposition 84	88	81	174
TOTAL	441	1,877	12,240

Source: California Department of Public Health 2012.

Notes:

[a] American Recovery and Reinvestment Act (ARRA) used the Safe Drinking Water State Revolving Fund (SDWSRF) project priority list for funding.

1999. California's current share of the national SDWSRF is 9.35 percent (Table 15-6), the highest allocation of all states.

Total SDWSRF funding provided to public water systems in executed loans and grants to date is more than $1.3 billion. Approximately 80 percent of these funds are distributed by CDPH as subsidized interest rate loans to public water systems serving disadvantaged communities (DACs). The remainder is distributed in the form of grants to DACs. Water systems determined to serve a DAC receive a zero percent interest rate loan and may receive grant funding. DACs are communities with a median household income (MHI) less than or equal to 80 percent of the statewide MHI and may receive grant funding up to 80 percent of the project costs based on affordability criteria. Severely DACs are communities with a MHI less than or equal to 60 percent of the statewide MHI and may receive grant funding up to 100 percent of the project costs based on affordability criteria.

The majority of the SDWSRF funding is subsidized, low-interest rate and zero-interest rate loans that typically have a 20-year repayment term. All loans are secured; however, the security varies and is most often provided by user water rates, charges, and/or surcharges. As the outstanding loans are repaid, they generate a steady repayment stream that currently exceeds $40 million per year. In accordance with State and federal SDWSRF laws, the funds from the repayment stream are added to the SDWSRF fund and can be utilized in the same manner.

SDWSRF Funding Priority

In accordance with federal requirements and State law, CDPH establishes the priority for SDWSRF funding based on the risk to public health. Each pre-application submitted for funding is evaluated and, if eligible for funding, is assigned a category, based on the problem to be addressed. Highest categories are problems associated with bacteriological pathogens, followed by nitrate, and then other chemicals that exceed primary (health-based) drinking water standards.

Table 15-6 California Safe Drinking Water State Revolving Fund: Capitalization Grants from the U.S. Environmental Protection Agency

Fiscal Year	DWSRF Grant (million $)	Percent of National DWSRF Funds
1997	75.68	—
1998	77.11	10.83% (FY1998-2001)
1999	80.82	—
2000	83.99	—
2001	84.34	—
2002	82.46	10.24% (FY2002-2005)
2003	81.97	—
2004	85.03	—
2005	84.85	—
2006	67.10	8.15% (FY2006-2009)
2007	67.10	—
2008	66.4	—
2009 SDWSRF	66.4	8.15%
2009 ARRA[a]	159.0	8.15%
2010	137.32	9.35% (FY2010-2013)

Source: U.S. Environmental Protection Agency's Drinking Water Needs Survey 2009 and the Federal Register. See http://water.epa.gov/grants_funding/dwsrf/allotments/ for more information on Drinking Water State Revolving Fund (DWSRF) state allotments.

Notes:

[a] In 2009, California Department of Public Health also received funding under the American Recovery and Reinvestment Act (ARRA) that essentially followed Safe Drinking Water State Revolving Fund (SDWSRF) funding rules.

After the appropriate funding category is determined, CDPH further prioritizes projects based on bonus points. Bonus points are used to rank projects within a category. The addition of bonus points will not move a project from one category to another. To the extent feasible, when a group of systems is invited to complete the application process for SDWSRF funding, all the systems within that category seeking funding that year are invited to apply. Bonus points are assigned based on affordability, consolidation, type of water system, and population.

CDPH factors in affordability by comparing the MHI of the community served by the proposed project to the statewide MHI level. Communities that are below the statewide average MHI level receive additional ranking consideration. This gives poorer communities a higher ranking within a category than communities with higher income levels.

For purposes of ranking projects within a category, any project that includes consolidation of separate existing water systems will receive additional ranking points. Consolidation ranking points support projects that will provide reliability, efficiency, and economy of scale that can be achieved with larger water systems while discouraging the proliferation of numerous separate small systems that have inherent inefficiencies and limitations.

The type of water system is considered in the prioritization process because there is a relatively higher health risk associated with persons who drink the same water each day over a period of time, known as accumulated exposure. Thus, community and NTNC water systems are ranked above TNC systems within a category and with the same bonus ranking points.

All projects within a category that have the same number of ranking points and are the same type of system are ranked in ascending order based on the population served by the water system. Smaller populations are ranked above higher populations.

CDPH combines all these factors to develop a Project Priority List (PPL) each year. CDPH then invites projects for funding from the PPL. Recently, Congress has required states to commit 20 percent of the SDWSRF funds to "green projects," such as water or energy efficiency, green infrastructure, or other environmentally innovative activities. CDPH has awarded a portion of the funding to install water meters in DACs.

American Recovery and Reinvestment Act

The American Recovery and Reinvestment Act was signed by President Obama on February 17, 2009. ARRA allocated $2 billion nationally for safe drinking water infrastructure improvements. California's share of these funds is $159 million and is administered by CDPH through its existing SDWSRF program. The ARRA funds were a one-time opportunity and did not require State matching funds.

CDPH issued funding agreements totaling $149 million to 51 projects statewide. These 51 projects are distributed among 47 community drinking water systems. The funds were committed to drinking water infrastructure projects identified as "ready to proceed." All funding agreements were issued by December 2009, and all projects were under construction by February 2010. The ARRA-funded projects are in different stages of construction, and all must be completed by June 30, 2013.

Proposition 50

Proposition 50, the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (California Water Code [CWC] Section 79500, et seq.) was passed in the November 2002 general election. CDPH is responsible for portions of the act that deal with water security, safe drinking water, and treatment technology. This approved bond measure allocated $485 million to CDPH to address drinking water quality issues. Proposition 50 authorizes up to 5 percent of the funding for CDPH to administer the funding programs listed below. In addition, 3.5 percent must be allocated for bond costs. Under Proposition 50, CDPH is also responsible for multiple funding programs described below.

Chapter 3, Water Security

CWC Section 79520 provides $50 million to CDPH to protect State, local, and regional drinking water systems from terrorist attacks or deliberate acts of destruction or degradation. These funds may be used for

- Monitoring and early warning systems.
- Fencing.
- Protective structures.
- Contamination treatment facilities.
- Emergency interconnection.
- Communications systems.
- Other projects designed to:
  - Prevent damage to water treatment, distribution, and supply facilities.
  - Prevent disruption of drinking water deliveries.
  - Protect drinking water supplies from intentional contamination.

CDPH developed criteria that prioritized Chapter 3 funding to water systems to construct emergency interties with adjacent water systems. Emergency intertie connections ensure there is an alternate connection to a water system if there is a disruption in water supplies during emergencies, such as natural catastrophes or terrorist attacks. This provides additional assurance of continuous water supplies to the largest populations.

Chapter 4, Safe Drinking Water

CWC Section 79530 provides funding to CDPH for grants for public water system infrastructure improvements and related actions to achieve safe drinking water standards.

Section 79350(a) (Chapter 4a) provides $70 million for grants to small community water systems (less than or equal to 1,000 service connections or less than or equal to 3,300 persons) to upgrade monitoring, treatment, or distribution infrastructure. It also provides grants for community water quality monitoring equipment, drinking water source protection, and treatment facilities necessary to meet disinfection byproduct drinking water standards. CDPH developed criteria that prioritized Chapter 4a funding to water systems based on public health risk, using the SDWSRF categories as well as other criteria specific to the funding section. In addition, the criteria give priority to DACs within each category.

Section 79350(b) (Chapter 4b) provides $260 million for grants to Southern California water agencies to assist in meeting California's commitment to reduce Colorado River water use to 4.4 million acre-feet per year. CDPH developed criteria that prioritized Chapter 4b funding to water systems in accordance with the bond language. Projects are assigned points based on three ranking criteria, and a cumulative score is determined for each project. The projects are then ranked by that score from lowest to highest. Criterion 1 ranks projects by Proposition 50/ AB 1747 categories and by water system population (from highest to lowest) within a category. Criterion 2 ranks projects by reduction of the annual volume of Colorado River water demand. Criterion 3 ranks projects by the cost per volume of the reduced demand.

Proposition 84

Proposition 84, the Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Act of 2006 (Public Resources Code Section 75001, et seq.) was passed in the November 2006 general election. This approved bond measure allocated $300 million to CDPH to address drinking water and other water quality issues in California. Proposition 84 authorizes up to 5 percent of the funding for CDPH to administer the funding programs. In addition, 3.5 percent must be allocated for bond costs. Within Proposition 84, CDPH is responsible for multiple funding programs listed below.

- Section 75021 provides $10 million for grants and direct expenditures for emergency and urgent actions to ensure safe drinking water supplies. CDPH developed criteria to determine the eligibility of emergency grant projects. All requests that meet the eligibility criteria are funded until the funds are exhausted. Factors that CDPH considers include:
  - Type of contaminant(s).
  - Degree of contamination.
  - Whether the health hazard is acute (immediate) or chronic (long-term).
  - Length of time to which consumers have been or will be exposed.
  - Any actual or suspected illnesses.
  - Any actions taken by the local health officer or the local director of environmental health department.
  - Other funds to resolve the public health threat or emergency.
  - Duration and extent of a water outage due to an emergency.
  - Duration and extent of loss of power due to an emergency.
- Section 75022 provides $180 million in grants for small community drinking water system infrastructure improvements for chemical and nitrate contaminants and related actions to meet safe drinking water standards. Pursuant to the 2011-2012 Budget Act, $7.5 million is allocated to projects in the cities of Santa Ana and Maywood.

  CDPH developed criteria that prioritize eligible projects in accordance with the bond language and subsequent legislation. Projects were scored by points based on:
  - Regulatory status of the principal contaminant to be addressed.
  - Health risk associated with the principal contaminant to be addressed.
  - Number of contaminants in the project's drinking water supply that exceed a primary drinking water standard.
  - Median household income of the applicant water system.
  - Project includes consolidation.
  - Project is part of a regional project.
- Section 75025 provides $60 million for immediate projects needed to protect public health by preventing or reducing the contamination of groundwater that serves as a major source of drinking water for a community. Pursuant to Senate Bill X2 1, $2 million of the funding is allocated to the State Water Resources Control Board to develop pilot projects in the Tulare Lake basin and the Salinas Valley that focus on nitrate contamination.

CDPH developed criteria that prioritize eligible projects in accordance with the bond language and subsequent legislation. Projects were scored by points that are based on:

- The regulatory status of the principal contaminant to be addressed.
- The health risk associated with the principal contaminant to be addressed.
- The number of contaminants in the project's drinking water supply that exceed a primary drinking water standard.
- The median household income of the applicant water system.
- Whether the project includes consolidation.
- Whether the proposed project is part of a regional project.

Regionalization/Consolidation

One way to improve the economy of scale, which results in the potential for many benefits including lower costs, is to increase regionalization of water supply systems. This can be achieved by physical interconnections between water systems or managerial coordination among utilities. CDPH has established a requirement for evaluating consolidation as part of every project funded under the available financial assistance programs. To address deteriorating infrastructure successfully for the hundreds of smaller public water systems, regionalization and consolidation may be necessary on a larger scale. It is not cost-effective for a small system to replace aging and deteriorated sources, treatment plants, and distribution systems fully. However, with a larger rate base to spread costs across, the economies of scale improve for consolidated systems. Managerial consolidation of water districts, even where the boundaries are not contiguous, can provide great savings to the consumers by sharing the costs of oversight and management of the systems, thus freeing up funds for system upgrades. Box 15-1 describes a regional consolidation project in the planning stages.

Disadvantaged Communities/Environmental Justice

There has been heightened interest in environmental justice issues as a result of nitrate contamination problems in public water systems, particularly those in agricultural areas such as the Central Valley and Salinas Valley. The governor also set State policy when he signed AB 685 in 2012 that added CWC Section 106.3, which declares that the established policy of the State recognizes every human being as having the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes. All relevant State agencies, including the California Department of Water Resources, State Water Resources Control Board, and CDPH, are required to consider this State policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and criteria are pertinent to the uses of water described in this section.

One of the challenges for water systems that serve DACs is finding a solution to funding new operation and maintenance costs associated with a new treatment plant needed owing to groundwater contamination or in order to meet stricter water quality regulations. CDPH through its three major funding programs provides grant funding and/or zero-percent interest loans for the construction of a new treatment plant that serves a DAC. However, State funding is not available for annual operation and maintenance costs. For many small DACs, this is a substantial financial burden because treatment plants generally are expensive to operate and maintain. If the

Box 15-1 Rosamond Community Services District Regional Consolidation Project

The Rosamond Community Services District (CSD) Regional Consolidation Project is currently in the feasibility and planning stage to solve water quality problems of nine small water systems (one high school, four mutual water companies, one apartment complex, and three mobile home parks) in the Rosamond area. Eight systems have arsenic maximum contamination levels (MCL) violations and one system has a uranium MCL violation. Funding for this regional consolidation project will be through a combination of Safe Drinking Water State Revolving Fund and Proposition 84 funding.

The ultimate plan will physically consolidate eight water systems with Rosamond CSD by using a combination of pipelines, storage tanks, and booster pumps. By consolidating the small water systems with Rosamond CSD, the customers of these small systems will receive water that meets drinking water quality standards and avoid installing treatment equipment which is very expensive to operate and maintain and may be unaffordable.

One mutual water company, which is farther away from Rosamond CSD and is currently under a court-ordered receivership with Rosamond CSD being the court appointed receiver, may need to install arsenic removal treatment equipment depending upon its affordability. This project will explore managerial consolidation of this mutual water company with the Rosamond CSD in an effort to improve the economy of scale for this project and to improve operational reliability of any treatment installed.

It is anticipated that Rosamond CSD will request construction funding for the project following completion of the feasibility and planning studies.

new operation and maintenance costs are inadequately funded, the water system runs the risk of improperly operating its treatment plant and delivering unsafe drinking water to its customers.

As part of the California Water Plan Update 2013 process, the California Department of Water Resources updated a 2005 report titled *Californians without Safe Water*. The updated report, titled *Californians without Safe Water and Sanitation*, is available online as a stand-alone file (California Department of Water Resources 2014) and also can be found in Volume 4, *Reference Guide*. The report continues the dialogue regarding Californians without safe drinking water and includes a number of recommendations to continue the progress toward ensuring that all Californians have safe drinking water.

Impact of Climate Change

Climate change projections include warmer air temperatures, diminishing snowpack, precipitation extremes and storm intensity, prolonged droughts, and sea level rise. These anticipated changes could affect water quality in regions that are already experiencing difficulty meeting current water demands.

Earlier snowmelt and more intense episodes of precipitation with increased flood peaks may lead to more erosion, resulting in increased turbidity and concentrated pulses of pollutants in source waters. Increased flooding may lead to sewage overflows, resulting in higher pathogen loading in source waters. These potential changes could result in challenges for surface water treatment plants and may require additional monitoring to quantify changes in source water quality and to meet post-treatment drinking water standards.

Increased water temperatures and reduced reservoir levels may result in more prevalent eutrophic conditions, increasing the frequency and duration of algal blooms. Higher water temperatures can also accelerate some biological and chemical processes, such as increasing growth of algae and microorganisms, depletion of dissolved oxygen, and various impacts on water treatment processes. Higher sea levels as a result of climate change could affect coastal groundwater basins by making protection of groundwater from seawater intrusion more difficult.

Adaptation

Increasing demand on limited available and valuable water resources will compound any climate change impact. The continued growth in the state will continue to stress the availability of the freshwater resources needed for domestic, agricultural, and industrial uses. Coastal water providers have begun evaluating and employing desalination of sea water as an additional drinking water supply. Desalinated sea water, although more expensive to develop owing to the high energy requirements and planning and permitting costs, has been identified as a reliable drought-proof supply.

Regionalization of water supply systems as an adaptation strategy will also help counter the effects of climate change by adding operational flexibility during periods of drought or flooding. Investments in drinking water facilities and conveyance systems will add efficiency and lead to enhanced sustainability in the future. Adaptation to climate change involving the provision of adequate drinking water will likely require specific regional strategies, described in this chapter, which focus on conservation, sustainability, and operational flexibility.

Mitigation

Demand for drinking water treatment and distribution will continue to increase as climate change has major impacts on water quality and availability of the freshwater resources used for drinking water. Adverse impacts on climate change related to increasing GHG emissions could result from energy uses in (1) drinking water treatment and distribution systems; (2) bottled water production, including related transportation and waste disposal; and (3) treatment of new sources of drinking water from low-quality groundwater and recycled wastewater. Nonetheless, improving water and energy efficiency from management strategies described in this chapter could have benefits that reduce energy uses and GHG emissions as part of climate change mitigation, including:

- Promoting opportunities to use more tap water and less bottled water to reduce related energy and GHG emissions.
- Conducting audits for water and energy efficiency in drinking water treatment and distribution systems.
- Providing operational efficiency and improving aging infrastructure to control water losses for water and energy saving.
- Developing programs and applying new technologies to reduce energy use in both water treatment plants and for new sources of drinking water, such as low-quality groundwater and recycled wastewater.
- Developing energy efficiency standards for drinking water treatment and distribution systems.

- Coordinating with water-use efficiency programs and using best management practices to save water and energy, such as utility leak detection, water conservation, and water efficiency pricing and incentives for installing water efficient appliances and landscaping.

Water Use Efficiency

The efficient use of water is regarded as a viable complement, and in some instances a substitute, to investments in long-term water supplies and infrastructure. Water use efficiency is a concept to maximize the use of water or minimize its waste. Water use efficiency will continue to be a key element of addressing reduced water availability and is regarded as a major step to take before turning to more costly water sources such as desalinated seawater. Water efficiency programs and practices may include utility leak detection, water conservation programs, water efficiency pricing and incentives for installing water efficient appliances and landscaping, as well as improvements in water recovery as part of water treatment plants (e.g., recycling water used in treatment plant processes for backwash).

An important aspect of strongly encouraging water conservation is the ability of the water utility to establish an escalating metered rate based on the volume of water used. This promotes full cost recovery, conservation, or efficiency pricing. Since 1992, California law has required urban water suppliers (those serving more than 3,000 connections or delivering more than 3,000 acre-feet of water per year) to install a water meter on new connections. More recently, AB 2572 established the requirement for retrofitting water meters on pre-existing connections and charging customers for water based on the actual volume of water used. Neither of these laws addresses smaller water systems that do not meet the definition of an urban water supplier.

Many larger water agencies have already taken advantage of conservation programs to reduce the need for new water supplies. The Los Angeles Department of Water and Power has shown success in conservation where water use today is the same as it was 40 years ago, despite a population increase of nearly 1 million people (City of Los Angeles Department of Water and Power 2010). Obtaining additional conservation increases will be more difficult and may result in higher costs to achieve.

To address water losses or unaccounted water, water utilities conduct audits to identify water main leaks, unmetered water use for parks and recreation consumption, water theft, and inaccurate meters. Deteriorated and aging infrastructure contributes to significant water leakage and a high rate of water main breaks and can play an important role in water losses. Nationally, there has been reported water losses by utilities of between 10 percent to nearly 50 percent of the water produced. Due to the continued aging of distribution infrastructures that are at or near the end of their useful life, water losses due to water main leaks can be expected to remain a significant and potentially increasing barrier to California's efforts to conserve water. Both the SDWSRF program and the ARRA funds administered by CDPH provide funding to drinking water systems for water meter installation. Water meters are an important tool to measure water losses in the distribution system.

Maintaining a Trained Workforce

California requires operators of water treatment plants and distribution systems to receive certification to perform these duties. This certification is designed to ensure that operators have adequate knowledge, experience, and training to operate these facilities properly. Due to the increased complexity of water system facilities, the importance of properly trained and certified operators is increasing.

Sustaining a trained workforce to maintain an adequate level of qualified oversight at water treatment plants and operation of distribution systems has been identified as an important issue. This is, in part, due to the increased number of people from the large Baby Boom generation beginning to leave the workforce. CDPH data indicate that the average age of operators certified in California is about 50, and the average age of Grade 5 treatment plant operators (the highest treatment certification available) is greater than 55 (Jordan 2006). Many water utilities will lose 30 to 50 percent of their current workforce within the next 5 to 7 years, which will result in an unprecedented knowledge drain. A knowledge retention strategy is necessary to ensure long-term success.

Knowledge retention, broadly termed *succession planning*, is the process of identifying and preparing suitable employees through mentoring, training, and job rotation to replace key staff, such as treatment or utility managers, within an organization as current managers retire. Succession planning will become more important in the near future to ensure the transfer of knowledge as less-experienced staff moves into higher decision-making positions. This issue applies to both the public and the private water sectors, as well as to the government agencies that regulate the water industry.

In November 2006, CDPH introduced the Expense Reimbursement Grant Program (ERG) for small water system operators using an EPA grant. The ERG provided funding for small water system operators to receive reimbursement for training to become certified operators or to maintain and advance their operator certification levels. This program provided training reimbursement for operators until all funding was expended in early 2011.

Treatment Technologies for Small Water Systems

Providing safe and affordable drinking water is still a significant challenge for small water systems. Economies of scale typically become more limited for the small system size categories, resulting in per-household costs for compliance with new regulations that can be more than four times higher than those for medium-to-large water systems (U.S. Environmental Protection Agency 2006). There have been advances in the effective use of point-of-use (POU) and point-of-entry (POE) technologies for certain contaminants under controlled circumstances for some small drinking water systems (Cadmus Group 2006). POU devices are those that treat water at the location where it is consumed, such as at the tap or a drinking fountain. POE devices are those that treat all of the water entering a home or building, not just water that is consumed. POE technologies treat all water that a consumer comes in contact with, such as bathing and hand washing, while a POU device provides treated water at one tap intended for drinking and cooking and is usually installed in the kitchen. The California Safe Drinking Water and Toxic Enforcement Act allows the consideration and approval of POE for compliance with drinking water standards where it can be demonstrated that centralized treatment at the wellhead or surface water intake is not economically feasible. The California Safe Drinking Water and Toxic Enforcement Act also allows the consideration of POU devices as per the above and provided they also demonstrate that the use of POE devices is either not economically feasible or POE devices would not be as protective of public health as POU devices. Specifically, only systems serving fewer than 200 connections may be eligible to use POU or POE devices; and they must first demonstrate that (1) the installation of centralized treatment is not immediately economically feasible, (2) usage of the POE or POU device is allowed under the federal Safe Drinking Water Act for the specific contaminant, and (3) the water system has submitted a pre-application for funding to correct the violation for the contaminant that the POE or POU device is proposed to treat.

New treatment technologies that are cost-effective and do not require extensive operator attention are often needed to address chemical contaminants that affect small water systems. Proposition 50 provided funding to demonstrate some of these technologies. As new technologies are proposed to treat water to drinking water standards, CDPH must review and approve these technologies and use staff dedicated to reviewing these technical aspects of drinking water treatment.

Treatment Residuals Disposal

In many areas, treatment options for contaminants are limited owing to residual disposal issues. For example, the disposal of brine from ion exchange and reverse osmosis treatment has been identified as a potential source of salinity in groundwater. California, and especially the central San Joaquin Valley, is experiencing increased salts in the groundwater. As the salinity of local groundwater sources increases, more water customers use water softeners to improve the quality at their tap. This, in turn, results in a higher discharge of salts to the wastewater treatment plants, which increases the salinity of wastewater and exacerbates the problem. The Central Valley Regional Water Quality Control Board completed a study in May 2006 on salinity in groundwater in the Central Valley, which introduced the concept of a long-term salinity management program for the Central Valley and for California (Central Valley Regional Water Quality Control Board 2006). Additional information is available in Chapter 19, "Salt and Salinity Management."

Disposal of residuals, such as backwash water or spent media, poses additional costs for water treatment, especially those that may be classified as a hazardous or radioactive waste due to the concentration and leaching characteristics of the contaminant. Selection of treatment alternatives, especially for arsenic, must consider disposal issues. The spent treatment plant media must be evaluated under the California Waste Extraction Test (WET) for classification before determining appropriate disposal options owing to the potential for the arsenic to leach from the media in a landfill environment. The California WET classification is more stringent than federal leaching tests. The City of Glendale water system conducted a study that evaluated treatment alternatives for removal of chromium-6 that included disposal of treatment residuals. (See Box 15-2 for additional information.)

Security of Drinking Water Facilities

Water system facilities are vulnerable to security breaches, acts of terrorism, and natural disasters (all-hazards). Water system personnel and the general public have developed a greater awareness of the vulnerability of California's critical infrastructure and key resources because of the events of September 11, 2001; Hurricane Katrina in 2005; and many other disasters and incidents since then. The enhancement of security and of emergency response and recovery capabilities is crucial to maintain a reliable and adequate supply and delivery of safe, clean, and wholesome drinking water. Just as crucial are forming, developing, and exercising relationships with partners and stakeholders.

Box 15-2 City of Glendale Chromium-6 Treatment Residuals Disposal Study

The City of Glendale completed a study comparing the treatment residuals waste produced by two treatment processes for removing chromium-6: a weak-based anion exchange (WBA) process and a reduction/coagulation process that removes chromium-6 through filtration (RCF).

The main waste in the WBA treatment process is spent ion exchange resin. Based on results of the federal Toxicity Characterization Leaching Procedure (TCLP) and the California Waste Extraction Test (WET), the waste resin is classified as a California-regulated nonRCRA waste (hazardous waste regulated by the State of California, other than hazardous waste within the state that is federally regulated per the Resource Conservation and Recovery Act) and requires special handling and disposal. Additional waste characterization is needed due to the detectable quantities of uranium and thorium in Glendale's source water. While these contaminants are in the source water at concentrations below the maximum contamination levels (MCL), they are removed in the treatment process and concentrated in the resin. Testing was also conducted to determine whether the waste resin would be classified as a Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) or a Low-level Radioactive Waste (LLRW). Findings indicated that waste resin would not be classified as TENORM as long as the waste resin could be taken out of service prior to reaching uranium concentrations of 0.05 percent by weight, where it would require even more expensive disposal and handling as a LLRW.

The wastes from the RCF process are mostly settled solids after thickening and dewatering. The solids from the RCF process are classified as California-regulated nonRCRA waste and they are not classified as either a TENORM or a LLRW since the RCF process does not remove or concentrate appreciable quantities of uranium.

The disposal of treatment waste streams in California adds a major cost component to the cost of treating drinking water. Rather than disposal at a local landfill or other approved land disposal option, spent resin or solids must receive special handling and be sent to special disposal facilities that accept hazardous and/or radioactive materials.

Under the U.S. Public Health Security and Bioterrorism Preparedness and Response Act of 2002, drinking water utilities serving more than 3,300 people are required to conduct vulnerability assessments and develop/update their emergency response plans to address these vulnerabilities. All of California's water utilities in this category have prepared these documents. These documents and their implementation are an important element in building and maintaining the ability to respond to security breaches and other catastrophes and to recover from them.

The accomplishments by the water industry, the wastewater industry, and regulatory agencies to protect California's water and wastewater facilities from all-hazards include:

- Emergency Water Quality Sample Kit (EWQSK) developed by CDPH and based on the EPA Response Protocol Toolbox. These sample kits provide water systems with a resource to sample drinking water quickly for an unknown contaminant during a credible event.
- Partnerships between water agencies and the regulatory community were established to address emergency response and recovery, including the California Water/Wastewater Agency Response Network (CalWARN), Laboratory Response Network (LRN), and the California Mutual Aid Laboratory Network (CAMAL Net). CalWARN systems facilitate a utilities-helping-utilities approach by providing assistance during a crisis. By establishing mutual aid agreements before a crisis occurs, CalWARN participants pave the way for member utilities within and outside of their respective regions to send valuable aid in a quick and efficient manner. CalWARN participants can access specialized resources to assess and assist water

and wastewater systems until such time as the system can develop a permanent operating solution.

- Water Infrastructure Security Enhancement (WISE) Guidelines, drafted for the Physical Security of Water/Wastewater Utilities by national water and wastewater organizations, provide recommendations for the management, operation, construction, and retrofit of water and wastewater treatment plants and distribution/collection systems to enhance physical security. The WISE Guidelines are at http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Security.aspx.
- Coordination among partners and stakeholders and developing those relationships are critical to a successful response and recovery, and to improving situational and operational awareness. The water and wastewater communities and respective regulatory organizations have formed many groups to accomplish this critical network that meet periodically and communicate regularly. These groups include:
    - InfraGard, created and sponsored by the Federal Bureau of Investigation as a public/private information sharing and analysis collaborative. It was established because the majority of critical infrastructures and key resources are owned and operated by private entities.
    - Local Terrorism Early Warning Groups (TEWG), which meet to exchange information and discuss local and national issues.
    - Water Information Sharing and Analysis Center (Water ISAC), a Department of Homeland Security-recognized center, which provides water and wastewater information sharing and analysis.
- Recognizing that communication during a crisis can make or break a successful response, the CDPH used the Centers for Disease Control and Prevention Crisis and Emergency Risk Communication (CERC) Toolkit and modified it specifically for the water and wastewater community. CDPH has conducted numerous CERC training classes detailing the toolkit and espousing the virtues of being prepared to address risk communication during a crisis.
- A successful response and recovery is also strongly dependent upon exercising the policies, procedures, processes, and partnerships. To that goal, the regulatory communities are providing training to the water and wastewater communities on designing and conducting tabletop exercises. Tabletop exercises are a low cost, low stress process by which partners can work together on scenarios and discover any gaps or gains. This is further strengthened by the nationwide acceptance, training, and use of the Department of Homeland Security, Homeland Security Exercise and Evaluation Program (HSEEP), which provides a nationwide framework for exercises and improvement.
- Numerous tools have been created to help water and wastewater utilities be better prepared for crises and emergencies. These include:
    - Water Health and Economic Analysis Tool (WHEAT) is a consequence analysis tool designed to assist drinking water and wastewater utility owners and operators in quantifying human health and economic consequences for a variety of scenarios that pose a significant risk to the water sector.
    - Vulnerability Self-Assessment Tool (VSAT) is a risk assessment software tool for water, wastewater, and combined utilities to assist drinking water and wastewater owners and operators to conduct security threats and natural hazards risk assessment as well as updating utility emergency response plans.

- FedFUNDS is a new interactive Web site created to help water and wastewater utilities navigate through the maze of Federal Disaster Funding. (See http://water.epa.gov/infrastructure/watersecurity/funding/fedfunds/index.cfm.)

Existing and Emerging Contaminants

New contaminants in drinking water are often discovered and then regulated because of increased pollution, improved analytical abilities, and/or a better understanding of health effects. Media attention to a particular contaminant has also resulted in a legislative response to address or speed up the regulatory process. Examples include hexavalent chromium, pharmaceuticals, and personal care products. In addition, the health effects of many known contaminants are re-evaluated and re-regulated as new information becomes available. For many emerging contaminants, such as pharmaceuticals and personal care products, there may not yet be a full understanding of the health risks they cause in drinking water and available treatment technologies to remove them from drinking water. For such contaminants, the pollution prevention and matching water quality to water use resource management strategies will help address water quality concerns while additional information is gathered. For pharmaceuticals and personal care products, control of discharge to the environment is the best initial approach via source control programs and reduction through wastewater treatment, rather than relying on drinking water treatment.

Emerging contaminants may be created by treatment itself, for instance, when water utilities implement new methods or processes for disinfecting water that may create new disinfection byproducts. For some contaminants, treatment options may be available, but they may be relatively expensive.

Recommendations

Because of the importance of drinking water, there is strong interest from many groups to promote improvements to drinking water treatment and distribution facilities, operation, and management. These groups include:

- Water system managers and operators.
- Local governmental agencies — city, county, planning.
- Regulatory agencies such as CDPH, local primacy agencies (county), and the EPA.
- Environmental and community stakeholders.

Based on the major issues outlined in this chapter, the following additional actions are needed to ensure there is adequate protection of public health through the maintenance of infrastructure, advancements in water treatment, and developing and maintaining relationships among the groups that advocate safe drinking water:

1. The Legislature should take necessary steps to maintain a sustainable source of funding of water supply, water treatment, and infrastructure projects to ensure a safe and reliable supply of drinking water for individuals and communities and to provide State matching funds for the federal SDWSRF.

2. Additional funding should be provided to CDPH to provide increased technical assistance to small water systems related to asset management and rate setting.

3. The Legislature should take steps to require publicly owned water systems to establish water rate structures at a level necessary to provide safe water, replace critical infrastructure, and repay financing for treatment and distribution system improvements necessary to meet drinking water standards.

4. State government should support enactment of a federal water infrastructure trust fund act that would provide a reliable source of federal assistance to construct and repair water treatment plants.

5. Additional programs should be developed to encourage regionalization and consolidation of public water systems. Regionalization and consolidation are useful both in achieving compliance with water quality standards and in providing an adequate economy of scale for operating and maintaining existing facilities as well as planning for future needs.

6. State government should continue to develop funding for small water systems and DACs to assist in complying with drinking water standards.

7. State government should continue to encourage conservation and develop additional incentives, such as expanded rebate programs, to allow water systems to reduce the waste of limited water resources.

8. Public water systems that provide flat rate water service should strongly consider changing to a metered water rate structure to discourage waste. In addition, water systems that have water meters for some customers, but not on all service connections, should strongly consider providing water meters for all customers.

9. State government should consider providing incentives that would encourage water systems to adopt rate structures that encourage conservation and discourage the waste of water.

10. The Legislature should establish a requirement for all public water systems, whether in urban or other areas of the state, to install a meter on each service connection and charge a metered rate for actual volume of water used.

11. California's regulatory agencies, such as the State Water Resources Control Board and CDPH, should maintain internship programs for college students to continue the interest of the next generation in water and environmental regulatory agencies.

12. State government should support research and development of new and innovative treatment technologies by providing funding for demonstration pilot projects. Additional program funding is also needed by CDPH to address the review and acceptance of these new treatment technologies adequately.

13. Water systems should fully evaluate residual disposal issues when planning new water treatment facilities due to increased costs and other issues associated with disposing treatment residual wastes.

14. All public water systems should be encouraged to join the California Water/Wastewater Agency Response Network. This program will provide mutual aid and assistance more quickly than the normal resource requests submitted through the Standardized Emergency Management System.

15. The control of pharmaceuticals and personal care products in the environment should be addressed initially via source control programs and reduction through wastewater treatment.

References

References Cited

American Society of Civil Engineers. 2013. *2013 Report card for America's infrastructure*. Washington (DC): American Society of Civil Engineers. [Web site.] Viewed online at: http://www.infrastructurereportcard.org/.

Cadmus Group, Inc. 2006. *Point-of-use or Point-of-entry Treatment Options for Small Drinking Water Systems*. Washington (DC): U.S. Environmental Protection Agency. 132 pp. April. EPA 815-R-06-010.Viewed online at: http://www.epa.gov/ogwdw/smallsystems/pdfs/guide_smallsystems_pou-poe_june6-2006.pdf.

CALFED Bay-Delta Program. 2000. Programmatic Record of Decision. Sacramento (CA): CALFED Bay-Delta Program. 3 volumes. 82 pp. Conveyance Program. [Web site.] Viewed online at: http://www.calwater.ca.gov/calfed/library/Archive_ROD.html.

California Department of Public Health. 2004. *Procedure for Cost-benefit Analysis of Arsenic*. Sacramento (CA): California Department of Public Health. [Web site.]

———. 2007. Final Statement of Reasons, Perchlorate Primary Maximum Contaminant Level (MCL), Title 22, California Code of Regulations. Sacramento (CA): California Department of Public Health. 54 pp. R-16-04. Viewed online at: http://www.cdph.ca.gov/services/DPOPP/regs/Documents/R-16-04%20WEBDRAFT%20FSOR.doc.

———. 2008a. Revision of waterworks standards. Effective Mar 9, 2008. Sacramento (CA): California Department of Public Health. Viewed online at: http://www.cdph.ca.gov/services/DPOPP/regs/Pages/R-14-03-RevisionofWaterworksStandards.aspx. Accessed: Nov. 12, 2009.

———. 2008b. Initial Statement of Reasons, Arsenic Primary Maximum Contaminant Level (MCL) Revision, Title 22, California Code of Regulations. April 8. Sacramento (CA): California Department of Public Health. 16 pp. DPH-04-017. Viewed online at: http://www.cdph.ca.gov/services/DPOPP/regs/Documents/DPH-04-017-ISOR-2008-04-08.doc.

———. 2009. "Community Water Fluoridation Program." California Department of Public Health. Sacramento (CA): California Department of Public Health. [Web site.] Viewed online at: http://www.cdph.ca.gov/programs/Pages/CommunityWaterFluoridationProgram.aspx. Accessed: Nov. 12, 2009.

California Public Utilities Commission. December 2013. "California Public Utilities Commission Regulated Water and Sewer Utilities". [Web site.] Viewed online at: http://www.cpuc.ca.gov/NR/rdonlyres/6C307A27-D962-48C6-8989-012C0609A2E6/0/UtilitycontactListasof12042013c.pdf.

City of Los Angeles Department of Water and Power. 2010. *Urban Water Management Plan 2010*. Viewed online at: http://www.water.ca.gov/urbanwatermanagement/2010uwmps/Los%20Angeles%20Department%20of%20Water%20and%20Power/LADWP%20UWMP_2010_LowRes.pdf.

Cromwell JE, Speranza E, Reynolds H. 2007. "The infrastructure crisis." Journal of the American Water Works Association. 99(4):109-115.

Donoho P. 2007. "Overview of bottled water." International Bottled Water Association. Presented to the City and County of San Francisco Commission on the Environment Policy Committee Meeting, July 16.

Grumbles B. 2007. Testimony of Benjamin H. Grumbles, Assistant Administrator for Water, U.S. Environmental Protection Agency before the Subcommittee on Water Resources and Environment and the Committee on Transportation and Infrastructure. U.S. House of Representatives. January 19. 9 pp. Viewed online at: http://www.epa.gov/ocir/hearings/testimony/110_2007_2008/2007_0119_bhg.pdf.

Honeycutt K, Canada HE, Jenkins MW, Lund JR. 2012. "Alternative water supply options for nitrate contamination. In: *Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater. Report for the State Water Resources Control Board Report to the Legislature*. Technical Report 7. Davis (CA): Center for Watershed Sciences. University of California, Davis. Viewed online at: http://groundwaternitrate.ucdavis.edu/files/139108.pdf.

Jordan B. 2006. "Creating our future." Journal of the American Water Works Association. 98(10):54-55.

Metropolitan Water District of Southern California. 2014. “Historical Water Rates” Los Angeles (CA): Metropolitan Water District of Southern California. [Web site.] Viewed online at: http://www.mwdh2o.com/mwdh2o/pages/finance/finance_02.html. Accessed on Jan., 2014.

National Resource Council. 2008. *Desalination: A National Perspective*. Executive Summary. Washington (DC): National Academies Press. 312 pp.

Regional Water Quality Control Board, Central Valley Region. 2006. *Salinity in the Central Valley, An Overview*. State Water Resources Control Board. California Environmental Protection Agency. Sacramento (CA): 60 pp. Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/centralvalley_salinity_alternatives_archives/initial_development/swrcb_02may06_ovrvw_rpt.pdf.

State Water Resources Control Board. 2012. “Communities that Rely on Contaminated Groundwater.” Sacramento (CA): State Water Resources Control Board. California Environmental Protection Agency. [Web site.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml.

U.S. Environmental Protection Agency. 2006. *Small Drinking Water Systems Variances – Revision of Existing National-level Affordability Methodology and Methodology to Identify Variance Technologies that are Protective of Public Health*. Washington (DC): Federal Register. 71(41). March 2.

———. 2009. *Drinking Water Infrastructure Needs Survey and Assessment: Fourth Report to Congress*. Washington (DC): U.S. Environmental Protection Agency. Office of Water. 64 pp. EPA 816-R-09-001. Viewed online at: http://water.epa.gov/infrastructure/drinkingwater/dwns/upload/2009_03_26_needssurvey_2007_report_needssurvey_2007.pdf.

———. 2011. “Perchlorate.” Unregulated drinking water contaminants. Washington (DC): U.S. Environmental Protection Agency. [Web site.] Viewed online at: http://water.epa.gov/drink/contaminants/unregulated/perchlorate.cfm#preliminary.

———. 2013. *Drinking Water Infrastructure Needs Survey and Assessment: Fifth Report to Congress*. Washington (DC): U.S. Environmental Protection Agency. Office of Water. 70 pp. EPA 816-R-13-006. Viewed online at: http://water.epa.gov/grants_funding/dwsrf/upload/epa816r13006.pdf.

Additional References

Bautista A. 2007. Seawater desalination update. Presented to Los Angeles Department of Water and Power. October.

Beverage Marketing Corporation. 2007. *Bottling Water Continues as Number 2 in 2007*. Alexandria (VA): Prepared by Beverage Marketing Corporation for the International Bottled Water Association. Viewed online at: http://www.bottledwater.org/public/2007%20Market%20Report%20Findings%20as%20reported%20in%20April%202008.pdf.

Black & Veatch. 2006. *2006 California Water Rate Survey*. Los Angeles (CA): Black & Veatch. 23 pp. Viewed online at: http://www.kqed.org/assets/pdf/news/2006_water.pdf.

California Department of Public Health. 2009. *Fluoridation by Public Water Systems*. Sacramento (CA): California Department of Public Health. [Web site.] Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Fluoridation.aspx. Accessed on Dec., 2009.

California Urban Water Agencies. 2007. *Climate Change and Urban Water Resources*. Sacramento (CA): California Urban Water Agencies. 16 pp. Viewed online at: http://www.cuwa.org/pubs/ClimateChangeUrbanWaterResources2007.pdf.

Cromwell JE, Smith JB, Raucher RS. 2007. “No doubt about climate change and its implications for water suppliers.” Journal of the American Water Works Association. 99(9):112-117.

Intergovernmental Panel on Climate Change. 2007. F*ourth Assessment Report: Climate Change 2007*. Geneva Switzerland: Intergovernmental Panel on Climate Change. 4 volumes. Viewed online at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml.

Metropolitan Water District of Southern California. 2009. “Finance.” Los Angeles (CA): Metropolitan Water District of Southern California. [Web site.] Viewed online at: http://www.mwdh2o.com/mwdh2o/pages/finance/finance01.html. Accessed on Dec., 2009.

Public Policy Institute of California. 2008. *Just the Facts - Water Supply and Quality*. Sacramento (CA): Public Policy Institute of California. Viewed online at: http://www.ppic.org/content/pubs/jtf/JTF_WaterJTF.pdf.

Satcher D. 2000. *Oral Health in America: A Report of the Surgeon General*. Washington (DC): U.S. Department of Health & Human Services. Viewed online at: http://www.surgeongeneral.gov/library/reports/oralhealth/.

The International Bottled Water Association and Beverage Marketing Corporation. 2012. *U.S. Consumption of Bottled Water Shows Significant Growth, Increasing 4.1 percent in 2011*. Alexandria (VA): Prepared by The International Bottled Water Association and Beverage Marketing Corporation. Viewed online at: http://www.bottledwater.org/content/us-consumption-bottled-water-shows-significant-growth-increasing-41-percent-2011.

U.S. Environmental Protection Agency. 2006b. *Total Coliform Rule (TCR) and Distribution System Issue Papers Overview*. Washington (DC): U.S. Environmental Protection Agency. Office of Water, Office of Ground Water and Drinking Water.16 pp. Viewed online at: http://www.epa.gov/safewater/disinfection/tcr/pdfs/issuepaper_tcr_overview.pdf.

———. 2012. “Drinking water state revolving fund (DWSRF).” Washington (DC): U.S. Environmental Protection Agency Grants and Funding. [Web site.] Viewed online at: http://water.epa.gov/grants_funding/dwsrf/index.cfm. Accessed: November 28, 2012.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 16

Groundwater/Aquifer Remediation

Rancho Cordova, CA. The Aerojet Rocketdyne Groundwater Extraction and Treatment Facility HA is fed by five separate groundwater extraction wells and treats approximately 2 million gallons of water per day. Groundwater pumped to the facility is treated for perchlorate and volatile organic compounds, using ion exchange resin and granular activated carbon, respectively, which are housed in beige vessels, one of which is depicted here.

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Portions of aquifers in many groundwater basins in California have degraded water quality that does not support beneficial use of groundwater. In some areas, groundwater quality is degraded by constituents that occur naturally (e.g., arsenic). In many urban and rural areas, groundwater quality degradation has resulted from a wide range of human (anthropogenic) activities. Groundwater remediation is necessary to improve the quality of degraded groundwater for beneficial use. Drinking water supply is the beneficial use that typically requires remediation when groundwater quality is degraded.

Contaminants in groundwater can come from a many sources, naturally occurring and anthropogenic. Examples of naturally occurring contaminants include heavy metals and radioactive constituents, as well as high concentrations of various salts from specific geologic formations or conditions. Climate change that results in altered precipitation, snowfall patterns, and rising sea levels may exacerbate salt water intrusion and flooding of low-lying infrastructure and urban facilities. These phenomena will add new challenges to protection of groundwater from contamination. In addition, groundwater can be contaminated by anthropogenic sources with organic, inorganic, and radioactive constituents from point and non-point sources. These anthropogenic sources include industrial sites, mining operations, leaking fuel tanks and pipelines, manufactured gas plants, landfills, impoundments, dairies, septic systems, and urban and agricultural activities. The contaminant having the most widespread and adverse impact on drinking water wells is arsenic, followed by nitrates, naturally occurring radioactivity, industrial/commercial solvents, and pesticides (see Table 16-1).

Groundwater remediation removes constituents, hereafter called contaminants, which affect beneficial use of groundwater. Groundwater remediation systems can employ passive or active methods to remove contaminants. Passive groundwater remediation allows contaminants to degrade biologically or chemically or disperse in situ over time. Active groundwater remediation involves either treating contaminated groundwater while it is still in the aquifer (in situ) or extracting contaminated groundwater from the aquifer and treating it outside of the aquifer (ex situ). Active in situ methods generally involve injecting chemicals into the contaminant plume to obtain a chemical or biological removal of the contaminant. Ex situ methods for treating contaminated groundwater can involve physical, chemical, and/or biological processes.

Active groundwater remediation systems that extract, treat, and discharge the treated groundwater to a water body or inject it back into the aquifer are commonly termed “pump and treat” systems. Remediation systems that extract and treat contaminated groundwater for direct potable, irrigation, or industrial use are commonly termed “wellhead treatment” systems. Any wellhead treatment prior to direct potable use must receive a permit from the California Department of Public Health (CDPH).

In the process of extracting groundwater for remediation, the groundwater flows through the aquifer toward the extraction wells where it is removed for treatment. A number of ex situ treatment methods are available to remove contaminants from groundwater and the cost effectiveness of each treatment method should be evaluated prior to selection of a specific treatment method. Ex situ treatment methods can either transfer the contaminant to the

Table 16-1 Ten Most Commonly Detected Contaminants at Active Community Drinking Water Wells

Anthropogenic Contaminants	Naturally Occurring Contaminants
Nitrate (as NO_3)	Arsenic
Perchlorate	Gross alpha particle activity
Tetrachloroethylene (PCE)	Uranium
Trichloroethylene TCE	Fluoride
1,2-Dibromo-3-chloropropane (DBCP)	
Carbon tetrachloride	

Source: State Water Resources Control Board 2013

atmosphere (directly or after combustion), to an adsorptive media, or to a concentrated liquid waste stream. If a volatile contaminant is transferred from the groundwater to the atmosphere, permits must be obtained from the local air district. If an adsorption media is used, such as granular activated carbon or ion exchange resin, the media may have to be disposed of as hazardous waste and this significantly increases the disposal cost. If the media is regenerated, then the waste residuals which are produced have to be disposed of as hazardous waste. If the contaminant is radioactive or the adsorption media removes radioactive compounds as a co-contaminant, such as uranium, then waste residuals may need to be disposed of as radioactive waste.

Whatever the treatment method listed below (see Table 16-2), it must be suited to the constituent that has contaminated the groundwater. Light, non-aqueous phase liquids (LNAPLs), such as hydrocarbons, float on the surface of the groundwater. Dense non-aqueous phase liquids (DNAPLs), such as perchloroethylene (PCE), have a specific gravity greater than water and sink to the bottom of the aquifer. Other contaminants, such as methyl tertiary butyl ether (MTBE), may be miscible in water and are in solution in the groundwater. Both LNAPLs and DNAPLs may partially dissolve in the groundwater or be adsorbed on soil particles within the aquifer.

Groundwater Remediation in California

Groundwater remediation in California involves ex situ groundwater extraction and treatment and passive (in situ) remediation, such as biodegradation and natural attenuation. There are approximately 16,000 sites in the state where investigation or remediation of contaminants is ongoing. Regional water quality control boards (RWQCBs), the California Department of Toxic Substances Control, or local agencies have regulatory oversight of these cleanups. The Superfund remediation sites are under control of the U.S. Environmental Protection Agency. About 7,500 of these sites have had a petroleum release from a leaking underground storage tank (UST) system. A petroleum release is usually detected by analyzing for total petroleum hydrocarbons and the more soluble constituents in fuel (benzene, toluene, ethyl benzene, and xylene, commonly called BTEX). In addition to these contaminants, polyaromatic hydrocarbons, naphthalene, and MTBE can be found at former leaking UST sites. Groundwater cleanup at petroleum sites primarily

Table 16-2 Treatment Methods

Pump and Treat — Groundwater Remediation
Activated alumina
Biological
Blending
Coagulation/filtration
Granular activated carbon (GAC)
Ion exchange (IX)
Lime softening
Packed tower aeration (air stripping)
Reverse osmosis (RO)
Ultra-violet photo ionization
In situ — Aquifer Remediation
Air sparging
Bio-sparging
Bio-venting
Cosolvents
Electrokinetics
Electron acceptors (nitrate, sulfate, ferric ions)
Electron donors (to degrade chlorinated hydrocarbons)
Fluid cycling
Hydrofracturing/Pneumatic fracturing
Soil vapor extraction
Surfactant enhancements
Thermal enhancements
Treatment walls
Vitrification

focuses on reduction of BTEX and MTBE because most other components of petroleum are only very slightly soluble in water and do not migrate far from the original source of the leak.

Remediation at petroleum UST sites may involve contaminant source removal (soil excavation and free-product removal if applicable). Further remediation can include soil vapor extraction, pump and treat, in situ remediation, or a combination of these methods. Pump and treat methodology tends to be expensive and is not employed if other effective remediation options are available. The discharge from a pump and treat system may also require a discharge permit issued by a regional water quality control board.

Approximately 800 sites in California use pump and treat systems. About one-third of these are at UST sites where shallow groundwater is typically affected. The treated-flow volumes are typically 10 to 20 gallons per minute.

Most groundwater extraction and treatment remediation systems are located at sites where volatile organic compound (VOC) solvents, such as trichloroethylene (TCE) and PCE, have contaminated groundwater. TCE has been used as an industrial cleaning and degreasing agent and PCE is a degreasing agent and has been the primary chemical used by dry cleaners for decades. Because TCE and PCE are DNAPLs in free phase, they tend to sink to the bottom of aquifers or pool on top of low permeability units, they rarely can be excavated and removed from greater depths. Both compounds have low solubilities in water but are considered carcinogenic at low concentrations. Remediation systems to extract and treat groundwater contaminated with such solvents may be required. These systems are expensive to operate and may be required to run for decades. The total volume of impacted groundwater remains unknown.

TCE and PCE are both being removed from groundwater in the San Gabriel Valley of Los Angeles. More than 30 square miles of the valley has been designated as a federal Superfund site due to commercial and industrial discharges contaminating groundwater. Since the San Gabriel basin aquifer supplies more than 90 percent of the water for the valley, the treated groundwater is pumped directly into the public water supply distribution system, provided it meets drinking water quality standards. Table 16-3 lists other projects for removal of VOCs.

Dry cleaning business operations present a significant threat to groundwater quality. Past practices commonly employed by dry cleaners resulted in PCE being discharged onto the ground at the business site or to the sewer. As many as 15,000 dry cleaning facilities have operated in California. Most of these sites, past and present, are small businesses in urban areas. The owners of these facilities typically do not have the resources necessary to fund an investigation and, if necessary, the remediation to remove PCE. Therefore, relatively few of the current and former dry cleaning sites have been investigated. Remediation at dry cleaning facilities typically involves soil vapor extraction. Where groundwater has been affected, pump and treat systems are employed.

Recent studies indicate that operating, non-operating, or poorly designed water wells and possibly oil and gas wells provide conduits whereby chlorinated solvents spread from shallow to deeper aquifers. The burden of dealing with PCE contamination of drinking water often falls on the water purveyor who pumps the groundwater and who may have to discontinue use of the well or install costly treatment equipment. The cost of dealing with the legacy of dry cleaning operations and other sources of chlorinated solvents is estimated to be in the billions of dollars. Treatment systems to remove PCE and other chlorinated solvents from groundwater may need to be operated for decades.

Perchlorate is used to manufacture solid propellant for rockets, fireworks, and other uses (e.g., production of matches, flares, pyrotechnics, ordnance, and explosives). Aerospace, military, and flare manufacturing facilities have been primary sources of perchlorate. Perchlorate also occurs naturally and has been found in fertilizer imported from Chile. Perchlorate is highly soluble in water and has adverse health effects at very low concentrations in drinking water. Perchlorate

Table 16-3 Community Drinking Water Systems that Rely on One or More Contaminated Groundwater Wells by Hydrologic Region

Regulated Contaminants												
HYDROLOGIC REGION[a]		NC	SFB	CC	SC	SR	SJR	TL	NL	SL	CR	
Inorganic Chemicals												**Total**
Arsenic	No. of Systems / Wells Affected[b]	12 / 16	9 / 10	21 / 36	26 / 44	41 / 73	58 / 120	62 / 131	8 / 19	41 / 119	9 / 19	287 / 587
Nitrate	No. of Systems / Wells Affected[b]	1 / 3	4 / 10	33 /51	81 / 270	9 / 9	17 / 26	54 / 75	0 / 0	6 / 6	1 / 2	206 / 452
Perchlorate	No. of Systems / Wells Affected[b]	0 / 0	0 / 0	3 / 3	47 / 166	1 / 1	0 / 0	4 / 4	0 / 0	1 / 2	1 / 1	57 / 177
HYDROLOGIC REGION		NC	SFB	CC	SC	SR	SJR	TL	NL	SL	CR	
Radioactivity												**Total**
Gross Alpha Activity	No. of Systems / Wells Affected[b]	0 / 0	0 / 0	5 / 6	47 / 89	3 / 4	38 / 76	46 / 78	3 / 7	28 / 50	13 / 23	183 / 133
HYDROLOGIC REGION		NC	SFB	CC	SC	SR	SJR	TL	NL	SL	CR	
Volatile Organic Chemicals												**Total**
Tetrachloroethylene (PCE)	No. of Systems / Wells Affected[b]	0 / 0	1 / 2	0 / 0	40 / 141	7 / 10	4 / 4	7 / 10	1 / 1	0 / 0	0 / 0	60 / 168
Trichloroethylene (TCE)	No. of Systems / Wells Affected[b]	2 / 2	1 / 2	0 / 0	38 / 146	0 / 0	1 / 2	2 / 7	0 / 0	0 / 0	0 / 0	44 / 159
HYDROLOGIC REGION		NC	SFB	CC	SC	SR	SJR	TL	NL	SL	CR	
Pesticides												**Total**
1,2-Dibromo-3-chloropropane (DBCP)	No. of Systems / Wells Affected[b]	0 / 0	0 / 0	0 / 0	7 / 29	0 / 0	12 / 28	17 / 61	0 / 0	0 / 0	0 / 0	36 / 118

Source: State Water Resources Control Board 2013

Notes:

[a] Hydrologic regions: NC - North Coast, SFB - San Francisco Bay, CC - Central Coast, SC - South Coast, SR - Sacramento River, SJR - San Joaquin River, TL - Tulare Lake, NL - North Lahontan, SL - South Lahontan, CR - Colorado River.

[b] Wells Affected exceeded a Primary Maximum Contaminant Level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

is being removed by either ion exchange or biological treatment from the Bunker Hill, Gilroy-Hollister Valley, Rialto-Colton, Sacramento, and San Gabriel groundwater basins. In the Gilroy-Hollister Valley, the groundwater is being treated to reduce/remove perchlorate prior to injection into the shallow aquifer.

Pesticides, especially the agricultural soil fumigants 1,2-dibromo-3-chloropropane (DBCP) and ethylene dibromide, have been found in groundwater in the San Joaquin Valley, Tulare Lake region and in Riverside and San Bernardino counties. Wellhead treatment systems have been installed by water purveyors in several communities.

Arsenic is the most widespread contaminant affecting an estimated 587 community drinking water wells (State Water Resources Control Board 2012). All 10 hydrologic regions in the state have community water systems that are affected by arsenic and must treat their water from affected wells to reduce the arsenic level below 10 micrograms per liter, the current maximum contaminant level (MCL).

Nitrate is considered the second most widespread groundwater contamination problem in California affecting community drinking water wells, primarily due to decades of agricultural application of -nitrogen-based fertilizers. Other contributors of nitrate to groundwater are septic systems, concentrated animal waste facilities (e.g., dairies), and percolation of wastewater treatment plant and food processing wastes. Nitrate-contaminated groundwater can be either treated with reverse osmosis, resin-based processes, or blended with higher quality water before being placed in a water supply distribution system. Several small communities throughout the state have not been able to afford nitrate treatment systems and they must inform residents that sensitive populations, including small infants and pregnant and nursing women, should not consume this untreated drinking water. Accordingly, these small communities should explore other options such as developing a new water source or interconnecting/consolidating with a neighboring community water system.

One area that is effectively dealing with salt management is the Chino basin in the Santa Ana River watershed. The Chino Basin Optimum Basin Management Program is operating a desalter to remove nitrate that has accumulated in the groundwater from long-term agricultural operations. The treated water is used for potable supply once the nitrate drinking water standard is met. The brine from the desalters is discharged to a “brine line” that feeds into the Orange County Sanitation District’s wastewater treatment plant. Effluent from the treatment plant is discharged to the Pacific Ocean through an outfall.

Septic tank systems can be a localized source of high nitrate contamination in groundwater as well as dairies and other agricultural activities. An estimated 250,000 to 600,000 private domestic wells in California are commonly located near septic systems because building codes allow a minimum of 100 feet of separation between the two. Contaminant plumes from septic tank leach fields have been shown to travel hundreds of feet horizontally in groundwater with little dispersion or dilution of the plume. Domestic wells that are shallow and are not properly sealed are vulnerable to surface contaminants including leachate plumes from nearby septic tank systems.

Potential Benefits

The potential benefits of remediating contaminated groundwater to use the water as a part of the available water supply are:

- There is an additional available water supply that would not be available without remediation.
- Avoiding the cost of buying an alternate water supply.
- Treated groundwater that meets water quality standards may be blended with other water supplies to increase the total available water supply.
- Groundwater from remediation projects and blended supplies that do not meet drinking water or other high water quality requirements may still be available to meet water needs that do not require such high quality water, thus increasing the overall water supply.
- There is a supply that is maintained and used throughout the state to meet up to 40 percent of the state's water demand.
- Less future wellhead treatment costs by preventing contaminant plumes from spreading.
- Use of the remediated aquifer for storage of excess surface water supplies.

Potential Costs

The cost of remediating groundwater includes:

- Cost of characterizing the groundwater or aquifer in terms of the contaminants present and the hydrogeology underlying the contaminant site.
- Capital cost of the remediation system.
- Operation and maintenance costs during the life of the project; remediation may be required for a long time.

Except for petroleum USTs, it is difficult to estimate the cost of cleaning contaminated sites. In 1989, the Legislature established the Underground Storage Tank Cleanup Fund to reimburse petroleum UST owners for the costs associated with the cleanup of leaking petroleum USTs. The fund disburses about $200 million annually to eligible claimants. In the 1990s, the cost to clean up an individual UST site typically ranged from $100,000 to $200,000. The cleanup of UST sites contaminated with MTBE costs significantly more, with reimbursements as high as the fund's limit of $1.5 million per site. As of June 2011, the Fund disbursed more than $3.1 billion to eligible claimants since its establishment.

A site where solvent contamination has reached groundwater may require continuous pump and treat operation for decades and cost millions of dollars. As previously discussed, most sites with solvent discharges (e.g., dry cleaning facilities) have yet to be investigated and remediated.

Based on cost data from the State Water Resources Control Board and the California Department of Public Health, Division of Drinking Water and Environmental Management, total groundwater remediation costs in California, excluding costs of salt management, could approach $20 billion during the next 25 years. The estimate is based on current costs for remediation, estimated future costs for similar remediation, newly discovered contamination, and emerging contaminants. Almost all of these costs are associated with contaminants from previous human activities (legacy contaminants). Current pollution prevention strategies are expected to result in significantly less discharge of contaminants such as petroleum fuel, solvents, and perchlorate.

Major Implementation Issues

Water Quality

Several groundwater quality issues complicate remediation efforts. The type and the concentration of the constituents vary from aquifer to aquifer. Contaminated water associated with historic commercial, agricultural, and industrial chemical discharges may contain a variety of regulated and unregulated contaminants. Non-point-source contamination, such as nitrates or elevated concentrations of boron or salts in agricultural areas, can be widespread in the subsurface and can leach into the groundwater from surface infiltration or rising groundwater levels. Rising sea levels may also increase resource needs to combat seawater intrusion. Contaminated water may be poorly characterized in terms of the contaminants that are present and defining the dimension of the plume is costly. California has a number of Superfund sites where treatment system costs may transfer to the State, which will require additional funding. Emerging contaminants may not be known at current detection levels. The impact of emerging contaminants is also not known. The ability to remediate emerging contaminants is not fully known because they usually occur at very low concentrations, although research is being conducted. Reverse osmosis and advanced oxidation processes may prove to be viable water treatment technologies for emerging contaminants that occur at low concentrations. To improve knowledge of groundwater quality, using analytical methods with very low detection levels, the State Water Resources Control Board's Groundwater Ambient Monitoring and Assessment Program (GAMA) was created in 2000. The program's main goals are 1) to improve statewide groundwater monitoring, and 2) to increase the amount of groundwater quality information available to the public. While this program has made significant progress, much more data is needed to overcome the current lack of knowledge of groundwater hydrogeology and geometry.

Aquifer Characteristics

California's groundwater basins usually include a series of alluvial aquifers intermingled with aquitards (California Department of Water Resources 2003). Lack of specific knowledge about the geometry and characteristics of an aquifer complicates groundwater remediation. Without this information, it is not possible to develop a cost-effective remediation strategy. How much groundwater is being pumped is unknown. The storage volume of each aquifer and how much of it is contaminated are likewise unknown. While such programs as GAMA, GeoTracker-GAMA (groundwater information system), and California Statewide Groundwater Elevation Monitoring (CASGEM) have significantly improved understanding of groundwater conditions in the state, much more data is needed to overcome the current lack of knowledge of groundwater hydrogeology, geometry, and characteristics.

Costs of Investigation and Treatment

Costs can impede groundwater remediation. Who will pay, who are the responsible parties, and what is the appropriate share for each responsible party? Site investigation is expensive, particularly when solvents are the contaminant. Groundwater treatment is expensive, and it can take years, decades, or longer to remediate contaminated groundwater sites. Delays in implementing groundwater remediation while the contaminants spread can significantly increase the cost and time required for remediation. This is especially true if long-term litigation is involved to determine responsible parties.

Aside from the UST Cleanup Fund, funding for remediation is provided by responsible parties or parties willing to do the remediation (e.g., city and county agencies). In urban areas, it is often difficult to assign responsibility for the legacy of many decades of discharges of contaminants from disparate sources. Where responsibility can be assigned, responsible parties may not be able to fund investigation and remediation (e.g., dry cleaning business owners). Therefore, wellhead treatment costs are often borne by water purveyors and their customers.

Climate Change

Climate change is likely to create increased groundwater pumping due to reduced surface water flows during summer months. Surface water flows will be reduced because more winter precipitation will fall as rain instead of snow which provides surface water flows when it melts in the summer. As extraction pressures on groundwater basins increase, there may be increased attempts to remediate contaminated aquifers. Climate change will also cause further degradation of groundwater quality in coastal areas due to seawater intrusion from sea level rise.

Adaptation

Developing additional groundwater supplies through remediation will increase California’s ability to provide water supplies during drought periods. Making more groundwater basins available for water storage also allows for augmentation of groundwater supplies with recycled or desalinated water. Desalination of coastal groundwater affected by seawater intrusion due to sea level rise may also serve as an adaptation strategy to protect groundwater supplies.

Mitigation

Some of the treatment technologies used for groundwater remediation are energy-intensive. Therefore, groundwater remediation may result in increased greenhouse gas (GHG) emissions. However, if groundwater basins can be restored and replenished, their reliable yield may facilitate less energy-intensive water imports, leading to reduced GHG emissions.

Better Public Education

Better public education and outreach is needed to inform people why source water protection and pollution prevention measures are important and necessary to protect groundwater resources. A better understanding of these measures would enable people to make educated choices and select appropriate actions when their activities may degrade water quality. When groundwater resources are not protected and become impacted by pollution, a community’s drinking water supply could require treatment that was previously not needed, significantly increasing the cost to rate payers. Additional information is available in Chapter 18, “Pollution Prevention,” and Chapter 29, “Outreach and Education,” in this volume.

Small Communities

Larger community water systems (CWS) are generally in a better position to deal with contaminated groundwater supplies, because these systems are better able to absorb costs associated with treatment or engineering solutions that address the contamination. These costs are passed onto the rate payers. Small CWS typically lack the infrastructure and economies of scale of larger systems and in some cases cannot afford to treat or find alternative supplies for a contaminated drinking water source. As a result, a small CWS can be more vulnerable to delivering contaminated groundwater to their customers. Some of these communities are small, rural, and disadvantaged and are the focus of environmental justice concerns (State Water Resources Control Board 2012).

Operation and Maintenance Costs for Removing Inorganic Chemicals

When evaluating alternatives to provide safe water to a community, water systems managers should evaluate the operation and maintenance costs associated with any treatment system being considered. For small water systems, a financial analysis should also be completed to assess if the community can afford to operate and maintain a new treatment facility. Annual operation and maintenance costs are typically high for removing inorganic chemicals such as arsenic, nitrate, and perchlorate. In the past the operation and maintenance costs for these treatment facilities has been underestimated, resulting in cost overruns and causing insolvency in some communities. State and federal funding is available to water systems, however most funding programs only cover the capital costs of installing the treatment system, and do not cover the ongoing operation and maintenance costs. There have been instances in which a community installed a treatment plant to remove a groundwater contaminant only to shut down the treatment facility later when it could not afford to operate and maintain the treatment facility.

Use of Extremely Impaired Water Sources for Domestic Water Supply

CDPH considers sources that exceed 10 times a chronic MCL or notification level (NL), or exceed three times an acute MCL or NL, or have several different types of contaminants, to be extremely impaired water sources and require more investigation and reliable treatment. The investigation involves identifying all known and possible contaminants that could be in the source, a risk assessment in the event of a treatment failure, and the resultant quality of the treated water. The treated water quality objective must take into account the allowable levels of the contaminants and the synergistic effect of similar compounds in the source water. This requires a public hearing to assess public acceptance.

Recommendations

The following recommendations can help prevent pollution, protect groundwater quality, and remediate groundwater where necessary to maintain California's water resources:

1. The Legislature should fund State regulatory agencies to identify historic commercial and industrial sites with contaminant discharges and identify viable responsible parties to investigate and remediate those sites.

2. State agencies, in coordination with local groundwater management agencies, should assist local governments and local agencies to implement source water protection measures based on the source water assessments that were completed as of 2003 to protect recharge areas from contamination and prevent future contamination.

3. State agencies, in coordination with local groundwater management agencies, should assist local agencies with authority over land use to prevent contamination of recharge areas.

4. Local government and local agencies with responsibility over land use should, in coordination with local groundwater management agencies, limit potentially contaminating activities in areas where recharge takes place and work together with entities that propose potentially contaminating activities to develop a sustainable good quality, long-term water supply for beneficial uses.

5. Work with the U.S. Environmental Protection Agency, the Bureau of Indian Affairs, and tribes to accomplish the objectives of recommendations 2, 3, and 4.

6. The State should establish and support research funding at California universities for wellhead treatment systems.

7. The State should establish and support research for detecting emerging contaminants by commercial laboratories and research how these contaminants affect human health and the environment.

8. Agencies involved in groundwater cleanup and oversight projects should collaborate and leverage resources and authorities to minimize overlap and improve outcomes.

9. Agencies involved in groundwater cleanup and groundwater purveyors should improve outreach and coordination for regional issues to develop new approaches to aquifer preservation and cleanup.

10. The State should re-evaluate the Water Well Standards and any related oil and gas well standards to ensure the standards spell out how to protect groundwater and drinking water from cross contamination via existing, abandoned, and destroyed wells.

References

References Cited

California Department of Water Resources. 2003. *California's Groundwater Bulletin 118 Update 2003.* Sacramento (CA). Viewed online at: http://www.water.ca.gov/groundwater/bulletin118/bulletin118update2003.cfm. Accessed: October, 2003.

State Water Resources Control Board. 2012. *Communities that Rely on Contaminated Groundwater. Draft Report to Legislature*. Sacramento (CA). Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml.

———. 2013. *Communities that Rely on a Contaminated Groundwater Source for Drinking Water*. Sacramento (CA). Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf.

Additional References

Belitz K, Dubrovsky MN, Burow K, Jurgers B, Johnson T. 2003. *Framework for a Ground-water Quality Monitoring and Assessment Program for California*. Sacramento (CA): U.S. Geological Survey and California Water Resources Control Board. Water Resources Investigations Report 03-4166. 78 pp.

California Department of Public Health. 2009. "Chemicals and Contaminants in Drinking Water." California Department of Public Health. Sacramento (CA): [Web site.] Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chemicalcontaminants.aspx. Accessed: Nov. 16, 2009.

California State Water Resources Control Board. 2009. "GAMA — Groundwater Ambient Monitoring & Assessment Program." California State Water Resources Control Board. Sacramento (CA): [Web site.] Viewed online at: http://www.waterboards.ca.gov/gama/. Accessed: Nov. 16, 2009.

Centers for Disease Control and Prevention. 2007. "NIOSH Pocket Guide to Chemical Hazards." Atlanta (GA): [Web site]. Viewed online at: http://www.cdc.gov/niosh/npg. Accessed: Oct. 26, 2012.

Focazio MJ, Reilly TE, Rupert MG, Helsel DR. 2002. *Assessing Ground-water Vulnerability to Contamination: Providing Scientifically Defensible Information for Decision Makers*. Circular 1224. Washington (DC): U.S. Department of the Interior and U.S. Geological Survey. 33 pp.

Freeze RA, Cherry JA. 1979. *Groundwater*. Englewood Cliffs (NJ): Prentice-Hall. 604 pp.

Harter T, Lund JR, Darby J, Fogg GE, Howitt R, Jessoe KK, Pettygrove GS, Quinn JF, Viers JH, Boyle DB, et al. 2012. "Addressing Nitrate in California's Drinking Water: With a Focus on Tulare Lake Basin and Salinas Valley Groundwater." [Report for the State Water Resources Control Board Report to the Legislature.] [California Nitrate Project, Implementation of Senate Bill X2 1.] Davis (CA): University of California, Davis, Center for Watershed Sciences. 78 pp. Viewed online at: http://groundwaternitrate.ucdavis.edu. Accessed: Nov. 27, 2012.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 17

Matching Water Quality to Use

Suisun Marsh. A joint project of DWR and the U.S. Bureau of Reclamation, the Suisun Marsh Salinity Control Gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. The purpose of lowering the saline content of the water is to preserve Suisun Marsh wetlands and associated habitats.

Contents

Chapter 17. Matching Water Quality to Use

Matching water quality to use is a management strategy that recognizes that not all water uses require the same water quality. One common measure of water quality is its suitability for an intended use; a water quality constituent often is only considered a contaminant when that constituent adversely affects the intended use of the water. High-quality water sources can be used for drinking and industrial purposes that benefit from higher quality water and lesser quality water can be adequate for some uses. For example, a water supplier chooses to use a groundwater source for municipal use, which requires less treatment before delivery, rather than a natural stream. The potential benefit to the municipal user could be reduced disinfection byproducts in the delivered drinking water source and a secondary benefit would accrue to the natural riparian system because water would be left instream. Further, some new water supplies, such as recycled water, can be treated to a wide range of purities that can be matched to different uses. The use of other water sources, like recycled water, can serve as a new source of water that substitutes for uses not requiring potable water quality. Instream uses are directly influenced by discharges from wastewater treatment and stormwater flows and these source discharges can provide benefits and challenges to uses such as aquatic life and recreation.

Matching Water Quality to Use in California

As part of the nine regional water quality control boards basin planning efforts, up to 25 water quality beneficial use categories for water have been identified for mostly human and instream uses (see the definition of "Beneficial Use," with regard to water quality and water rights, in the Update 2013 Glossary). For this strategy, the beneficial uses discussed are primarily water quality-related beneficial uses. A second definition of beneficial uses of water is also defined by the California Code of Regulations for the purposes of applying for a water right to appropriate water. These two definitions of beneficial uses overlap, but differ enough so that one needs to be aware of the distinction (see California Code of Regulations, Title. 23, Sections 659-672).

Human uses are categorized as consumptive (e.g., municipal, agricultural, and industrial supplies) and non-consumptive (e.g., navigation, hydropower generation, and recreation). Instream uses include aquatic ecosystem uses, fish migration, spawning, and preservation of rare, threatened, and endangered species. Matching water quality to most of these uses is important because water is generally used as is (i.e., without treatment) except for municipal and industrial uses. In addition, aquatic organisms are more sensitive to some pollutants than humans. For example, the presence of dissolved metals at low concentrations can be lethal to sensitive fish species.

Matching Water Quality to Agricultural Use

Farmers currently match crops to the available water quality. In general, irrigation water should contain levels of constituents, such as salinity and boron, which will not inhibit the yields of some of the crops. Conversely, agricultural water supplies that have low levels of salts may require adding gypsum to improve percolation. Agricultural water supplies may require filtration to remove particulate matter that could clog low pressure irrigation systems and reduce soil infiltration rates. For example, the Imperial Irrigation District runs all water that it diverts from the Colorado River at Imperial Dam through siltation basins to remove suspended particulates before the water is released into the All American Canal. In setting objectives for the reasonable protection of agricultural use in the 1995 Water Quality Control Plan for the San Francisco Bay/ Sacramento-San Joaquin Delta Estuary, the State Water Resources Control Board reviewed the suitability of soils to determine anticipated crop types and set the salinity objectives to meet the needs of these crop types.

Matching Water Quality to Instream and Ecosystem Use

Ambient, instream water must be suitable to support a wide range of aquatic habitats and conditions. Thus, water quality for instream ecosystem uses generally must meet physical, chemical, and microbial parameters specific to the habitat and instream needs. One particular water quality objective that greatly affects fisheries is temperature. An example of an effort made to match water quality to an environmental use for temperature is the Temperature Control Device at Shasta Dam, which was built to make a better match of water temperature to the reproductive needs of salmonid fish downstream. When viewed from a watershed level, decisions about whether to use instream versus out-of-stream sources, such as groundwater and recycled water, to meet future municipal and agricultural demands may result in the decision to leave water instream in favor of using out-of-stream alternatives.

Matching Water Quality to Drinking Water Use

In order to avoid the additional cost of treatment and to provide multiple protection barriers for public health, it is best that drinking water supplies start with the highest quality source water reasonably possible. Historically, California's urban coastal communities — Los Angeles, San Francisco, Oakland, and Berkeley — constructed major aqueducts to sources such as Hetch Hetchy, Owens Valley, and the Mokelumne River. Later, water supplies of lesser quality, such as the Sacramento-San Joaquin Delta and the Colorado River, were also tapped for domestic water supplies. In response, many utilities already manage water quality by blending higher quality water supplies with those of lower quality, as well as matching treatment processes to source water quality, as required by regulation. For example, Metropolitan Water District of Southern California (MWD) dilutes high salinity Colorado River water with lower salinity water from the Sacramento-San Joaquin Delta (Delta). This improves the public's acceptance of tap water, as well as facilitating groundwater recharge and wastewater recycling projects. At the same time, MWD dilutes the higher bromide and organic carbon levels in Delta water with Colorado River water to help reduce disinfection byproducts in treated water. In Solano County, higher quality, less variable Lake Berryessa water is blended with lower quality, highly variable North Bay Aqueduct water from the Delta. Likewise, many water suppliers have the capability to blend groundwater, local surface water, and imported supplies to achieve a desired water quality, although some utilities may choose to use water supplies based upon cost minimization or water rights considerations instead. Some water agencies even blend water and water quality from different levels of the same reservoir by using different intake levels. Many water management actions, such as conjunctive use, water banking, water use efficiency, and water transfers, intentionally or unintentionally result in one type of water quality traded for, or blended with, another.

In the Upper Santa Ana River Water Basin, matching water quality to its effective use has been ongoing through a complex watershed-wide method. With the addition of the Seven Oaks

Dam, water quality from the reservoir has improved, while at the same time, effluent flow downstream of the reservoir has increased. By using the increased flow of lower quality effluent for groundwater recharge, the region could increase its dry year sources while using the higher quality reservoir water for direct delivery of water for municipal uses.

Matching Water Quality to Industrial and Commercial Use

Businesses also match water quality to use. For instance, ultra-pure water is needed in many manufacturing processes in the Silicon Valley and San Francisco Bay Area. To produce ultra-pure water, manufacturers prefer higher quality (low total dissolved solids) Hetch Hetchy water over Delta or groundwater supplies that are also available in the region. The West Basin Municipal Water District offers different qualities of recycled water at different costs that are tailored to different uses, including process water for petroleum refining. At least one concrete plant in San Francisco captures and reuses its low-quality stormwater runoff for concrete production. The use of saline water and wastewater for power plant cooling has been promoted by the State Water Resources Control Board, as described in its Power Plant Cooling Policy adopted on June 19, 1975 (State Water Resources Control Board 1975), and implemented by the regional water quality control boards.

Water Quality Exchange Projects

There are potential regional opportunities to exchange water to make a better match of the water quality needs of the constituent service areas. This would result in lower treatment costs and associated energy and greenhouse gas (GHG) emissions.

The CALFED Bay-Delta Program (CALFED) identified two potential water quality exchange projects, the San Joaquin Valley-Southern California Water Quality Exchange Program and the Bay Area Water Quality and Supply Reliability Program, to improve water quality and water supply reliability, as well as disaster preparedness, on a regional basis. These programs could promote matching water quality to water use with potentially no degradation to the ultimate use of the water. For instance, a local water agency in the Bay Area with access to a water supply of relatively lower water quality could fund water recycling or water conservation projects in another agency's service area that has a higher quality water supply in exchange for the higher quality water saved by those projects. This concept is being pursued under the Bay Area Integrated Regional Water Management Plan (IRWMP) — *Water Supply and Water Quality Functional Area Document* (RMC 2006).

Under the San Joaquin Valley-Southern California Water Quality Exchange Program, MWD is working with both the Friant Water Users Authority and the Kings River Water Association to investigate the feasibility of exchanging water supplies. MWD is interested in these exchanges to secure higher quality Sierra water supplies that could lower their cost of treatment and increase their ability to meet more stringent drinking water quality regulations. In return for participating in the water quality exchange, Friant and Kings are interested in securing infrastructure improvements, financed by MWD, which will increase water supply reliability for their members. In this type of exchange, however, increased salinity levels are the largest water quality issue. If water is drawn from a poorer quality supply and the basin has no outlet, then the salinity level in the groundwater will increase (for further discussion, see Chapter 19, "Salt and Salinity Management," in this volume). This program is still being pursued as part of the September 2006

San Joaquin River Settlement (refer to *NRDC et al. v. Rogers et al.* 2006) (San Joaquin River Restoration Program 2009).

Statutory Language

Several sections of the California Water Code and the California Code of Regulations provide guidance for the use of water, as well as specify legal and regulatory requirements, and thus define the potential for utilizing this strategy.

- The use of potable domestic water sources for nonpotable use is considered a waste and unreasonable use if recycled water of adequate quality is available (Water Code Section 13550).
- Existing water rights holders are free to use recycled water, desalinated water, or water polluted by waste to a degree which affects the water for other water quality beneficial uses over their normal higher quality water source, without fear of losing their water right due to non use (Water Code Section 1010).

Potential Benefits

Agriculture

For agricultural and instream uses, water quality matching is an integral part of water quality management because there is generally no treatment of these water supplies prior to their use.

Drinking Water

For drinking water, appropriately matching high-quality source waters can reduce the levels of pollutants and pollutant precursors that cause health concerns in drinking water. In addition, less costly treatment options can be used when water utilities start with higher quality source waters. In turn, this increases water supply reliability and assures multiple barriers of protection for public health.

Municipal and Industrial

For municipal and industrial customers, using water high in salinity can damage plumbing fixtures, water-using devices, and equipment all of which increases costs. A 1999 study conducted by the U.S. Department of the Interior and MWD found that for every decrease of 100 milligrams-per-liter in salinity, there is an economic benefit of $95 million annually to MWD’s customers (Bookman-Edmonston 1999).

Instream/Ecosystem Benefits

For instream uses, maintaining water temperature suitable for fish and aquatic organisms is an integral part of managing instream water quality for the benefit of the ecosystem. Temperature control devices, as used on Shasta Dam, provide reservoir operators with a mechanism to adjust the water temperature of reservoir outlet flows to meet the needs of the downstream ecosystem better.

Opportunities for Blending of Sources

Improved treated water quality and water supply reliability are also potential benefits of water quality matching for those agencies that have access to a diverse water supply portfolio. One example is the Santa Clara Valley Water District, its retail agencies, and other water suppliers along the South Bay Aqueduct which have access to Delta water, Hetch Hetchy, local surface water, and groundwater. During droughts, seawater intrusion increases the level of salinity, including bromide, in Delta water supplies. In such an event, agencies and regions with water source flexibility could use more groundwater or local surface water, if available, both of which are relatively bromide-free. When water with high levels of bromide is disinfected, there may be additional treatment costs incurred to minimize the formation of potentially carcinogenic disinfection byproducts.

Avoided Treatment Costs

Water that contains lower levels of salinity is a better match for domestic water quality uses and for irrigating salt-intolerant crops such as strawberries and avocados. As previously noted, some agencies blend water supplies to achieve a desired water quality, including salinity levels. If low salinity water supplies are unavailable, water utilities may have to treat high salinity water supplies to achieve a desired water quality. In the Chino basin, utilities already desalinate groundwater for domestic use. In the San Francisco Bay Region, the Zone 7 Water Agency and Alameda County Water District (ACWD) also desalinate groundwater for domestic use. For example, the capital costs alone of ACWD's new groundwater desalting project in Newark were $1.3 million per acre-foot per day of capacity, with operations and maintenance costs of $500 per acre-foot.

No-Cost Water Quality Exchange

In 2003, a no-cost water quality exchange was implemented between the Environmental Water Account (EWA), Kern Water Bank, and MWD. Under the exchange, EWA had purchased groundwater in the Kern Water Bank, seeking to avoid a storage fee for leaving the purchased water in the bank. MWD offered to receive EWA's purchased water in exchange for providing the EWA with a surface water supply later in the year when EWA could use the water. MWD benefited from the exchange because it received groundwater supplies with low total organic carbon and bromide levels during a period when MWD was unable to blend total organic carbon levels down with Colorado River supplies.

Another example of a no-cost exchange is when an urban water user provides agricultural water users with surface supplies during the peak agricultural water demand period. During these periods, agricultural users would otherwise be forced to use groundwater and might face pumping constraints. In return for access to surface supplies, the agricultural user returns a similar amount of pumped groundwater during the fall-winter period when there is excess groundwater pumping capacity and there are undesirable levels of bromide and total dissolved solids in Delta surface supplies.

In addition to water-supply benefits, the use of Delta water in groundwater recharge and banking operations may provide water quality benefits as well as substantially reducing levels of turbidity, pathogens, and organic carbon upon withdrawal. Recharge and banking will result in better quality water with respect to these pollutants if the water is percolated.

Climate Change

As precipitation patterns change, water scarcity is likely to increase. Increased conflict over how to use available water might arise. Matching water quality to use allows for multiple uses below drinking water standards (and a few above those standards) and could increase water supply reliability for urban systems, agriculture, and the environment. Climate change may have an overall negative effect on water quality; climate change impacts such as sea level rise, droughts, and floods additionally would affect water quality.

Adaptation

Generally, treating less water to higher standards may increase adaptive capacity by increasing supply reliability for drinking water. If, for example, more buildings use recycled water for toilets and irrigation, the overall demand for potable water will decrease, making urban systems more resilient when faced with diminished supplies due to climate change impacts. Taking steps such as changing plumbing codes, increasing recycled water production, and allowing for greater flexibility for agricultural irrigation system water quality can help to protect critical drinking water supplies.

Mitigation

Matching water quality to use has mitigation benefits and drawbacks. There are energy benefits from treating less water to a higher quality than is needed for the intended use. Increased energy use, however, may result from increased treatment of municipal wastewater that is sometimes necessary to make that recycled water available for safe, non-potable uses. Moreover, new distribution infrastructure will be necessary in certain instances, and the construction of that infrastructure would result in GHG emissions.

Linkages to Other Resource Management Strategies

Pollution Prevention

This strategy has a direct link to the pollution prevention strategy because maintaining water to its highest quality through pollution prevention allows greater potential uses of the water. The higher the quality of water, the greater potential there is to match quality to use.

Municipal Recycled Water

Water quality is matched to use when municipal wastewater is treated to recycled water standards for non-potable use such as irrigation. This allows greater flexibility in the use of local water supplies and reduces the amount of potable water needed for a community if recycled water replaces potable water that is used for irrigation.

Salt and Salinity Management

As water is used and reused, the potential for buildup of salts in the water makes the water less suitable for reuse. Salinity management is necessary to preserve the maximum potential uses of the water.

Groundwater/Aquifer Remediation

Matching water quality to use can be used as a management tool for aquifer protection. One example of this is in the Salinas groundwater basin where recycled water will be supplied to agriculture in lieu of groundwater. This in-lieu recharge is used to combat further seawater intrusion.

Potential Costs

Water Exchange Costs

CALFED estimated that water quality exchanges could cost nearly $100 million (in 2004 dollars) during Stage 1 implementation. These costs can be broken down into costs to build the infrastructure that matches quality to use, the long-term conveyance costs, administrative costs (negotiation costs), swapping place of use, and institutional costs.

Infrastructure and Conveyance Costs

In most cases, costs for matching water quality to use will also include new conveyance systems to connect source waters different from those currently being used. Matching quality to use involves moving water from where it is available to where it is needed, incurring costs for energy, capacity, and hydraulic losses. These costs can come in the form of incentive payments for participants (e.g., the incentive for the Friant/Kings-MWD programs is MWD's willingness to invest in local infrastructure that will benefit the exchange partners).

Major Implementation Issues

Water Quality Exchanges

Water quality exchanges face similar regulatory, institutional, and third-party impact issues that water supply transfers face (for further discussion, see Chapter 8, "Water Transfers," in this volume). In particular, water supplies are generally governed by place-of-use restrictions that must be addressed when exchanging water supplies. Moreover, water quality exchanges could have adverse third-party impacts such as increasing the salinity of local groundwater, reducing the availability of higher quality instream water needed for fisheries, and limiting agriculture to salt-tolerant crops. These water quality exchanges should be evaluated for their impact on energy use and GHG emissions, in addition to the increase in supply and satisfaction of increased demand.

Effluent-Dominated Streams

Many streams in California have become dominated by effluent releases from wastewater and stormwater releases resulting from diversions of water out of streams and lakes for beneficial human uses. In addition, many streams in the semi-arid West that were naturally and seasonally intermittent or ephemeral have become perennial due to wastewater discharges or nuisance flows from stormwater systems. The conversion from intermittent/ephemeral stream types has changed the type of ecosystem being supported. For example, the native red-legged frog thrives in ephemeral stream systems. When these systems are converted to perennial streams, bull frogs, predators of the red-legged frog, can thrive and expatriate the red-legged frog from its habitat. Water pollution reduction is typically directed at eliminating the discharge of water coming from wastewater and stormwater. This strategy could restore some native intermittent/ephemeral ecosystems, but would also remove the "created" perennial ecosystems. In fact, the opposite may occur: where effluent has replaced perennial flows, the removal of the effluent could convert historically perennial systems into ephemeral systems unless natural flows could be restored.

As water is withdrawn from streams and lakes in the rain-fed watershed, effluent discharges have been increasing. While effluent discharges might be seen as replacing the natural sources of water in some watersheds, the timing and quality of the water is much different from natural conditions. For example, the effluent is typically warmer than the natural flow from formerly snowmelt-fed or groundwater-fed streams and may contain more salts and other contaminants. This situation typically benefits non-native fish species over native species.

Usability of Water

There is often a high cost incurred by water supplies that become either unsuitable for certain uses, or very expensive to use because of contamination. An example is the contamination of water supplies by methyl tertiary-butyl ether (MTBE, a gasoline additive that may cause cancer), which initially closed 80 percent of Santa Monica's drinking water wells, determined in a study by the Environment California Research and Policy Center (Jahagirdar 2003). This contamination forced the city to increase its dependence on imported water sources and later to install treatment facilities to reduce MTBE levels.

Another example, a study by the University of California, Davis, on nitrate contamination in the Tulare Lake basin and Salinas Valley, found that many small drinking water systems in these areas that rely on groundwater have nitrate contamination that exceeds the drinking water standard. One solution that matches water quality to use is to switch from the nitrate contaminated groundwater to surface water (Harter et al. 2012).

Salinity

Agricultural drainage, imported Colorado River water, seawater intrusion in the Delta, and coastal aquifers all contribute to increasing salinity in all types of water supplies which can adversely affect many beneficial uses including irrigation, fish and wildlife, and domestic use. The primary tool to reduce salinity impacts is matching water quality to use because many sources of salinity, such as seawater intrusion, are natural and treatment to remove salinity is relatively expensive. If the source water has less salinity, the discharge after use will also have less salinity. Further, water supplies that are high in salinity increase the cost of recycling or recharging them into aquifers for subsequent reuse. The State Water Resource Control Board adopted a Recycled Water Policy in 2009 (State Water Resources Control Board 2009-0011) that directed stakeholders to develop salt and nutrient management plans. In addition, the regional water quality control boards have recognized the need to develop salt management strategies to prevent high-quality waters from being degraded due to salt discharges. The Santa Ana Regional Water Quality Control Board has adopted a salt management plan, and the Central Valley Regional Water Quality Control Board is working on a salt management strategy.

Operations Criteria for Storage and Conveyance

Most reservoirs and other projects, such as water transfers and the EWA described above, operate to achieve goals and objectives related to water supply, power production, flood control, fish and wildlife protection, and even recreation — but not water quality. In the Delta, there are water quality standards for salinity and temperature in project operations that protect agricultural, instream, and municipal and industrial uses. However, these ambient water quality standards do not reflect water user demand for lower salinity water supplies.

Upstream and Downstream Partnerships

Few partnerships presently exist between upstream source water areas, downstream water users, and the water users in between that affect water quality, resulting in a critical disconnect in the overall system. Such partnerships could lead to pollution prevention or trading opportunities that could create more efficient water quality protection. For example, a downstream partner with an interest in protecting water quality may wish to pay for projects or initiatives in the upstream partner's area of influence. California encourages these partnerships through grants funded by various bond measures to develop and implement an IRWMP.

Ecosystem Restoration and Drinking Water Supplies

Some ecosystem restoration projects, such as wetlands restoration, may improve habitat and even some aspects of water quality, but at the same time may degrade other aspects of water quality, such as the increase of mercury or organic carbon, from a drinking water perspective. The CALFED Ecosystem Restoration program has reviewed this potential conflict in matching water quality to use in the Delta (California Department of Fish and Game 2009).

Recommendations

1. The State should facilitate and streamline water quality exchanges that are tailored to make better matches of water quality to use, while mitigating any adverse third-party impacts of such transfers, including the increase or decrease in net energy use and greenhouse gas emissions.

2. The State, local agencies, and regional planning efforts should review potential impacts on streams by projects aimed at eliminating discharge of wastewater or causing changes to the natural timing and quality of water and make recommendations on how to mitigate these impacts.

3. The State should facilitate water reuse downstream by encouraging upstream users to minimize the impacts of non-point urban and agricultural runoff and treated wastewater discharges.

4. The State should support the development of salt management plans for all watersheds where salt is a constituent of concern.

5. The State and local agencies should better incorporate water quality into reservoir, Delta, and local water supply operations, as well as facility reoperation and construction. For example, the timing of diversions from the Delta, and thereby the concentrations of salinity and organic carbon in those waters, could be better matched to domestic, agricultural, and environmental uses. Alternatively, the timing and location of urban and agricultural discharges to water sources, including the Delta, could also be coordinated with the eventual use of water conveyed by potentially impacted diversions. Facilities conveying municipal and industrial water could also be separated from those conveying water for irrigation.

6. The State, local water agencies, and regional planning efforts should manage water supplies to optimize and match water quality to the highest possible use (e.g., drinking water) and to the appropriate treatment technology.

7. Consistent with the watershed-based source-to-tap strategy recommended in “Pollution Prevention,” Chapter 18 in this volume, the State should facilitate systemwide partnerships between upstream watershed communities and downstream users along the flow path in order to find ways to make better matches of water quality to use. Ongoing integrated regional water management planning efforts are facilitating systemwide partnerships to make better matches of water quality to use.

8. The State should support research for solutions to the potential conflicts between ecosystem restoration projects and water quality for drinking water.

References

References Cited

Bookman-Edmonston Engineering Inc. 1999. *Salinity Management Study. Final Report. Long-Term Strategy and Recommended Action Plan*. Sacramento (CA): Prepared for the U.S. Department of the Interior and Metropolitan Water District of Southern California.

California Department of Fish and Game. 2009. “Environmental Water Quality — Mercury.” Sacramento (CA): California Department of Fish and Game. [Web site.] Viewed online at: http://www.dfg.ca.gov/ERP/wq_mercuryissues.asp. Accessed: December 2009.

Harter T, Lund JR, Darby J, Fogg GE, Howitt R, Jessoe KK, Pettygrove GS, Quinn JF, Viers JH, Boyle DB, et al. 2012. *Addressing Nitrate in California’s Drinking Water: With a Focus on Tulare Lake Basin and Salinas Valley Groundwater*. Report for the State Water Resources Control Board Report to the Legislature. California Nitrate Project, Implementation of Senate Bill X2 1. Davis (CA): University of California, Davis, Center for Watershed Sciences. 78 pp. Viewed online at: http://groundwaternitrate.ucdavis.edu. Accessed: Nov. 27, 2012.

Jahagirdar S. 2003. *Down the Drain: Six Cases of Groundwater Contamination That Are Wasting California's Water*. Los Angeles (CA): Environment California Research & Policy Center. 24 pp. Viewed online at: http://calwater.ca.gov/content/Documents/meetings/2003AndLess/DWQP_MeetingNotes_2-28-03/MeetingMaterials_DownTheDrain_2-28-03.pdf.

RMC. 2006. *Bay Area Integrated Regional Water Management Plan — Water Quality and Water Supply*. Draft final. Sacramento (CA): Prepared by RMC. 82 pp. Viewed online at: http://bairwmp.org/docs/functional-area-documents/water-quality-and-water-supply/at_download/fileUpload.

San Joaquin River Restoration Program. 2009. "San Joaquin River Restoration Program." Sacramento (CA): [Web site.] Viewed online at: http://www.restoresjr.net/index.html. Accessed: Nov. 16, 2009.

State Water Resources Control Board. 1975. *Resolution No. 75-58 Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Power Plant Cooling*. Sacramento (CA): State Water Resources Control Board. 9 pp. Viewed online at: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1975/rs75_058.pdf.

———. 2009. *Resolution No. 2009-0011 Policy for Water Quality Control for Recycled Water*. Sacramento (CA): State Water Resources Control Board. 3 pp. Viewed online at: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2009/rs2009_0011.pdf.

Additional References

Alameda County Water District. 2009. "Alameda County Water District." Fremont (CA): [Web site.] Viewed online at: http://www.acwd.org. Accessed: Nov. 16, 2009.

CALFED Bay Delta Program. 2000. Water Quality Program Plan. Final programmatic EIS/EIR Technical Appendix. Sacramento (CA). 342 pp. Prepared by CALFED Bay Delta Authority. Viewed online at: http://www.calwater.ca.gov/content/Documents/library/306.pdf.

Friant Water Users Association. 2009. SJR Settlement. Lindsay (CA): Friant Water Users Association. [Web site]. Viewed online at: http://fwua.org/sjr/sjr.htm. Accessed: Dec., 2009.

Ising L. 2005. *Jumping through hoops: strict environmental regulations challenge producer*. The Concrete Producer. [Trade Magazine.] http://deltacouncil.ca.gov/science-program/delta-science-plan. Sep:1-6.

Jahagirdar S. 2006. *A Clean Water Future for California — How California's Water Boards Can Clean up Nine of the State's Biggest Polluted Rivers, Lakes and Bays*. Los Angeles (CA): Environment California Research & Policy Center. 100 pp. Viewed online at: http://cdn.publicinterestnetwork.org/assets/hWKYZ4d-Fj2hfEy8nonACQ/clean_water_future.pdf.

Natural Resources Agency and State Water Resources Control Board. 2002. *Addressing the Need to Protect California's Watersheds: Working with Local Partnerships*. Sacramento (CA): Natural Resources Agency and State Water Resources Control Board. Report to the Legislature required by Assembly Bill 2117, Chapter 735, Statutes of 2000. 79 pp. Viewed online at: http://resources.ca.gov/watershedtaskforce/AB2117LegReport_041102.pdf.

Sacramento River Watershed Program. 2009. "Sacramento River Watershed Program." Sacramento (CA): [Web site]. Viewed online at: http://www.sacriver.org. Accessed: Nov. 16, 2009.

U.S. Bureau of Reclamation. 2009. "Environmental Water Account." Sacramento (CA): [Web site]. Viewed online at: http://www.usbr.gov/mp/EWA/index.html. Accessed: Dec., 2009.

U.S. Geological Survey. 2009. Water Information. Reston (VA): [Web site.] Viewed online at: http://water.usgs.gov/owq/. Accessed: Nov. 16, 2009

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 18

Pollution Prevention

Carmichael, CA. Two young volunteers collect debris in Arcade Creek during Creek Week, an annual program sponsored and coordinated by the Sacramento Area Creeks Council, in which volunteers improve and enhance the area's urban waterways and enjoy a week of educational activities and fun.

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Boxes

Chapter 18. Pollution Prevention

Pollution prevention can be defined as the reducing or eliminating of waste at the source by modifying production processes, promoting the use of non-toxic or less toxic substances, the implementation of practices or conservation techniques including activities that reduce the generation and/or discharge of the pollutants, and the application of innovative and alternative technologies which prevent pollutants from entering the environment prior to treatment. These preventive activities can also include new equipment designs or technology, reformulation or redesign of products, substitution of raw materials, updating or improvements of existing management practices, continued maintenance of previously implemented management practices, training and education/outreach, and improved collaboration.

Pollution prevention begins at the source. Sources of water quality pollution can be categorized into two types: point-source and non-point-source. In California, point-source pollution prevention is addressed through the Clean Water Enforcement and Pollution Prevention Act of 1999, Water Code Section 13263.3(d)(1), which authorizes the State Water Resources Control Board (SWRCB), a regional water quality control board (RWQCB), or a publicly owned treatment works (POTW) to require a discharger to prepare and implement a pollution prevention plan. A point-source discharger is defined per Water Code Section 13263.3(c) as any entity required to obtain National Pollutant Discharge Elimination System (NPDES) permit or any entity subject to the federal pretreatment program. A non-point discharger is any discharger not covered by a NPDES permit.

Pollution prevention can contribute to the protection of water quality for beneficial uses by protecting water at its source and therefore may reduce the need and cost for other water management and treatment options. By preventing pollution, restoring, and then protecting improved water quality throughout a watershed, water supplies can be used and reused by a greater number and types of downstream water uses. Protecting water quality through appropriate pollution prevention is consistent with a watershed management approach to water resources problems.

As increasing emphasis is placed on protecting instream uses for fish, wildlife, recreation, and scenic enjoyment, surface water allocations administered under ever-tightening restrictions are posing new challenges and giving new direction to the SWRCB's water rights activities. In a landmark case, *National Audubon Society v. Superior Court*, the California Supreme Court held that California water law is an integration of both public trust and appropriative right systems, and that all appropriations may be subject to review if "changing circumstances" warrant their reconsideration and reallocation. At the same time, it held that like other uses, public trust values are subject to the reasonable and beneficial use provisions of the California Constitution. Together with the SWRCB, the courts have concurrent jurisdiction in this area.

The difficulty comes in balancing the potential value of a proposed or existing water diversion with the impact it may have on the public trust. After carefully weighing the issues and arriving at a determination, the SWRCB is charged with implementing the action, which would protect the latter. The courts also have concurrent jurisdiction in this area.

As with all of the other pieces of the California water puzzle, protecting through pollution prevention, restoring/improving impaired water quality, and allocating the limited resource fairly and impartially among many competing users (while not creating or increasing water quality pollution issues with these allocations), are among some of the SWRCB's greatest challenges.

Pollution Prevention in California

In the past, the main water pollution prevention focus was primarily on those from point-source discharges. Pollution can enter a water body from point-sources like municipal wastewater treatment facilities, industrial wastewater treatment facilities, or municipal discharges from stormwater runoff. In recent years, however, as point-sources have been more effectively regulated and controlled, the remaining so-called "non-point-sources" of pollution have become one of the main concerns of the SWQCB and RWQCBs. These non-point source pollutants are generated from a variety of sources, including land use activities associated with agricultural operations and livestock grazing, forestry (silviculture) practices, uncontrolled urban runoff not covered by permits, deposition of airborne pollutants, hydromodification, and discharges from marinas and recreational boating activities. There are many approaches such as regulations (e.g., dischargers under the Water Code), voluntary/self-determined (e.g., locally led entities that desire a cleaner environment and that conduct riparian and ecosystem restoration activities), or incentive-based (e.g., U.S. Department of Agriculture Natural Resource Conservation Service Environmental Quality Incentives Program (EQIP) — National Water Quality Initiatives funding for implementing Agriculturally-based Management Practices) that are available for preventing non-point source water pollution. Understanding, planning for, assessing, documenting, managing, tracking, and controlling non-point source pollution through better land use management has been and will continue to be developed. Additional information on land use is available in the "Land Use Categories and Pollution Prevention" section in this chapter or in Chapter 24, "Land Use Planning and Management," in this volume.

Coordinating the prevention of both point- and non-point sources of pollution in concert with one another has been shown to help identify priority areas of focus. As resources continue to become increasingly limited, the ability to identify and focus funding resources through coordinated efforts will be of great importance.

The U.S. Environmental Protection Agency (EPA), SWRCB, California Coastal Commission (CCC), and RWQCBs coordinate closely on non-point source pollution issues. These agencies implement permitting, enforcement, remediation, monitoring, and watershed-based programs to prevent pollution. In addition, as part of California's non-point source Program Fifteen-Year Strategy (non-point source Program Strategy) that started in 1998, the SWRCB established an Interagency Coordinating Committee (IACC) to assist other state agencies with non-point source regulatory authorities and/or land use responsibilities to familiarize themselves with each others' non-point source activities, and to better leverage their resources. The Irrigated Lands Regulatory Program Roundtables and the Marina's IACC meetings continue to be two of the most effective of these originally formed groups.

Non-point source dischargers are responsible for ensuring that their discharges do not adversely impact water quality in the state. In an effort to prevent pollution, restore impaired water quality, and protect improved water quality, a number of government agencies provide funding for water quality projects using state bond funded grants and loans, and federal Clean Water Act section 319 (CWA 319) implementation grants. Some of the government agencies that administer and provide this funding include the SWRCB, Department of Water Resources, Department of Pesticide Regulations, Department of Conservation, and EPA. Unless new state water bond funding is approved by voters in the coming years, these bond funds will eventually be depleted with only the CWA 319 implementation grants continuing through the SWRCB. The amount of federal funding made available to the SWRCB for CWA 319 implementation grants has declined by 13 percent in 2010 and 10 percent in 2011. This funding is expected to continue to decline in the future. The need for increased CWA 319 federal funding and improved collaboration, cooperation, and leveraging of all funding sources will be extremely important in order to sustain a high level of water quality improvements, pollution prevention, and restoration efforts. The SWRCB non-point source program has identified watershed-based plan development and funding coordination for implementation as a high priority.

Pollution prevention can require a cultural change, one that encourages more anticipation and internalizing of real environmental costs by those who may generate pollution, and which also requires building a new relationship with all stakeholders to find the most cost-effective means to achieve those goals.

Antidegradation Policies

Pollution prevention can be provided through the adoption and implementation of policies to protect and/or maintain high water quality. The federal Clean Water Act requires each state to adopt a statewide antidegradation policy and establish procedures for its implementation. The California and federal antidegradation policies require, in part, that where surface waters have a higher quality than necessary to protect beneficial uses (e.g., designated uses of the water which can include, but are not limited to, domestic, municipal, agricultural and industrial supply, power generation, recreation, aesthetic enjoyment, navigation, and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves), the high quality of those waters must be maintained unless otherwise provided for by the policies. The federal antidegradation policy prohibits any activity or discharge that would lower the quality of surface water that does not have assimilative capacity with limited exceptions. The California Antidegradation Policy, which predates the federal Clean Water Act, was adopted by the SWRCB in 1968 as SWRCB Resolution No. 68-16. SWRCB Resolution 68-16 establishes the requirement that state water discharges be regulated to achieve the “highest water quality consistent with maximum benefit to the people of the state.” The state’s Antidegradation Policy applies more comprehensively to water quality changes than the federal policy because it also applies to groundwater and not just surface water.

The Antidegradation Policy has been incorporated into all RWQCBs’ water quality control plans (basin plans). A basin plan establishes a comprehensive program of actions designed to preserve, enhance, and restore water quality in all water bodies within the state. The basin plan is each RWQCB’s master water quality control planning document and includes the beneficial uses of water within the RWQCB’s jurisdiction, water quality objectives to protect the beneficial uses, and a program of implementation to achieve the water quality objectives. Federal laws require states to adopt water quality standards. In California, the beneficial uses and water quality objectives are the state’s water quality standards.

Water Quality Monitoring

California Water Quality Monitoring Council

Senate Bill 1070 was enacted to orchestrate more effectively the many water quality monitoring efforts already in progress within the state, and to make that process more visible to users and to entities committed to the protection, monitoring, and supply of water to all its users. It provides for the creation of a structure to allow the public to access any available water quality data, current methods and research, as well as current regulations and enforcement actions. The bill also created the California Water Quality Monitoring Council to connect the myriad activities throughout the state in a more cohesive and sensible manner with the ability to provide direction to reduce redundancies, prioritize actions, and recommend funding necessary to provide the critical information necessary to protect California's water.

The California Water Quality Monitoring Council provides multiple perspectives on water quality information and highlights existing data gaps and inconsistencies in data collection and interpretation, thereby identifying areas for needed improvement in order to address the public's questions. The Monitoring Council has developed a set of "My Water Quality" Internet portals supported by expert stakeholder work groups, which include members from local, state, federal, and non-governmental organizations. The initial Internet portals were developed around water quality themes in an easy to understand manner and to answer the following water quality questions:

- Is It Safe To Swim In Our Waters?
- Is It Safe To Eat Fish and Shellfish From Our Waters?
- Are Our Ecosystems Healthy?

Additional "My Water Quality" Internet portals are planned and will address the following water quality questions:

- Is Our Water Safe to Drink?
- Are Our Stream and River Ecosystems Healthy?
- Are Our Tidepool Ecosystems Healthy?
- Are Our Estuary Ecosystems Healthy?
- Are Our Ocean Ecosystems Healthy?

Surface Water Ambient Monitoring Program

The Surface Water Ambient Monitoring Program (SWAMP) is a statewide monitoring effort that provides the scientifically sound data necessary to manage California's water resources effectively. Ambient monitoring refers to the collection of information about the status of the physical, chemical, and biological characteristics of the environment. The SWRCB and the RWQCBs introduced SWAMP in 2001. The program's purpose is to monitor and assess water quality to determine whether California is meeting its water quality standards and protecting its beneficial uses. Data from SWAMP are used to improve the state's water quality assessment and impaired water bodies list, required under CWA Sections 305(b) and 303(d), respectively. In addition, regional efforts underway by the Central Coast Ambient Monitoring Program are briefly described in Box 18-1.

Box 18-1 Central Coast Ambient Monitoring Program

The Central Coast Ambient Monitoring Program (CCAMP) is the Central Coast's regional component of SWAMP. CCAMP plays a key role in assessing Central Coast regional goals and has a number of program objectives: (1) assess watershed condition on a five-year rotational basis using multiple indicators of health, (2) assess long-term water quality trends at the lower ends of coastal creeks, (3) conduct periodic assessments of harbors, estuaries, lakes, and near-shore waters using multiple indicators of health, and (4) support investigations of other water quality problems including emerging contaminants, sea otter health, pathogenic disease, toxic algal blooms, and others.

Groundwater Ambient Monitoring and Assessment Program

The Groundwater Ambient Monitoring and Assessment (GAMA) Program was created in 2000 by the SWRCB and it is California's comprehensive groundwater quality monitoring program. GAMA collects data by testing the untreated, raw water in different types of wells for naturally-occurring and human-made chemicals. GAMA compiles these test results with existing groundwater quality data from several agencies into a publicly-accessible Internet database called Geo-Tracker GAMA and is available at http://geotracker.waterboards.ca.gov/gama/. The main goals of GAMA are to improve statewide groundwater monitoring and increase the availability of groundwater quality information to the public.

California Monitoring and Assessment Program

In 2004, California Monitoring and Assessment Program for Wadeable Perennial Streams was initiated. This program builds on EPA's Environmental Monitoring and Assessment Program using a probabilistic monitoring design incorporating land use classes to allow for assessments of status and trends in aquatic life beneficial use protection in streams. Historic Environmental Monitoring and Assessment Program data were analyzed to produce assessments of the condition of streams statewide and in special study areas in Northern and Southern coastal California. Several assessments will also be completed focusing on providing water quality information statewide, and for the broad land use categories such as urban, agriculture, and forested areas. Based upon the highly extrapolative nature of this program, practitioners with intimate familiarity with specific water body conditions have questioned the sensitivity of this approach to identifying barriers to migration, which cause impairment to anadromous fish populations in water bodies displaying generally good water quality. These efforts directly relate to Recommendation 3 of this strategy in the 2005 California Water Plan and can be seen as some success in responding to this recommendation.

Since 2000, California has conducted three successive probability surveys of its perennial streams and rivers, each with a focus on biological endpoints. These surveys are now combined and are managed collectively by the SWAMP under its Perennial Streams Assessment Program. In 2010, SWAMP's Perennial Streams Assessment conducted the SWRCB's eleventh continuous year of probability monitoring of perennial, wadeable streams. To date, the program has collected biological data (invertebrates, algae) and associated chemical and habitat data from approximately 850 probabilistic sites statewide. These surveys have produced a wealth of data that can and should be used to inform many decisions made by California's water resource agencies. For example, the assessments in the *2006 California Water Quality Assessment Report*

(Clean Water Act Section 305(b) Report) were based in large part on data from these surveys. Data from these surveys were also used in the development of the *2010 Integrated Report* (Ode et al. 2011).

Surface Water Quality Assessment and Total Maximum Daily Loads (TMDLs)

The CWA Section 305(b) requires each state to report biennially on the quality and condition of its waters. CWA Section 303(d)(1)(A) requires each state to identify waters within its boundaries which are not meeting water quality standards. The reports submitted by states serve as the basis for EPA's *National Water Quality Inventory Report to Congress*. The SWRCB and RWQCBs conduct physical, chemical, and biological monitoring of the waters of the state and prepare a biennial assessment report for EPA (SWRCB 2012a).

California's CWA Section 303(d) (CWA 303d) Listing Policy sets the rules to identify which waters do not meet water quality standards, even after point-source dischargers have installed the required levels of pollution control technology (SWRCB 2009a). The federal law requires that states establish priority rankings for water on the CWA Section 303(d) list and develop action plans, called Total Maximum Daily Loads (TMDLs) for specific pollutants to improve water quality and protect designated beneficial uses. TMDLs can take various forms, but most commonly are adopted through the basin plans for the region.

Water bodies are most often listed as impaired for sediment, pathogens, nutrients, increased temperature, pesticides, metals, and organic chemicals. The resulting TMDLs are then implemented through the point-source and non-point source regulatory programs such as:

- National Pollutant Discharge Elimination System (NPDES) permits for point-sources (e.g., wastewater treatment facilities, stormwater runoff).
- State waste discharge requirements (WDRs) for point-sources not subject to the NPDES permit program and non-point-source discharges.
- Prohibitions for discharges other than agriculture.
- Conditional waivers of WDRs.

Multiple pollutants can be addressed in a single TMDL or multiple water bodies in a watershed may be addressed in a single TMDL. The RWQCBs are currently developing more than 181 TMDLs, addressing approximately 255 listings in 2011-12. Schedules have been developed for establishing all required TMDLs during a 13-year period. More detailed schedules of work to be undertaken in the short-term have also been developed. The SWRCB *Annual Performance Report* currently provides the number of TMDLs adopted, number of listings addressed by TMDLs, and total number of listings remaining. These performance reports are updated annually and are available at http://www.waterboards.ca.gov/about_us/performance_report_1112/plan_assess/#more.

Many significant pollution problems today are the result of persistent legacy pollutants, such as mercury, that were extracted from the Coastal Range and were used to process gold in the Sierra Nevada mines in the 19th century, industrial chemicals, such as polychlorinated biphenyls (PCBs) used in electrical transformers, and pesticides such as dichlorodiphenyltrichloroethane (DDT). These pollutants also contaminate sediments, making ecosystem restoration efforts more difficult. Hydraulic mining during the 1900s still has an adverse impact on numerous Central Valley rivers and the San Francisco Bay, as well as major parts of the Klamath River watershed. Some environmental contaminants of concern, such as mercury, selenium, PCBs, and DDT are persistent and/or are bioaccumulate up the food chain. These contaminants may negatively impact communities and Native American tribes dependent upon subsistence fisheries.

In 2011, the EPA issued its final decision regarding the water bodies and pollutants added to California's 303(d) Lists and 305(b) Reports, referred to as the *2010 Integrated Report*. This supersedes the 2006 California Clean Water Act 303(d) List as California's current 303(d) List. The 2010 California CWA 303(d) List now includes 87,399 impaired river miles and 7,582,984 acres of impaired lakes and bays. In some cases, a water body is listed for more than one pollutant. There are a total of 3,489 pollutant-water body listings. There have been a total of 1,473 listings addressed, 957 of which were addressed by a TMDL and during the 2010 303(d) listing cycle, and 122 de-listings to date. The *2010 Integrated Report* includes a web-based interactive map and is available at http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml.

Groundwater Quality

Human activities increase the discharge of salt, nitrates/nutrients, and other pollutants. Such activities include the application of fertilizers (even at accepted optimal agronomic rates), application of imported water for irrigation containing dissolved salts, and industrial, municipal, and domestic wastewater discharges. Salts are leached to groundwater by rainfall or irrigation practices. Additionally, salts in native soils can be dissolved by irrigation water and leached to groundwater. For additional discussion, see Chapter 19, "Salt and Salinity Management," in this volume.

Nitrate pollution of groundwater results from various sources including the use of nitrogen fertilizers, percolation of wastewater treatment plant and food processing wastes, leachate from septic system drainfields, animal corrals, manure storage lagoons, urban parks, lawns, golf courses, and leaky sewer systems. A recent study of the Tulare Lake basin and Salinas Valley growing areas found that nitrate from agricultural fertilizer is the largest threat to groundwater quality in these areas (Harter et al. 2012). Nitrate contamination of community water system wells is also the most frequently detected anthropogenic (human-caused) contaminant, affecting more than 450 wells that are used by more than 200 community water systems statewide (SWRCB 2013). Wellhead treatment programs and blending with higher quality water are both effective at reducing the nitrate level in drinking water supplies. However, the extra cost to remove or reduce nitrate to below safe levels is often expensive and unaffordable for disadvantaged communities. Individual residences served by domestic wells are also at risk if these are located in or near known areas of nitrate contamination. Domestic wells generally tap shallow groundwater making them more susceptible to contamination. Many of these well owners are unaware of the quality of the well water, because the State does not require them to test their water quality. For additional discussion on groundwater contamination, see Chapter 16, "Groundwater/Aquifer Remediation," in this volume.

Groundwater Recharge Area Protection

Protecting recharge areas is important since they provide a primary means to replenishing groundwater supplies. Good natural recharge areas are those where good quality surface water is able to percolate unimpeded to groundwater. If recharge areas cease functioning properly, there may be insufficient groundwater storage for later use. Protection of recharge areas requires a number of actions based on two primary goals: (1) ensuring that areas suitable for recharge continue to be capable of adequate recharge rather than become covered by urban infrastructure such as buildings and roads, and (2) preventing pollutants from entering the groundwater in order to avoid expensive treatment that would be needed prior to potable, agricultural, or industrial uses.

Protection of recharge areas is necessary to maintain the quantity and quality of groundwater in the aquifer. However, protecting recharge areas by itself does not provide a supply of water. Recharge areas only function when aquifer storage capacity is available, and when regional and local governments and agencies work together to protect or secure an adequate supply of good quality water to recharge the aquifer. Climate change may alter precipitation and runoff patterns, which will impact groundwater recharge (see the "Climate Change" section in this chapter). Protecting existing and potential recharge areas allows them to serve as valuable components of a conjunctive management and a groundwater storage strategy.

Zoning can play a major role in protecting a recharge area by amending land use practices so that existing recharge sites are retained as recharge areas. In the past, some areas that provided good rates of recharge were paved over or built upon and are no longer available to recharge the aquifer. Local governments often lack a clear understanding of recharge areas and the need to protect those areas from development or contamination. Land use zoning staff does not always recognize the need for recharge area protection for water quantity and water quality. For further discussion, see Chapter 25, "Recharge Area Protection," in this volume.

Drinking Water Source Assessment and Protection

Drinking water originates from streams, rivers, lakes, and underground aquifers. These sources usually require water treatment to remove contaminants before it is delivered to customers as drinking water. However, the cost and level of water treatment, as well as the risks to public health, can all be reduced by protecting source water from contamination. Establishing drinking water source assessment and protection programs are necessary to identify contaminating activities and implement practices to protect source water. Ultimately, everyone from government agencies to local communities, including business and citizens, plays a role to ensure that drinking water sources are protected.

Assessment of Drinking Water Sources

The assessment of drinking water sources is the first step to develop a complete drinking water source protection program. A source water assessment is a study that defines the land area contributing water to a public water system source, identifies the major potential contamination activities that could affect the drinking water supply, and determines how susceptible the public water supply is to this potential contamination. The Safe Drinking Water Act requires states to develop EPA-approved programs to carry out assessments of all source waters in their state.

Local communities, water systems, and citizens can then use the publicly available study results to take actions to reduce potential sources of contamination and protect drinking water (EPA 2012). In California, most source water assessments for public drinking water sources have been completed and are available at http://swap.ice.ucdavis.edu/TSinfo/TSintro.asp.

In addition to source water assessments, public water systems that treat surface water are required to conduct a watershed sanitary survey every five years. At a minimum, this survey includes:

- Physical and hydrogeological description of the watershed.
- Summary of source water quality monitoring data.
- Description of watershed activities and sources of contamination that affect source water quality.
- Description of any significant changes that have occurred since the last survey, which could affect the source water quality.
- Description of watershed control and management practices.
- Evaluation of the system's ability to meet water treatment requirements.
- Recommendations for corrective actions to improve source water quality.

These watershed sanitary surveys provide an assessment of the watershed, identify possible contamination sources, and recommends actions needed to protect and improve source water quality.

Protection of Drinking Water Sources

In California, drinking water systems are encouraged to establish a source water protection program to protect their supply sources from contamination. Source water protection measures are established to prevent contamination of groundwater and surface water being used or considered for use as a source of drinking water. These include non-regulatory measures, such as best management practices (BMPs), and regulatory methods such as issuing permits. A source water protection program is a valuable tool for several reasons.

- It is the most cost-effective method to ensure the safety of a drinking water supply.
- It is part of a multi-barrier approach to provide safe drinking water; treatment alone cannot always be successful in removing contaminants.
- It improves public perception of the safety of drinking water.
- It helps to ensure safe drinking water that is essential for public health and economic well-being of communities.

A drinking water source protection program envisions a partnership between local, state, and federal agencies to ensure that the quality of drinking water sources is maintained and protected. Recently, the Central Valley RWQCB launched a multi-year effort to develop a drinking water policy for surface waters in the Central Valley (see Box 18-2).

Box 18-2 Central Valley Drinking Water Source Policy

Public water systems that use surface waters must comply with increasingly stringent laws and regulations designed to provide increasing protection for public health. In August 2000, the CALFED Bay-Delta Program issued a Record of Decision (ROD) requiring the California Bay-Delta Authority, with the assistance of Department of Public Health (DPH), to coordinate a comprehensive Source Water Protection Program. One element of this Source Water Protection Program is to establish a Drinking Water Policy for the Delta and upstream tributaries.

The Central Valley Regional Water Quality Control Board has been working with a workgroup made up of interested stakeholders including federal and State agencies, drinking water agencies, and wastewater, municipal stormwater, and agricultural interests to develop a drinking water policy to help protect drinking water supplies. These efforts resulted in a Drinking Water Policy for Surface Waters of the Delta and Its Upstream Tributaries that was adopted by the Central Valley Regional Water Quality Control Board in July 2013. The policy includes narrative water quality objectives for the pathogens *Cryptosporidium* and *Giardia*, along with implementation provisions, and clarification that the narrative water quality objective for chemical constituents includes drinking water constituents of concern. The workgroup evaluated land use changes and potential control measures that could be expected to occur in the next 20 years. The workgroup concluded that organic carbon would not increase at drinking water intakes based on the cumulative effect of several factors that included reduction in agricultural lands and increasing regulations as well as increased urbanization. While pathogens were not specifically modeled in this effort, current monitoring indicates that the new narrative water quality objective is being met. Additional information is available at http://www.waterboards.ca.gov/centralvalley/water_issues/drinking_water_policy/index.shtml.

Stricter Water Quality Regulations

Over the past 10 years the RWQCBs have begun to impose stricter water quality standards to meet the requirements of the California Toxics Rule and to enforce total maximum daily load (TMDL) allocations. In 2000 the EPA adopted the California Toxics Rule (section 131.38 of Title 40 of the Code of Federal Regulations) which set numeric water quality criteria for California's surface waters. The SWRCB subsequently adopted a *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California* also known as SIP which is the State's implementation plan for the California Toxics Rule. The RWQCBs then began including monitoring requirements and effluent limits for toxic pollutants in NPDES Permits. Around the same time, the RWQCBs started to adopt TMDL allocations and enforcing these TMDLs in NPDES permits, waste discharge requirements, and conditional waivers.

Land Use Categories and Pollution Prevention

The state non-point source program addresses non-point source pollution by promoting management measures (MMs) and management practices (MPs) for each of the six separate land use categories: agriculture, urban, forestry (silviculture), marinas and recreational boating, hydromodification, and wetlands. Management measures serve as general goals for the control and prevention of polluted runoff. Site-specific MPs are then used to achieve the goals of each management measure. Management practices refer to specific technologies, processes, siting criteria, operating methods, or other alternatives to control non-point source pollution.

The SWRCB, the RWQCBs, and the California Coastal Commission have developed and adopted successive, five-year plans (non-point source implementation plans) to implement the non-point source program strategy. The non-point source 15-Year Strategy (1998-2013) focuses on the progress made in the non-point source program thus far, describes the additional regulatory, educational, and financial tools made available to the RWQCBs, and identifies the need for prioritizing resources and efforts. The goals of the current non-point source implementation plan are similar to those of the past five-year plans (2008-2013) with a closer focus on the following activities:

- Implementing the Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program (non-point source Implementation and Enforcement Policy) by the RWQCBs, particularly through the RWQCB's use of regulatory tools.
- Concentrating non-point source resources on TMDL planning, assessment and implementation priorities, and shifting these funds away from pollution prevention outreach.
- Improving coordination and leveraging of resources with other funding organizations, such as USDA (EQIP), SWRCB's Clean Water State Revolving Fund (CWSRF), Department of Conservation Watershed Program Grants, Department of Water Resources Integrated Regional Water Management, and others.
- Focusing overall efforts and resources on high priority watersheds and problems, as defined by priority TMDLs and other region-specific problems.
- Acknowledging the balancing act required by SWRCB programs to clean up waters polluted by non-point-sources and to preserve clean waters.

In the next five years, the SWRCB expects to have a fully integrated database of existing and tested management measures and management practices, many success stories based on proper implementation and maintenance of these measures and practices, well-established cleanup programs based on actions taken pursuant to the non-point source Implementation and Enforcement Policy, and an accurate assessment of the remaining non-point source pollution problems in the state. The non-point source program strategy will be updated by the SWRCB non-point source program after receiving new EPA non-point source program plan guidance. The goal of this new guidance is to ensure a more cohesive and consistent set of non-point source strategies and reporting requirements for all states. At this time, the SWRCB will be well-positioned to take another long-term look at the future of non-point source pollution cleanup priorities.

The SWRCB has developed the Nonpoint Source Encyclopedia (http://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia.shtml) to help practitioners choose management practices for implementation. It is a free, online reference guide designed to facilitate a basic understanding of non-point source pollution control and to provide quick access to essential information from a variety of sources. This is done through hyperlinks to other resources available on the Internet. The purpose of the Nonpoint Source Encyclopedia is to support the implementation and development of the non-point source aspects of TMDLs and watershed action plans with a goal of protecting high quality waters and restoring impaired waters. The companion tool, the Management Practices MP Miner (http://mpminer.waterboards.ca.gov/mpminer/), allows users to cull data from studies of management practices, peer reviewed and otherwise, by filtering studies using relevant site-specific variables, such as land use category, pollutant of concern, and removal efficiency required. Both tools are available at the SWRCB Web site as indicated above.

Agriculture

Agricultural activities that cause non-point source pollution can include poorly located or managed animal feeding operations, overgrazing, plowing too often or at the wrong time, and improper, excessive, or poorly timed application of pesticides, irrigation water, and fertilizer. Farm and ranching pollutants include sediment, nutrients, pathogens, pesticides, metals, and salts. To control non-point source pollutants generated from this land use category, agricultural management measures should address:

- Erosion and sediment control.
- Facility wastewater and runoff from confined animal facilities.
- Nutrient management.
- Pesticide application.
- Grazing management.
- Irrigation water management.
- Education and outreach.

Urban

Controlling polluted runoff in urban areas is a challenge. Negative impacts of urbanization on coastal and estuarine waters are well documented in a number of publications including California's CWA Section 305(b) and Section 303(d) reports and the Nationwide Urban Runoff Program. Major pollutants found in runoff from urban areas include sediment, nutrients, oxygen-demanding substances, road salts, heavy metals, petroleum hydrocarbons, plastics, pesticides, pathogenic bacteria, and viruses. In addition to organic carbon and pathogens, suspended sediments constitute the largest mass of pollutant loadings from urban areas into receiving waters. Construction is a major source of sediment erosion. Petroleum hydrocarbons result mostly from automobile sources. Plastics, including plastic bags and bottles, are mainly the result of urban runoff. Nutrient and bacterial sources include garden fertilizers, leaves, grass clippings, pet wastes, homeless encampments, and faulty septic tanks. As population densities increase, there is a corresponding increase in trash and pollutant loadings that is generated from human activities. Many of these pollutants enter surface waters via runoff without undergoing treatment. To control non-point source pollutants generated from this land use category, urban management measures should address:

- Runoff from developing areas, construction sites, and existing development.
- Septic tank systems.
- Transportation development (roads, highways, and bridges).
- Education and outreach.

Forestry (Silviculture)

Silviculture can contribute pollution to rivers and lakes. Without adequate controls, forestry operations may degrade the characteristics of waters that receive drainage from forest lands. Sediment concentrations can increase due to accelerated erosion, water temperatures can increase due to removal of over-story riparian shade, dissolved oxygen can be depleted due to the accumulation of slash and other organic debris, and concentrations of organic and inorganic chemicals can increase due to harvesting, fertilizers, and pesticides. To control non-point source pollutants generated from this land use category, forestry management measures should address:

- Preharvest planning.
- Streamside management areas.
- Road construction/reconstruction.
- Road management.
- Timber harvesting.
- Site preparation/forest regeneration.
- Fire management.
- Revegetation of disturbed areas.
- Forest chemical applications.
- Wetland forest management.
- Postharvest evaluation.
- Education and outreach.

Marinas and Recreational Boating

Recreational boating and marinas are increasingly popular uses of coastal areas and inland surface water bodies (e.g., lakes, the Sacramento-San Joaquin Delta, and San Francisco Bay), and they are an important means of public access to navigable waterways. Therefore, California must balance the need for protecting the environment and the need to provide adequate public access. Because marinas and boats are located at the water's edge, pollutants generated from these sources are less likely to be buffered or filtered by natural processes. When boating and adjunct activities (e.g., those that take place at marinas and boat maintenance areas) are poorly planned or managed, they may pose a threat to water quality and the health of aquatic systems.

Water quality issues associated with marinas and recreational boating include:

- Poorly flushed waterways.
- Pollutants discharged from the normal operation of boats (recreational boats, commercial boats, and live-aboards).
- Pollutants carried in stormwater runoff from marinas, ramps, and related facilities.
- Physical alteration of wetlands and of shellfish/other benthic communities during construction of marinas, ramps, and related facilities.
- Pollutants generated from boat maintenance activities on land and in the water.
- Dredging in marinas and boat maintenance areas.
- Introductions of aquatic invasive species, both plant and animal, that degrade water quality, ecosystem processes, and water infrastructure.

Common pollutants generated from marinas and recreational boating activities include copper, bacteria and pathogens, oil and grease, nutrients, and aquatic and invasive species such as quagga mussels and *Caulerpa taxifolia*. To control non-point source pollutants generated from this land use category, marina and recreational boating management measures should include:

- Marina facility assessment, siting, and design – water quality assessment, marina flushing, habitat assessment, shoreline stabilization, stormwater runoff, fueling station design, sewage facilities, and waste management facilities.
- Operation and maintenance – solid waste control, fish waste control, liquid material control, petroleum control, boat cleaning and maintenance, sewage facility maintenance, and boat operations.
- Education and outreach.

Hydromodification

Hydromodifications that can impair water quality include channel modification (channelization), flow alterations, levees, and dams. Channel modification activities are undertaken in rivers or streams to straighten, enlarge, deepen, or relocate the channel. These activities can affect water temperature, change the natural supply of fresh water to a water body, and alter rates and paths of sediment erosion, transport, and deposition. Hardening the banks of waterways with shoreline protection or armor also accelerates the movement of surface water and pollutants from the upper reaches of watersheds into coastal waters.

Channelization can also reduce the suitability of instream and streamside habitat for fish and wildlife by depriving wetlands and estuarine shorelines of beneficially-enriching sediments, affecting the ability of natural systems to filter pollutants, and interrupting the life stages of aquatic organisms. Dams can adversely impact hydrology, the quality of surface waters, and riparian habitat in the waterways where the dams are located. A variety of impacts can result from the siting, construction, and operation of these facilities. For example, improper siting of dams can inundate both upstream and downstream areas of a waterway. Dams reduce downstream flows, thus depriving wetlands and riparian areas of water. During dam construction or dredging, removal of vegetation and disturbance of underlying sediments can increase turbidity and cause excessive sedimentation in the waterway. Further, metered flows from dams fail to exert the forces that build and maintain channel structure and beneficial floodplain functions.

The erosion of shorelines and streambanks is a natural process that can have either beneficial or adverse impacts on riparian habitat. Excessively high sediment loads resulting from erosion can smother submerged aquatic vegetation, cover shellfish beds and tidal flats, fill in riffle pools, and contribute to increased levels of turbidity and nutrients (EPA 2009a). To control non-point source pollutants generated from this land use category, hydromodification management measures should address:

- Channelization-channel modification.
- Dam construction and operation – erosion and sediment control and chemical pollutant control issues, and the downstream impact of reservoir releases on riparian habitat.
- Streambank and shoreline erosion control.
- Education and outreach.

Wetlands

Wetlands and riparian areas reduce polluted runoff and enhance water quality by filtering out runoff-related contaminants, such as fine-grained sediment, nutrients (nitrogen and phosphorus), and some metals. Functional wetlands and riparian systems provide other services such as surface and groundwater storage, flood control (with adequate set-backs), and storm surge attenuation. They also support valuable wildlife and aquatic habitats. Highly modified wetlands and riparian systems are typically managed for a few beneficial uses or services, are costly to maintain, and have questionable long-term sustainability. Natural wetlands are self-sustaining when not adversely impacted by pollution.

Changes in hydrology, soil texture, water quantity, and/or species composition can impair the ability of wetland or riparian areas to filter out excess sediment and nutrients and therefore can result in deteriorated water quality. Wetlands and riparian areas may be impacted or destroyed by construction, filling, or other alterations. Historically, significant losses of wetlands have been caused by draining wetland soils for conversion to croplands, or dredging wetland soils for waterway navigation. Spongy wetland soils are compacted by over-grazing and grading. Loss of wetland acreage increases polluted runoff, leading to degradation of surface water quality.

To control non-point source pollutants generated from this land use category, wetlands management measures should address:

- Protection of wetlands and riparian areas.
- Restoration of wetlands and riparian areas.
- Vegetated treatment systems.
- Education and outreach.

Potential Benefits

For the vast majority of contaminants, it is generally accepted that a pollution prevention approach to water quality is more cost-effective than end-of-the-pipe treatment of wastes or advanced domestic water treatment for drinking water. Pollution prevention measures that treat or manage concentrated pollutants at the source are usually more cost-effective and practical than attempting to treat larger downstream flows that have diluted the pollutant. By preventing further degradation of water through pollution prevention, there is an overall improvement of water quality over time in both surface and groundwater. Pollution prevention can be considered in the context of adaptation, while pollution treatment is generally associated with mitigation.

Pollution prevention activities, such as stormwater runoff management and low-impact development, can reduce or maintain the peak runoff from urbanized areas such that they can meet the channel capacity of the natural system without the need to construct new protection structures. Additional information is available in Chapter 20, “Urban Stormwater Runoff Management,” in this volume.

Small rural water systems, which generally lack technical and financial capacities, may be more reliant upon pollution prevention measures than other options available to larger systems, such as advanced treatment. When surface water is polluted, the only other available source is groundwater. Therefore, preventing pollution of surface water keeps options for water supply open, which is especially important in areas where the groundwater resources may already be in overdraft.

By protecting the quality of surface water and near-shore coastal waters, this management strategy provides multiple benefits or uses by providing opportunities for water recreation activities, as well as serving as a water source for desalination plants, and maintaining suitable habitat for wildlife. A number of non-point source success stories have been highlighted by the EPA (see Box 18-3 for additional information).

Potential Costs

According to the 2008 EPA Clean Watersheds Needs Survey, California needs more than $30 billion over the next 20 years to meet water quality and water-related public health goals of the Clean Water Act (EPA 2009b). This survey emphasized point-source discharges from wastewater treatment systems, which estimated more than $20 billion is needed to prevent point-source discharges. Measures to address and prevent non-point source pollution were likely underestimated. Currently, EPA is conducting the 2012 Clean Watersheds Needs Survey and is expected to release a final report in 2014. There have been a number of requests and recommendations to represent the funding need for non-point source pollution more accurately in the 2012 survey.

An assessment of water quality conditions in California shows that non-point source pollution has the greatest effect on water quality. It affects some of the largest economic segments of the state's economy, ranging from agriculture to the tourist industry. As previously discussed, non-point-sources are not readily controlled by conventional means. Instead, they are controlled with preventive plans and practices used by those directly involved in those activities and by those overseeing such activities. The following examples provide some insight into the complexity and costs associated with non-point source pollution prevention in California.

Clean Beaches

Runoff from urban areas can contain heavy metals, pesticides, petroleum hydrocarbons, trash, plastics, and animal and human waste (Heal the Bay 2009). This urban runoff can have a detrimental impact on one of California's greatest natural and economic resources, its world-renowned beaches. This natural resource attracts millions of tourists and locals each year. The direct revenues generated by the California beach economy are substantial. Unfortunately, runoff from creeks, rivers, and storm drains creates the largest source of water pollution for the beaches. Often the currents in the bays, around offshore islands, and along sections of the coast can exacerbate pollution by trapping or directing pollutant to a particular area along the coast. Some stretches of beaches in Southern California are permanently posted by local health departments as being unsafe for swimming and surfing, or they periodically post such warnings after storm events. It is recommended that no one swim in the ocean during a significant rain event and for at least three days following a significant rain event due to contaminated urban stormwater runoff draining directly into the ocean. During dry weather, California beaches experience much better water quality, although sewer spills that result in beach closures and other sources of pollution exist year-round.

Box 18-3 EPA Non-Point-Source Success Stories

The EPA has highlighted a number of non-point-source success stories that were identified by states as being primarily non-point-source-impaired and having achieved documented water quality improvements. These highlighted projects have received funding from Clean Water Act (CWA) section 319 and/or other funding sources dedicated to solving non-point-source impairments. The California success stories include the following water bodies:

- Big Meadow Creek and Upper Truckee River.
- Chorro Creek.
- Sacramento and Feather Rivers.
- San Diego Creek.
- San Joaquin Basin (Grasslands Watershed).
- San Joaquin River.
- Whiskeytown Lake.

These success stories are available at http://water.epa.gov/polwaste/nps/success319/index.cfm.

In response to the poor water quality and significant exceedances of bacterial indicators revealed through monitoring at California's beaches, the Clean Beaches Initiative (CBI) Grant Program was initiated by Assembly Bill 411 (Statutes of 1997, Chapter 765). The water quality goal of the CBI is to make beaches safe for recreational ocean water contact. The CBI Grant Program provides funding for projects that restore and protect the water quality and the environment of coastal waters, estuaries, bays, and near-shore waters. Scientific studies have shown that water with high bacteria levels can cause infections, rashes, and gastrointestinal and respiratory illnesses (SWRCB Clean Beaches Initiative 2001).

The CBI Grant Program has provided about $100 million from voter-approved bonds for approximately 100 projects since it began under the 2001 Budget Act. Typical projects include the construction of disinfecting facilities, diversions that prevent polluted storm water from reaching the beach, and scientific research that will enable early notification of unhealthy swimming conditions.

California beaches are an important environmental and economic resource for the state and the nation. Efforts such as the CBI that fund stormwater diversions and other water quality improvement projects are creating benefits that will likely far outweigh their costs. For more information on CBI, go to http://www.swrcb.ca.gov/water_issues/programs/beaches/cbi_projects/index.shtml.

Irrigated Agriculture

In 2012, the Central Valley RWQCB adopted general waste discharge requirements for growers in the Eastern San Joaquin River watershed that are members of the third-party group (East San Joaquin Water Quality Coalition) representing the area. The order covers an estimated 3,600 growers with 835,000 acres under production. The Central Valley RWQCB estimates that the total cost of compliance with this order is expected to be approximately $99 million dollars per year or $119 per acre annually. Approximately $113 of the $119 per acre annual cost is associated with implementation of management practices to protect surface and groundwater quality. Other costs included in the total amount are third-party costs (monitoring, reporting, tracking, and administration), state fees, and farm plans (Central Valley RWQCB 2012a).

Major Implementation Issues

Irrigated Agriculture

Many surface water bodies are impaired because of pollutants from agricultural sources. Statewide, approximately 7,986 miles of rivers/streams and some 310,370 acres of lakes/reservoirs are on the state's impaired water bodies list or Clean Water Act 303(d) list as being impaired by runoff from irrigated agriculture. Agricultural discharges including irrigation return flow, flows from tile drains, and stormwater runoff affect water quality by transporting pollutants such as pesticides, sediments, nutrients, salts (including selenium and boron), pathogens, and heavy metals from cultivated fields into surface waters. Groundwater bodies have also suffered pesticide, nitrate, and salt contamination. A recent report by UC Davis titled *Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater* (Harter et al. 2012) found that agricultural fertilizers and animal wastes applied to cropland are by far the largest regional sources of nitrate in groundwater in the Tulare Lake basin and Salinas Valley.

In an effort to control and assess the effects of discharges from irrigated agricultural lands, the Los Angeles, Central Coast, Central Valley, and San Diego RWQCBs have adopted comprehensive conditional waivers of waste discharge requirements. The Colorado River and North Coast RWQCBs have adopted Conditional Prohibitions as a TMDL implementation plan incorporated into their respective basin plans, and the Santa Ana Region RWQCB is in the initial phase of developing an irrigated lands regulatory program. In the future, other RWQCBs may also adopt waivers for agricultural discharges in order to implement TMDLs. An estimated 40,000 growers, who cultivate more than 9 million acres, are subject to RWQCBs' irrigated agriculture regulatory programs in these regions. These RWQCBs have made significant strides to implement their irrigated agriculture regulatory programs and are committed to continue their efforts to work with the agricultural community to protect and improve water quality.

Urban Impacts

Urbanization alters flow pathways, water storage, pollutant levels, rates of evaporation, groundwater recharge, surface runoff, the timing and extent of flooding, the sediment yield of rivers, and the suitability and viability of aquatic habitats. The traditional approach to managing urban and stormwater runoff has generally been successful at preventing flood damage, but it has several disadvantages. In order to convey water quickly, natural waterways are often straightened and lined with concrete, resulting in a loss of habitat and negatively impacting natural stream physical and biological processes. Urbanization creates impervious surfaces, meaning stormwater does not infiltrate into subsurface aquifers. This increases runoff volumes and velocities, resulting in streambank erosion and potential flooding problems downstream.

Urban runoff from both storm-generated and dry weather flows has also been shown to be a significant source of pollution by washing contaminants such as nutrients (lawn fertilizers and pet wastes), pesticides, oil and grease, metals, organic chemicals, human pathogens, and debris (especially plastics and plastic particulates) from city streets and other hard surfaces into surface waters and beaches.

One approach to address urban runoff is the watershed approach, which attempts to emulate and preserve the natural hydrologic cycle that is altered by urbanization. The watershed approach consists of a series of Best Management Practices designed to reduce the pollutant loading and reduce the volumes and velocities of urban runoff discharged to surface waters. These Best Management Practices may include facilities to capture, treat, and recharge groundwater with urban runoff, public education campaigns to inform the public about stormwater pollution, including the proper use and disposal of household chemicals, and technical assistance and stormwater pollution prevention training. Additional information is available in Chapter 20, “Urban Stormwater Runoff Management,” and Chapter 25, “Recharge Area Protection,” in this volume.

Legacy Pollutants

Abandoned mines and former industrial and commercial sites, such as gas stations and dry cleaning operations, often leave behind contamination problems without a clear link to any legally responsible or financially viable party or entity to pay for the cleanup. State and federal governments and potentially responsible parties often become involved in extensive regulatory and legal proceedings to determine the legal and financial responsibility while the contaminants remain.

Contaminants of Emerging Concern

Traditionally, drinking water systems focus on pathogens (disease-causing microorganisms), chemicals, and disinfectant by-products (potential cancer-causing contaminants) that are regulated or will be regulated in the near future. Recently, other unregulated chemicals and pollutants have been discovered to have unexpected health and environmental effects. Chemicals found in pharmaceuticals and personal care products (PPCPs), by-products of fires and fire suppression, and discarded elements of nanotechnology are emerging as potential water contaminants. Most of these emerging pollutants have not yet been subject to rigorous assessment or regulatory action.

However, there has been progress in understanding which constituents of emerging concern (CECs) impact the environment and drinking water supplies. The Southern California Coastal Water Research Project convened a science advisory panel that released a report on monitoring strategies for CECs in aquatic ecosystems to provide guidance when developing CEC monitoring programs (Anderson et.al. 2012). The San Francisco Estuary Institute recently released a report on CECs in the San Francisco Bay that will serve as a basis for the long-term strategy for future CEC monitoring in the San Francisco Bay (Klosterhaus et.al. 2013). Also the SWRCB amended its Recycled Water Policy in 2013 to include monitoring requirements for constituents of emerging concern (CECs) in recycled water used for groundwater recharge reuse. Information on these monitoring requirements is available at: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/2013/rs2013_0003_a.pdf. Additional information on

CECs in available in Chapter 12, “Municipal Recycled Water,” and Chapter 15, “Drinking Water Treatment and Distribution.”

Institutional Barriers

Institutional barriers can contribute to the difficulty of addressing pollution from uncontrolled runoff, especially as the state moves towards a broader watershed approach to pollution prevention and regulatory action. Various state, local, and federal agencies have divided jurisdiction over groundwater versus surface waters, polluted runoff versus point-source discharges, water quantity versus water quality issues, and even over monitoring and assessing pollutants. These various “stovepipes” of regulatory authority can hamper the more holistic watershed approach to water quality management, and will need to be addressed in the coming years. Management and regulation of water quality in California is fragmented among at least eight state and federal agencies, and no one agency is totally responsible for water quality from source to tap. For example, the SWRCB and RWQCBs regulate ambient water quality, while the Department of Public Health primarily regulates treatment and distribution of potable water. Further, surface water storage and conveyance in California is managed mostly by the Department of Water Resources and the U.S. Bureau of Reclamation, while groundwater is usually not managed in a coordinated manner at all. Moreover, providing drinking water to Californians is an obligation of cities, water districts, private water companies, and small water systems that generally were not formed in any comprehensive pattern.

Efforts to coordinate, collaborate, and leverage various agency authorities towards improvements of water quality in California have been initiated and will need to continue in order to alleviate these institutional barriers. Finally, the diffuse nature of non-point source pollution and the need to control sources on private and public land adds to the difficulties of instituting pollution prevention measures.

Climate Change

Climate change may exacerbate concentrations of pollutants in rivers and lakes from multiple sources. Higher temperatures will cause more algal blooms, reducing dissolved oxygen levels and decreasing filter capacity. Storm events following forest fires may result in increased deposition of pollutants in waterways. Also, pesticide application may increase as more pests survive warmer and drier winter conditions. In the urban environment, the projected stronger storms may also overwhelm urban stormwater systems, leading to additional dispersion of pollutants into waterways.

Adaptation

New standards for land use and development, such as fewer impervious surfaces, more on-site use of rainwater, and more vegetated areas should assist to reduce the amount of pollution in populated areas. Forest management techniques, such as small biomass removal and integrated pest management practices, can also reduce the likelihood of catastrophic fires and increased pesticide use to combat pest infestations. Another adaptation measure may include higher levels of treatment for discharges into rivers and lakes. In the agricultural sector, reduced application of nitrogen-based fertilizers could advance adaptation by maintaining groundwater quality for beneficial uses.

Mitigation

Vehicles are one of the major mobile (non-point) sources of pollution. Shifts to reduce vehicle use and away from gasoline-fueled vehicles may reduce the volume of pollutants entering waterways. Fewer pollutants could result in reduced water treatment needs, which would mean less energy usage and fewer GHG emissions. Further adoption of low-impact development measures could also reduce pollution in urban settings. In agricultural settings, additional use of integrated pest management and reduced fertilizer application techniques could reduce the energy use associated with pesticide application and groundwater nitrates treatment. In recognition that biomass resources generated by agriculture can be used as an energy source and as a strategy to address climate change, the dairy industry developed digester facilities that produce electricity from dairy manure. The Central Valley RWQCB supported this effort with the adoption of general waste discharge requirements (Order R5-2010-0116 and R5-2011-0039) that streamline the permitting process for these facilities.

Onsite Wastewater Treatment Systems (OWTS)

In 2012, the SWRCB adopted an Onsite Wastewater Treatment Systems (OWTS) policy to allow continued use of OWTS while protecting water quality and public health. The use of OWTS, including septic tanks and leachfields, can be an effective means of treating and disposing of domestic wastewater in rural locations where centralized wastewater treatment systems are not available. However, there have been occasions in the state where OWTS, for various reasons, have not satisfactorily protected either water quality or public health. Some instances of these failures are related to the OWTS not being able to adequately treat and dispose of waste as a result of poor design or improper site conditions. Others have occurred where the systems are operating as designed, but their densities are such that the combined effluent resulting from multiple systems is more than can be assimilated into the environment. From these failures, California must learn how to improve usage of OWTS and prevent such failures from happening again.

As California’s population continues to grow, and there are both increased rural housing densities and the building of residences and other structures in more varied terrain than ever before, there are increased risks of causing environmental damage and creating public health risks from the use of OWTS. What may have been effective in the past may not continue to be effective as conditions and circumstances surrounding particular locations change. So necessarily, more scrutiny of OWTS installation is demanded from all those involved while maintaining an appropriate balance of only the necessary requirements so that the use of OWTS remains viable.

Wastewater Infrastructure Needs

While great strides have been made to provide treatment of wastewater before being discharged to surface water, many older wastewater treatment plants are unable to meet new stricter water quality discharge requirements. As a result many wastewater treatment plants have been upgraded or are planned to be upgraded in the near future to meet these new requirements. In California, the EPA 2008 Clean Watersheds Needs Survey found that more than $26 billion is needed over the next 20 years for wastewater infrastructure needs. (EPA 2009b). The EPA is currently conducting the 2012 Clean Watersheds Needs Survey and is expected to release a final report in 2014. Along with funding capital costs to upgrade a wastewater treatment facility, local and regional wastewater agencies also ensure that new operation and maintenance costs associated with operating an upgraded wastewater treatment facility are funded.

Recommendations

1. Pollution prevention and management of water quality impairments should be based on a watershed approach. A watershed-based approach adds value, reduces cost, promotes cross-media, and integrates programmatic and regional strategies.

2. The Department of Water Resources should collaborate with the SWRCB to integrate the basin plans and other statewide water quality control plans and policies into a comprehensive water quality element of the California Water Plan.

3. The California Water Quality Monitoring Council should include a focus on emerging, unregulated contaminants in order to provide an early warning system of future water quality problems, as well as identify trends in water quality using multiple indicators of health. Drinking water supplies should have outcome-based monitoring, such as biomonitoring and waterborne disease outbreak surveillance. The proposed Interagency Water Quality Program would be modeled after the existing Interagency Ecological Program. The groundwater portion of this effort should be consistent with the recommendations of the Groundwater Quality Monitoring Act of 2001 and DWR Bulletin 118, while the surface water aspects should be coordinated with the SWRCB's Surface Water Ambient Monitoring Program.

4. Regional, tribal, and local governments and agencies should establish drinking water source and wellhead protection programs to shield drinking water sources and groundwater recharge areas from contamination. These source protection programs should be incorporated into local land use plans and policies.

References

References Cited

Anderson P., Denslow N., Drewes J., Olivieri A., Schlenk D., Scott G., Snyder S., 2012. *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems, Recommendations of a Science Advisory Panel*. Available at: http://www.waterboards.ca.gov/water_issues/programs/swamp/cec_aquatic/docs/cec_ecosystems_rpt.pdf.

Central Valley Regional Water Quality Control Board. 2012a. *Central Valley Regional Water Quality Control Board. Order R5-2012-0116. Waste Discharge Requirements General Order for Growers within the Eastern San Joaquin River Watershed that are Members of the Third-Party Group*. Fresno (CA): Central Valley Regional Water Quality Control Board. 184 pp. Viewed online at: http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/general_orders/r5-2012-0116.pdf.

Harter T, Lund JR, Darby J, Fogg GE, Howitt R, Jessoe KK, Pettygrove GS, Quinn JF, Viers JH, Boyle DB, Canada HE, DeLaMora N, Dzurella KN, Fryjoff-Hung A, Hollander AD, Honeycutt KL, Jenkins MW, Jensen VB, King AM, Kourakos G, Liptzin D, Lopez EM, Mayzelle MM, McNally A, Medellin-Azuara J, Rosenstock TS. 2012. *Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake Basin and Salinas Valley Groundwater*. Davis (CA): Prepared for: the State Water Resources Control Board SBX2 1 Report to the Legislature. Center for Watershed Sciences, University of California, Davis. 78 pp. Viewed online at: http://groundwaternitrate.ucdavis.edu.

Heal the Bay. 2009. "Beach Report Card." Santa Monica (CA): Heal the Bay. [Web site.] Viewed online at: http://www.healthebay.org/brcv2/. Accessed: Dec., 2009.

Klosterhaus, S., Yee D., Sedlak, M., Wong, A., Sutton, R. 2013. *Contaminants of Emerging Concern in San Francisco Bay: A Summary of Occurrence Data and Identification of Data Gaps*. RMP Con-tribution 698. San Francisco Estuary Institute, Richmond, CA. 121 pp. Available at: http://www.sfei.org/sites/default/files/698%20CEC%20synthesis.pdf.

Ode PR, Kincaid TM, Fleming T, Rehn AC. 2011. *Ecological Condition Assessments of California's Perennial Wadeable Streams: Highlights from the Surface Water Ambient Monitoring Program's Perennial Streams Assessment (PSA) (2000-2007). A collaboration between the State Water Resources Control Board's Non-Point Source Pollution Control Program (NPS Program), Surface Water Ambient Monitoring Program (SWAMP), California Department of Fish and Game Aquatic Bioassessment Laboratory, and the U.S. Environmental Protection Agency.* Sacramento (CA): 104 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/swamp/docs/reports/psa_smmry_rpt.pdf.

State Water Resources Control Board. 2001. Clean Beaches Initiative Grant Program. State Water Resources Control Board. [Web site.] Viewed online at: http://www.swrcb.ca.gov/water_issues/programs/beaches/cbi_projects/index.shtml.

———. 2009a.Total Maximum Daily Load Program, Section 303 (d) Policy Development. Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/303d_listing.shtml. Accessed: Dec., 2009.

———. 2012a. Total Maximum Daily Load Program, California's 2009 Clean Water Act Section 303(d) List of Water Quality Limited Segments. Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml. Accessed May, 2012.

———. 2013. *Communities that Rely on Contaminated Groundwater. Report to the Legislature*. Sacramento (CA): State Water Resources Control Board. 181 pp. Viewed online at http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/docs/ab2222.pdf.

U.S. Environmental Protection Agency. 2009a. *National Water Quality Inventory: Report to Congress 2004 Reporting Cycle*. Washington (DC): U.S Environmental Protection Agency. EPA 841-R-08-001. 43 pp. Viewed online at: http://water.epa.gov/lawsregs/guidance/cwa/305b/upload/2009_01_22_305b_2004report_2004_305Breport.pdf.

———. 2009b. "Clean Watersheds Needs Survey (CWNS)." Washington (DC): U.S. Environmental Protection Agency. [Web site.] Viewed online at: http://www.epa.gov/cwns. Accessed: Dec., 2009.

———. 2012. "Water: Source Water Protection." Washington (DC):U.S. Environmental Protection Agency. [Web site.] Viewed online at: http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/basicinformation.cfm.

Additional References

CALFED Bay-Delta Program. 2000. "Water Quality Program." Sacramento (CA): CALFED Bay-Delta Program. [Web site.] Viewed online at: http://www.calwater.ca.gov/calfed/objectives/Water_Quality.html. Accessed: Nov. 16, 2009.

California Coastal Commission. 2009a. Sacramento (CA): California Coastal Commission. [Web site.] Viewed online at: http://www.coastal.ca.gov. Accessed: Nov. 16, 2009.

———. 2009b. "Water Quality Program Statewide Nonpoint Source (NPS) Program Information." Sacramento (CA). California Coastal Commission. [Web site.] Viewed online at: http://www.coastal.ca.gov/nps/npsndx.html#NPS. Accessed: Dec., 2009.

———. 2009c. "Water Quality Program Interagency Coordinating Committee." Sacramento (CA). California Coastal Commission. [Web site.] Viewed online at: http://www.coastal.ca.gov/nps/iacc.html. Accessed: Dec., 2009.

California Department of Public Health. 2009. "Chemical contaminants in drinking water." Sacramento (CA): California Department of Public Health. [Web site.] Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chemicalcontaminants.aspx. Accessed: Dec., 2009.

———. 2007. "Drinking Water Source Assessment and Protection (DWSAP) Program." Sacramento (CA): California Department of Public Health. [Web site.] Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Pages/DWSAP.aspx.

California Department of Water Resources. 2003. *California's Groundwater*. Sacramento (CA): California Department of Water Resources. Bulletin 118 Update 2003. 265 pp. Viewed online at: http://www.groundwater.water.ca.gov/bulletin118/update2003/.

California Water and Land Use Partnership (CA WALUP). 2009. [Web site.] Viewed online at: http://cawalup.urbanocean.org/index.php?title=Main_Page. Accessed: Dec., 2009.

California Water Quality Monitoring Council. 2012. Sacramento (CA). [Web site.] Viewed online at: http://www.waterboards.ca.gov/mywaterquality/. Accessed: May, 2012.

Center for Water and Land Use. 2009. Davis (CA): University of California, Davis Extension. [Web site.] Viewed online at: http://extension.ucdavis.edu/unit/center_for_water_and_land_use/. Accessed: Dec., 2009.

Central Coast Regional Water Quality Control Board. 2009a. "Agricultural Regulatory Program." San Luis Obispo (CA): Central Coast Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.swrcb.ca.gov/rwqcb3/water_issues/programs/ag_waivers/index.shtml. Accessed: Nov. 16, 2009.

———. "Ambient Monitoring Program (CCAMP)." 2009b. San Luis Obispo (CA): Central Coast Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.ccamp.org/. Accessed: Nov. 16, 2009.

———. 2009c. "E. coli, Food Safety, and Water Quality Issues." San Luis Obispo (CA): Central Coast Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.swrcb.ca.gov/rwqcb3/water_issues/programs/ag_waivers/food_safety.shtml. Accessed: Nov. 16, 2009.

Central Valley Regional Water Quality Control Board. 2009. "Irrigated Lands Regulatory Program (ILRP)." Fresno (CA): Central Valley Regional Water Quality Control Board. [Web site.]. Viewed online at: http://www.swrcb.ca.gov/rwqcb5/water_issues/irrigated_lands/. Accessed: Nov. 16, 2009.

———. 2012b. "Drinking Water Policy." Fresno (CA): Central Valley Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/rwqcb5/water_issues/drinking_water_policy/. Accessed: Nov. 30, 2012.

Colorado River Basin Regional Water Quality Control Board. 2009. "Basin Plan Prohibitions and TMDLs for Agricultural Discharges." Palm Desert (CA): [Web site.] Viewed online at: http://www.swrcb.ca.gov/coloradoriver/public_notices/. Accessed: Nov. 16, 2009.

Office of Environmental Health Hazard Assessment. 2007. "Development of a Set of Impervious Surface Coefficients: A Tool for Watershed Analysis" (updated: Jan. 30, 2007). Sacramento (CA): Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. [Web site.] Viewed online at: http://www.oehha.ca.gov/ecotox/isc031006.html. Accessed: Dec., 2009.

———. 2009a. "Environmental Protection Indicators for California (EPIC)." Sacramento (CA): Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. [Web site.] Viewed online at: http://oehha.ca.gov/multimedia/epic/aboutepic.html. Accessed: Nov. 16, 2009.

———. 2009b. "Safe Eating Guidelines." Sacramento (CA): Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. [Web site.] Viewed online at: http://www.oehha.ca.gov/fish/so_cal/index.html. Accessed: Dec., 2009.

Klasing S, Brodberg R. 2008. *Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene*. Sacramento (CA): Office of Environmental Health Hazard Assessment. California Environmental Protection Agency. 122 pp. Viewed online at: http://www.oehha.ca.gov/fish/gtlsv/pdf/FCGsATLs27June2008.pdf.

Los Angeles Regional Water Quality Control Board. 2009. "Waivers of Waste Discharge Requirements" Los Angeles (CA): Los Angeles Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.swrcb.ca.gov/rwqcb4/water_issues/programs/tmdl/waivers/index.shtml. Accessed: Nov. 16, 2009.

National NEMO Network. 2009. Haddam (CT): University of Connecticut. Middlesex Cooperative Extension Center. [Web site.] Viewed online at: http://nemonet.uconn.edu/. Accessed: Dec., 2009.

National Ocean Economics Program. 2009. Monterey (CA): [Web site.] Viewed online at: http://www.oceaneconomics.org/. Accessed: Dec., 2009.

State Water Resources Control Board. 1999. "Surface Water Ambient Monitoring Program (SWAMP). AB 982. Water Code, sections 13191 and 13192." Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/swamp/.

———. 2000. *Volume 1. Nonpoint Source Program Strategy and Implementation Plan (1998-2013)*. Sacramento (CA): State Water Resources Control Board. California Environmental Protection Agency. California Coastal Commission. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/nps/protecting.shtml.

———. 2003a. *A Comprehensive Groundwater Quality Monitoring Program for California. Report to the Governor and Legislature*. Sacramento (CA): State Water Resources Control Board. 121 pp. Viewed online at: http://www.waterboards.ca.gov/gama/docs/final_ab_599_rpt_to_legis_7_31_03.pdf.

———. 2003b. *2002 CWA Section 305(b) Report*. Sacramento (CA): State Water Resources Control Board. Total Maximum Daily Load Program. 168 pp. Viewed online at: http://www.swrcb.ca.gov/water_issues/programs/tmdl/305b.shtml. Accessed: Dec., 2009.

———. 2004. *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program*. Sacramento (CA): State Water Resources Control Board. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/nps/docs/oalfinalcopy052604.pdf.

———. 2008a. *Nonpoint Source Encyclopedia*. Sacramento (CA): State Water Resources Control Board. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/nps/encyclopedia.shtml. Accessed: Dec., 2009.

———. 2008b. *Strategic Plan Update, 2008-2012*. Sacramento (CA): State Water Resources Control Board. Regional Water Quality Control Boards. 45 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/hot_topics/strategic_plan/docs/final_draft_strategic_plan_update_090208.pdf.

———. 2009b. "Nonpoint Source (NPS) Pollution Control Program. NPS Implementation Tools." Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/nps/. Accessed: Dec., 2009.

———. 2009c. "Management Practices MP Miner." Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://mpminer.waterboards.ca.gov/mpminer/.

———. 2012b. GAMA – Groundwater Ambient Monitoring & Assessment Program. Sacramento (CA): State Water Resources Control Board [Web site.]. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/gama/. Accessed: May, 2012.

———.2012c. *The California Water Boards' Annual Performance Report - Fiscal Year 2010-11*. Sacramento (CA); State Water Resource Control Board. Viewed online at: http://www.waterboards.ca.gov/about_us/performance_report_1011/. Accessed: May, 2012.

U.S. Environmental Protection Agency. 2005. *Protecting Water Quality from Agricultural Runoff*. Washington (DC): U.S. Environmental Protection Agency. Nonpoint Source Control Branch. EPA 841-F-05-001. 2 pp. Viewed online at: http://www.epa.gov/owow/nps/Ag_Runoff_Fact_Sheet.pdf.

———. 2009c. "Concentrated Animal Feeding Operations – Final Rule." Washington (DC): U.S. Environmental Protection Agency. National Pollutant Discharge Elimination System (NPDES). [Web site.] Viewed online at: http://cfpub1.epa.gov/npdes/afo/cafofinalrule.cfm. Accessed: Dec., 2009.

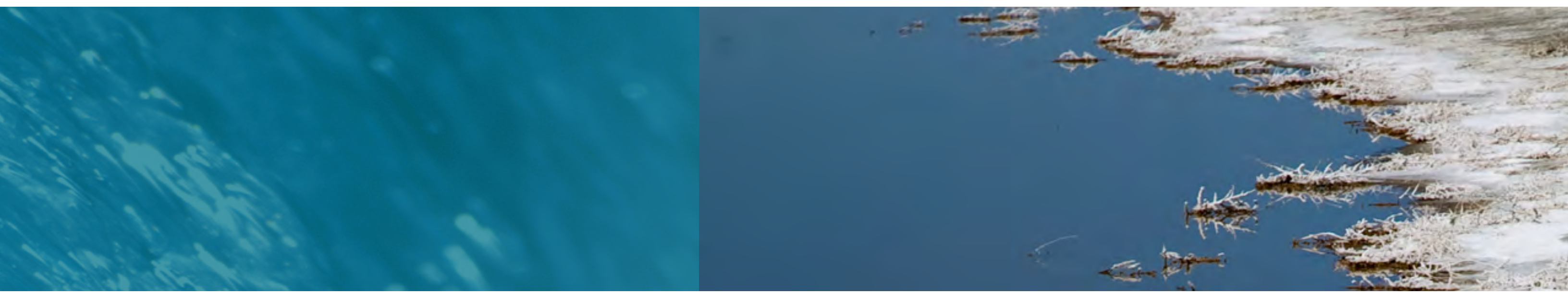
———. 2009d. "Animal Feeding Operations." Washington (DC): U.S. Environmental Protection Agency. National Pollutant Discharge Elimination System (NPDES). [Web site.] Viewed online at: http://cfpub1.epa.gov/npdes/home.cfm?program_id=7. Accessed: Dec., 2009.

U.S. Geological Survey. 2009. "National Water Quality Assessment Program." Washington (DC): U.S. Geological Survey. [Web site.] Viewed online at: http://water.usgs.gov/nawqa/. Accessed: Nov. 16, 2009.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 19

Salt and Salinity Management



San Joaquin Valley. Agricultural evaporation ponds, such as this one, are used to dispose of saline drainwater where there are no opportunities for discharge into the San Joaquin River.

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Chapter 19. Salt and Salinity Management

Unlike the crisis scenarios California routinely prepares for, chronic water quality problems like increasing salinity do not trigger overnight evacuations or mobilize teams of emergency personnel. Salinity generally shows up in localized areas, expands slowly, and produces incremental rather than event-based effects. Salinity impacts can be measured as yearly reduction of crop production and farmable land across an impacted region, lost jobs, higher utility rates, reduction of community growth potential, loss of habitat, premature corrosion of equipment, and lost opportunities. Salinity issues are rarely considered newsworthy until the impacts have already occurred.

Managing salt today can avoid significant cost increases. For one portion of California, a State Water Resources Control Board study found that Central Valley salinity accumulations, if unmanaged, are projected to cause a loss of $2.167 billion in California's value of goods and services produced by 2030 (Howitt et al. 2009). Income is expected to decline by $941 million, employment by 29,270 jobs, and population by 39,440 due to the increase in commercial operating expenses incurred by water supplies that have higher salinity concentrations. The study examined the impact to irrigated agriculture, confined animal operations, food processors, and residential water users. Potential benefits of implementing a salinity management program just in the Central Valley are estimated to be $10 billion by 2030. There have been similar studies conducted in other parts of the state and nation. The Southern California Salinity Coalition was formed in 2002 to address the critical need to remove salt from water supplies and to preserve water resources in California (see www.socalsalinity.org/index.htm). The Multi-State Salinity Coalition addresses similar issues (see www.multi-statesalinitycoalition.com). Both groups indicate that proactive salt management through combinations of source control, treatment, storage, export, real time management with dilution and recycling, is economically beneficial.

Salinity management not only reduces salt loads that impact a region, it is also a key component of securing, maintaining, and recovering usable water supplies. Salt is ubiquitous throughout the environment and it is a conservative constituent meaning it is never destroyed, just concentrated or diluted and transported. It also means that the concentration and loads of salt within any given area will have direct impacts on most of the resource management strategies in place or currently being developed.

While there is no single solution that can be implemented to resolve increasing salinity, incremental management steps, such as those outlined in the Recommendations Section, can move the state forward to address this growing threat to the California economy.

Background

Salts may be defined as materials that "originate from dissolution or weathering of the rocks and soil, including dissolution of lime, gypsum, and other slowly dissolved soil minerals" (Ayers, Westcot 1994). "Salinity" describes a condition where dissolved minerals are present from either natural or anthropogenic origin and carry an electrical charge (ions). In water, salinity is usually measured as electrical conductivity (EC) or total dissolved solids (TDS) and the major ionic substances found in water are calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and nitrate. Both salinity measurement methods give an indication of salt concentrations in water or soils, but since mineral ions do not all carry the same electrical charge and organic dissolved solids can skew TDS readings, these measurement methods must either identify the sample location (e.g., the sample was collected in a tidal estuary, at a municipal outfall or from a domestic supply well) or be used in tandem with additional analyses.

Salt is present to some degree in all natural water supplies because soluble salts in rocks and soil begin to dissolve as soon as water reaches them. Since salts are conservative, any water use and reuse increases salinity as each use subjects the water to evaporation. If reused water passes through soil, additional dissolved salts will be picked up. The continued concentration of salt is a major element of any recycled water project as noted in the State Water Resources Control Board Recycled Water Policy (Resolution 2009-0011) and discussed in Chapter 12, "Municipal Recycled Water" in this volume.

Salinity problems in California, as in other parts of the world, tend to have both natural and human causes. California's natural geology, geography, and hydrology create different salinity concerns in different parts of the state. Coastal areas are subject to natural fluctuations in seawater intrusion on local aquifers. Centralized, closed basins (e.g., the Tulare Lake basin) are natural salt sinks where water moves downhill to the center of the basin, evapoconcentrates and impacts both surface and groundwater. In addition, many of California's most productive soils originate from ocean sediments that are naturally high in salts. Surface water dissolves that salt and either transports it downstream or it infiltrates through the soil column to add additional salt to the groundwater.

Human activities have changed both the rate and distribution of salt accumulation in California. Increasing seawater intrusion in coastal aquifers has been triggered by local groundwater pumping that removes more fresh water than is recharged into an aquifer. Climate change and the projected sea level rise associated with it will make this problem worse. Salts are often added to soil or water intentionally as fertilizers or soil amendments or to assist in industrial, domestic, or other processes (e.g., food processing and water softening). In the Owens Valley and other arid areas of California, diversion or lack of local water supplies leaves saline soils exposed to wind and dust storms may transport salt over great distances before deposition.

Salts may also enter a watershed through inadvertent means. These might be thought of as "unintentional salts," where human action aimed at some other purpose results in salts being added to the watershed. An example is the use of home water softeners that discharge salts into the sanitary sewer system increasing the salt load to both the wastewater treatment plant and the watershed. Many homeowners may be unaware of this.

California's extensively modified natural water systems and constructed conveyance channels supply large cities, small communities, farms, and wetlands with water, but each water delivery carries a salt load of varying degrees depending on the source water. When water is consumed through use, the majority of its salt load remains at or near the site of consumption. One example is imported Colorado River water used in Southern California. The Imperial Irrigation District reported that approximately one ton of salt is contained in each acre-foot (af) of imported Colorado River water (Imperial Irrigation District 2010). In 2011 alone, the importation added approximately 4.3 million tons of salt to Southern California (3.6 million tons of salt to the Colorado River Hydrologic Region and 0.7 million tons of salt to the South Coast Hydrologic

Region) based on water use from the Colorado River (U.S. Bureau of Reclamation 2012). Another example is the state and federal systems designed to capture water exiting the Central Valley through the Sacramento-San Joaquin River Delta (Delta). This water provides replacement irrigation supplies for water diverted from the San Joaquin River basin, additional irrigation supplies for the Tulare Lake basin, and municipal supplies for the Central Coast and Southern California. In the San Joaquin Valley, there is not enough salt exiting the basin through the area's rivers and streams to offset the imported and recirculated salts. Because the Tulare Lake basin is a closed basin, it captures and retains all imported salt. Figure 19-1, using Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) water delivery data through 2010, depicts the mean annual salt loads conveyed to and from the Delta through the major river systems of the Central Valley.

New Delta Influence: Tidal Action, Delta Levees, New Conveyance Facilities, and Water Salinity

Tidal forces from the Pacific Ocean move into the San Francisco Bay and collide with the Delta outflow from the Sacramento and San Joaquin rivers, which creates a long and gradual salinity gradient. The position of this gradient depends upon the tidal cycle and the flow of freshwater through the Delta. Before the major dams were built, the upper edge of this salinity gradient moved deep into the Delta during drier years. The salinity reached as far as Stockton on the San Joaquin River and beyond Courtland on the Sacramento River. Today, Shasta, Folsom, Oroville, and New Melones Reservoirs help control salinity intrusion by providing fresh water releases during the drier parts of the year.

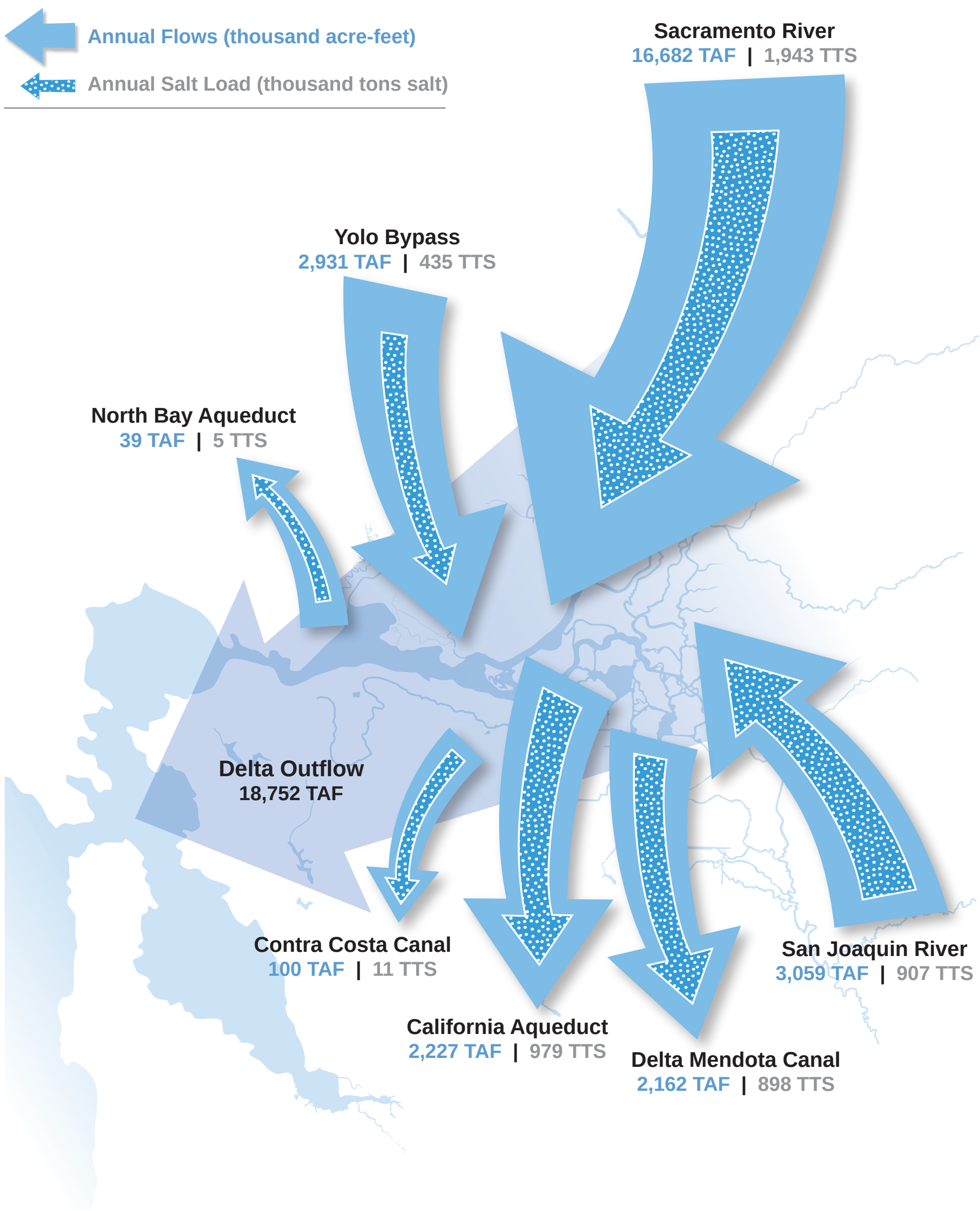
Delta waterways are a major geographical feature of the of California's water resources system because they receive runoff from more than 40 percent of the state's land area and pumping facilities convey this fresh water from the north to the south. Due to continuous land subsidence, the western Delta islands need protection from flooding by levees. Levees also help to protect water-export facilities in the southern Delta from saltwater intrusion by displacing water and maintaining the salinity balance.

If the fragile Delta levee system fails and the islands become inundated with saline water, the water available to the pumping facilities near the Clifton Court Forebay may become too saline to use or can cause major short-term water quality problems. For instance, during one incident an island was flooded under low-flow conditions and at the Contra Costa Canal intake chloride levels reached 440 parts per million (ppm), which is well above the California secondary standard for drinking water of 250 ppm.

In addition, climate change projections indicate that the Pacific Ocean level along the California coast will rise by 14 inches on average by 2050 and as much as 55 inches by 2100 (State of California Sea-Level Rise Task Force 2010). This change will likely increase tidal flows and therefore increase salinity levels in inland Delta waterways. Because much of the water used in the state passes through the Delta, managed outflows will have to be increased to repel intruding seawater and maintain water quality standards.

To overcome these and other risks, the State Water Project (SWP) and the Central Valley Project (CVP), under the umbrella of the Bay Delta Conservation Plan goal of improving the reliability of delivery of water supplies, propose constructing a distinct water delivery system to carry Delta freshwater flows. Proposed infrastructure alternatives for this new system would move

Figure 19-1 Salt Load (Mean of Annual Averages from 1959 to 2012)



Source: Department of Water Resources and the U.S. Bureau of Reclamation

water around, through, or under the Delta to convey water from the Sacramento River near Hood to the major water distribution facilities in the South Delta. From 1999 to 2010, the average salinity level at the Sacramento River near Hood was 92 milligrams per liter (mg/L) TDS. By comparison, salinity levels south of the Delta at the SWP's Banks Pumping Plant and at the Delta Mendota Canal were 218 mg/L and 275 mg/L TDS, respectively. This is more than double the salinity level north of the Delta. Any of the proposed conveyance facilities would have a major impact in reducing salinity loads, described below, with an estimated salinity load reduction near 1 million tons of salt per year.

State water contractors conclude that the new system would reduce salinity loads in the San Joaquin Valley, facilitate Metropolitan Water District's water supply blending goals with the saltier Colorado River water, and improve the quality of water used for groundwater replenishment and recycling. They estimate a benefit of $95 million per year in regional water quality savings (Bookman-Edmonston Engineering, Inc. 1999). The benefits for the CVP contractors would be significant as well, since salinity levels tend to be higher at the South Delta federal intakes than anticipated using the new system. Figure 19-2 shows a comparison of salt loads delivered by the proposed Delta tunnel conveyance facilities with the existing South Delta state and federal water delivery facilities.

While such reductions could alleviate a portion of the salt loading occurring in other basins, as was recognized during the development of the federal CVP and the SWP, continued salt imports combined with consumptive use in closed basins, such as the Tulare Lake basin, requires development of an out-of-basin conveyance to reach sustainability.

Beneficial Use Impacts

Most salts provide some benefit to living organisms when present in low concentrations. However, salinity very quickly becomes a problem when consumptive use and evaporation concentrate salts to levels that adversely impact beneficial uses.

In California, waters of the state (surface and groundwater) are designated as having one or more beneficial uses such as municipal supply, agricultural irrigation, aquatic life, and recreation. Most designations are adopted by regional water quality control boards, which have the responsibility of protecting the uses within their region's boundaries. In addition, the State Water Resources Control Board (SWRCB) Resolution No. 88-63 (State Water Resources Control Board 1988) directed each regional water quality control board to designate surface water and groundwater in the region as being potentially suitable for drinking water unless certain existing conditions apply. A water body is exempted from the designation if, for example, salinity is 5000 µS/cm or more and where "it is not reasonably expected by regional water quality control boards to supply a public water system." The three water uses that salinity generally impacts first are agricultural production (AGR), drinking water (MUN), and industrial processing (PRO) as shown in Table 19-1. Regional water quality control boards develop regulatory thresholds to determine if there are actions needed to protect a use. The thresholds are developed by taking into consideration established thresholds, background conditions, and existing and potential beneficial uses. Figure 19-3, developed by the U.S. Department of Agriculture (USDA) Natural Resource Conservation Service, depicts areas of soils with high salinity and/or sodicity using common thresholds where most crops are negatively impacted. Under current management, these impacted areas are anticipated to continue expanding. Note that the coverage is not complete throughout the Mojave Desert Region so it does not represent some areas suspected to have high salinity and/or sodicity.

While AGR, MUN, and PRO are the beneficial uses most sensitive to excess salinity, there are also potential impacts on environmental uses. Habitat can be impaired, breeding areas can become less functional, and in extreme cases, organisms can succumb to salt toxicosis. It is beyond the scope of this general salinity discussion to address the impacts of specific ions in

Table 19-1 Example of Impacts of Salinity on Three Beneficial Uses

Beneficial Use	Salinity Threshold (µS/cm)[a]	What Does the Target Protect?
AGR	Variable	The Food and Agriculture Organization of the United Nations (FAO) notes that an EC of 700 µS/cm protects the most salt-sensitive crops under normal irrigation operations. Ayers and Westcot describe how the target can be shifted somewhat by adjusting irrigation practices.
MUN	900 (long-term) 2200 (short- term)	This range of numbers, used by the Department of Public Health, is based on taste thresholds. Health-based standards exist for concentrations of specific ions such as nitrate and chloride.
PRO	Variable	The basin plans do not cite a threshold value to protect industrial process use, but it is known that some industrial processes require low salinity water.

Notes:

AGR = agricultural supply

EC = electrical conductivity

MUN = municipal and domestic supply

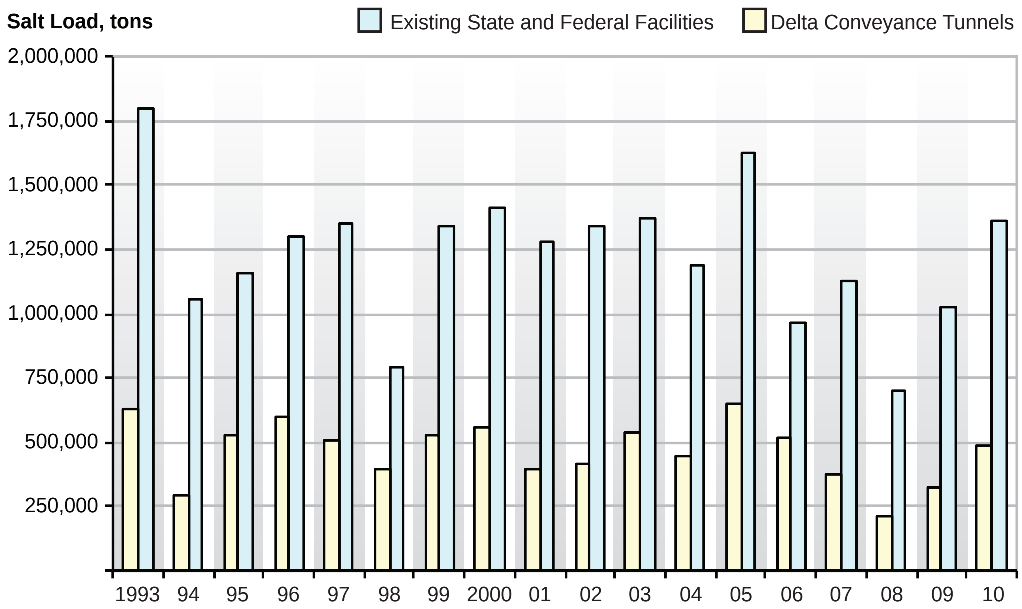
PRO = industrial process supply

[a] Electrical conductivity is reported in microsiemens per centimeter (µS/cm).

great depth, but certain individual ions can limit attaining beneficial use even when the general salinity level may not otherwise pose a problem. Groundwater recharge can be impacted when the receiving aquifer cannot accept the saline water without violating California's anti-degradation policy (State Water Resources Control Board 1968). Groundwater overdraft also poses a salinity problem in areas like Madera County where the excessive drawdown of fresh water leaves the aquifer vulnerable to intrusion from high salinity shallow groundwater in neighboring areas, threatening the basin's supply of usable water for drinking and irrigation. The Salton Sea Authority reports that salinity is a growing problem in this water body due, to a large extent, the continued conservation efforts that will dramatically reduce inflows. Although the reduction in flow reduces salt loads, the reduction also decreases the total volume, increasing salt concentrations and exposing shoreline. If these trends continue, there will be an increasing negative impact on beneficial uses including fish reproduction, commercial fishing, and recreation (Salton Sea Authority 2009).

Beneficial use discussions sometimes leave the impression that water supports one set of uses and then becomes waste. In California, as in most arid states, this is rarely true. Many California communities routinely use water that has previously been diverted multiple times for irrigation or municipal use and returned to a water body. There is often a high demand for recycled water for landscape use, but salt concentrations must be managed to protect the beneficial use (in this case, irrigation and groundwater recharge) or this potential water supply is lost. High salinity in delivered water is a major obstacle for developing cost-effective recycled water of acceptable quality.

Figure 19-2 Salt Loads Comparison: Existing South Delta State and Federal Pumping Plant Intakes vs. Proposed Delta Conveyance Tunnels



Salt and Salinity Management in California

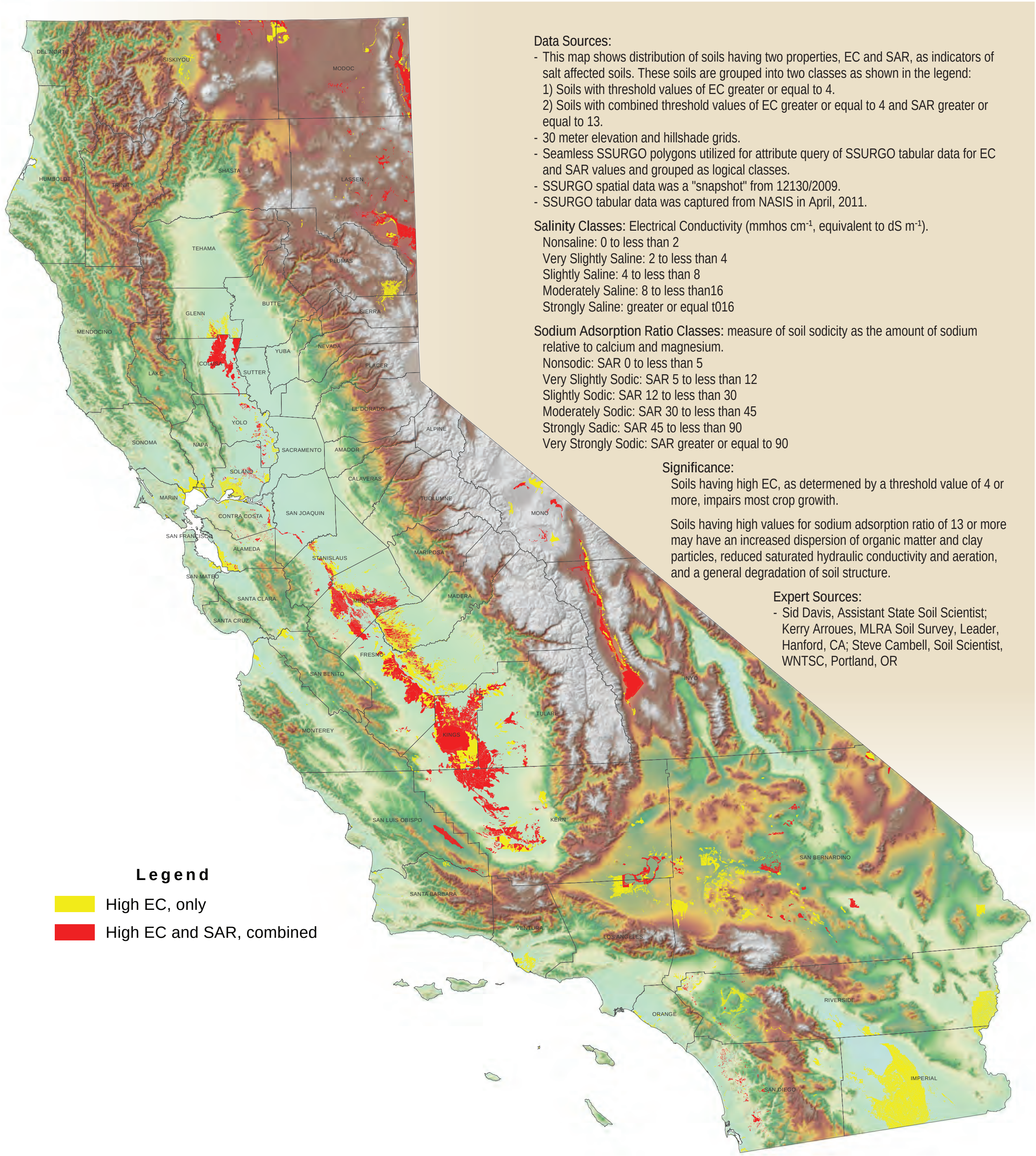
Over the centuries, salts have been poorly managed in all parts of the globe where irrigation has been used. Mismanagement has often been attributable to a poor understanding of the dynamics of salt movement. Displaced salt can accumulate over time to salinize soils and aquifers, in much the same way that sweeping a room displaces dust. Unless sufficient dust is picked up and taken out of the room at some point, it will continue to accumulate and redisperse, ultimately making the room unfit for use. Most irrigation practices tend to have this effect on agricultural land unless steps are taken to ensure that salt is not just displaced within a basin but is sustainably managed, including concentrating and exporting it if needed.

Lack of knowledge is not the only cause of salt mismanagement. In his book, *Collapse*, Jared Diamond describes how Australia's current salinity problems can be traced back to decisions to mine the continent of its resources rather than harvest resources sustainably and preserve the land for future generations (Diamond 2005). Today's Australians are living with that legacy and attempting to reverse the damage caused by more than a century of salt mismanagement, in addition to facing unprecedented drought conditions. Californians will avoid this fate only by making sustainable salt management a priority today.

Salt management must address two major issues. These are (1) short-term impacts from elevated concentrations and (2) long-term impacts from displacing large loads of salt into areas where they can accumulate — the soil profile and groundwater. Historically, strategies to deal with excess salinity have included source control, dilution, and displacement. More recent strategies are treatment, storage, export, real-time management and recycling, and a long-term strategy is adaptation. These different strategies are described in more detail below.

Figure 19-3 Areas of California Soils with High Salinity and/or Sodicity (USDA)

A Preliminary Assessment of Salt Affected Soils in California
Distribution of soils with:
1) EC >4 mmhos cm^{-1} for wt aveg of 0-100 cm soil depth
2) Combined SAR >13 and EC >4 mmhos cm^{-1} for wt aveg of 0-100 cm soil depth



Source: Natural Resources Conservation Service

Source Control

Source control can be defined as a broad array of measures to use water more efficiently and to manage it in a way that reduces the magnitude and adverse effects of salinity. Most regulatory activities have focused first on source control. The controls may be site- or industry-specific (e.g., improvement and/or removal of water softeners, replacing mixtures of chemicals in industry processes, good housekeeping and internal storage of industrial chemicals to avoid spills) or may have a broader base such as (1) minimizing soil amendments used in crop production, (2) using an alternate water source to lower initial concentrations, and (3) reusing the same volume of water to decrease overall loads within a given region. Source control, like other management options, walks a delicate balance between managing the salt concentrations and loads. Box 19-1, "Case Study 1: Santa Clarita Valley Automatic Water Softener Project," provides an example of measureable source control success.

Dilution and Displacement

Agricultural operations typically displace salts suspended in the soil by applying more irrigation water than the crop is able to use in order to flush salts out of the root zone and to relocate them to a lower part of the soil profile below the root zone or to groundwater (the leaching fraction). However, salt may wick upwards again if evaporation exceeds recharge. Salt concentrations in surface water can be decreased by dilution with lower salinity water. Conversely, the salt load transported in water can increase with dilution since dilution water generally carries some salt load as well. A high volume of low salinity water can move significant amounts of salt to other areas, making it also worthwhile to investigate whether management of salinity is appropriate in areas where salt problems do not exist yet. All of these factors and more must be taken into account when developing strategies. Dilution and displacement strategies must be coupled with long-range water, ecosystem, and land resource management planning so that opportunities to move closer to a sustainable salt balance in California's hydrologic basins are not missed.

Opportunities could include (1) taking advantage of wet water years to transport salts back to the ocean and to store water for future use as dilution flow or to prevent saline water intrusion, (2) leveraging funding availability where a community can use both public and private monies to upgrade infrastructure to improve salt management, and (3) developing new businesses such as energy production (using saline water for cooling, sending high salt, high nitrate dairy waste to digesters for methane production, collecting salt to capture energy in solar ponds). All of these can also centralize salt collection as discussed below.

Treatment

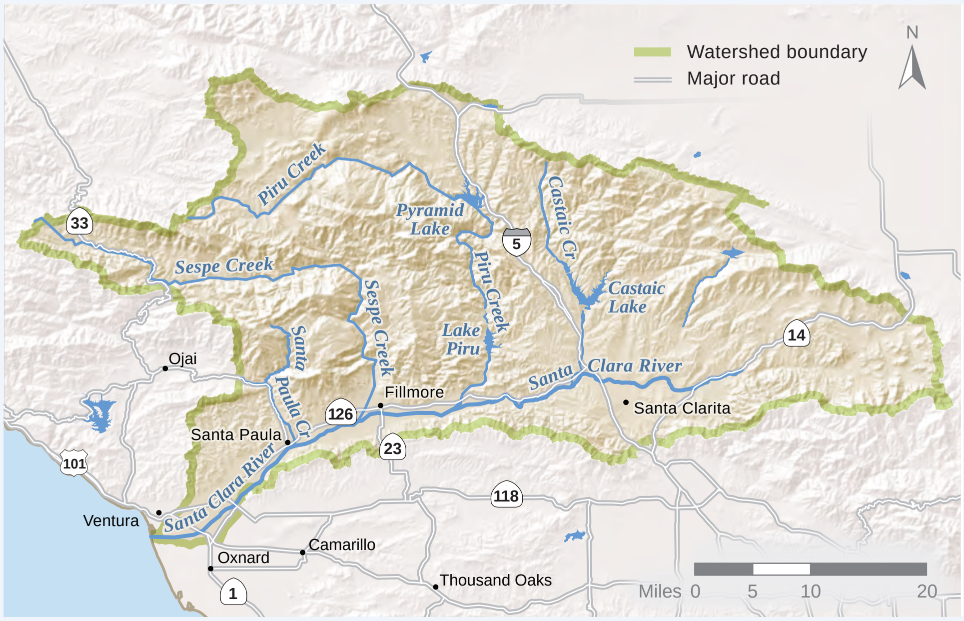
Recent salt management strategies have included treatment using membrane or distillation technologies. Treatment, however, generates a highly saline solid or liquid waste product that must be managed appropriately and also has a significant energy demand. Treatment technologies are used sparingly in much of the state because energy and waste disposal costs can often exceed the economic value of the fresh water being produced. There have been some pilot studies of combined energy generation/salt separation methodologies. Given the heightened focus in California on energy and greenhouse gas (GHG) reduction, these methodologies may gain more attention as a possible salt management strategy. Because mineral salts are not all the same, salt treatment technologies vary in effectiveness and cost for any given situation. For example,

Box 19-1 Case Study 1: Santa Clarita Valley Automatic Water Softener Project

In 2002, the Los Angeles Regional Water Quality Control Board adopted a chloride total maximum daily load (TMDL) for the Upper Santa Clara River that became effective in 2005. Implementation of the TMDL included special studies to identify sources of chloride in the region and to look at appropriate chloride thresholds for the protection of salt sensitive agriculture, endangered species, and groundwater. Significant sources of chloride in the region included the potable water supply, which included chloride from imported State Water Project water and from industrial, commercial, and residential users of the sewer system. The largest controllable source of chloride, contributing approximately one-third of the chloride in the wastewater, was from residential self-regenerating water softeners (also known as automatic water softeners) discharging to the sewer system.

Source control through removal of the automatic water softeners (AWS) was considered the most cost-effective way of removing chloride from the wastewater treatment plant discharges to the Santa Clara River, compared to more costly and energy intensive alternatives such as treatment through reverse osmosis. In 2003, a prospective ban on AWS installations was enacted and a voluntary buy-back program was initiated for existing AWS. In 2006, new legislation was enacted which granted the Santa Clarita Valley Sanitation District the authority to require the removal of all existing residential AWS if approved by a vote of the District's ratepayers. In 2008, the Santa Clarita Valley Sanitation District's voters passed Measure S, which required removal of all existing residential AWS. To date, the Santa Clarita Valley community has removed more than 7,900 AWS, which has significantly reduced chloride levels in the treated wastewater discharged to the river. Although further chloride reductions are required to comply with the TMDL, the unprecedented removal of AWS made major strides in lowering chloride levels in the treatment plant discharges and will significantly reduce the cost of compliance to the community.

Figure A Santa Clara River Watershed



Source: Los Angeles Regional Water Quality Control Board desalination of high sulfate groundwater requires a different approach than desalination of high sodium seawater. Desalination is a relatively mature technology, but additional research and development is needed to make brackish water desalination cost-effective in a broader range of settings. Current technology is generally cost-prohibitive for use in removing salts from wastewater treatment plant discharges due to the high costs of the reverse osmosis desalinization process and disposal of the byproduct brine concentrate. Some exceptions include some groundwater desalination plants in Southern California that have access to ocean brine disposal, notably the Orange County Groundwater Replenishment System, which desalinates local wastewater treatment plant effluent and injects the product water into the groundwater to prevent seawater intrusion into the local groundwater aquifer and for later extraction for water supply. In the Orange County case, the brine water component is discharged into an existing ocean outfall. For a broader discussion of desalination and recycled water, see Chapter 10, "Desalination — Brackish Water and Seawater," and Chapter 12, "Municipal Recycled Water," in this volume.

Collection and Storage

Salt collection and storage is another strategy that is often used in inland areas and in most cases is required for the waste stream generated in treatment processes. Collection and storage may not be a sustainable solution if the collection area could release the salt to groundwater or if a severe storm event could potentially re-disburse the salt outside of the collection area. Evaporation basins, such as the one shown in the photo, raise other environmental issues as well. A collection and storage strategy is expensive and requires a large amount of land and appropriate mitigation for the impacts to wildlife. Although other constituents may also complicate collection strategies, there are success stories. Boxes 19-2 and 19-3 describe Case Studies 2 and 3, respectively, and are examples of farm-level salt management. Ideally, collected salt could be marketed as an industrial product. There have been some preliminary studies, but it is not generally considered feasible to market salt harvested as a byproduct of drainage management. As an example, industrial salt users require a purer and less seasonally variable product than can be produced from most saline drainage collection facilities. There has also been some discussion of harvesting and marketing other materials (selenium, boron) from certain salty waste streams to make the waste less of an environmental problem, but this strategy would have the same issues of cost-effectiveness, purity, and seasonal variability. However, markets change and it may be worthwhile to pursue these options in the future. Salt treatment, including brackish water at $500 to $1,200/af and seawater desalination at $1,000 to $2,500/af, will continue to be an expensive, but an increasingly attractive alternative for communities as California continues to grow and demand for water increases (cost information from Desalination Resource Management Strategy).

Export

In many regions of the state, isolation and storage of salts is providing only a short-term management solution due to the inability to isolate fully the ever-growing salt mass that accumulates over time. More areas are looking at export opportunities such as brine lines to move salt to the ocean — a natural process that was interrupted in some basins by hydrologic modification. One successful brine line was developed in the Santa Ana watershed through a stakeholder process spearheaded by the Santa Ana Watershed Project Authority (SAWPA). The system is the primary method of long-term salt balance for the basin as discussed in Box 19-4, containing Case Study 4. Several coastal wastewater treatment plants also have ocean outfalls.

Box 19-2 Case Study 2: Integrated On-Farm Drainage Management — A Farm-level Solution to Problem Salinity

In the late 1990s, the 1,200-acre AndrewsAg farm in Kern County was a cotton and alfalfa operation. Drainage water from the farm was discharged to a 100-acre evaporation pond. Unfortunately, the high concentrations of salts and selenium in the pond posed a serious risk to wildlife. To develop a practical farming system that would eliminate the evaporation pond as the final disposal point for the drainage water, and therefore provide a safe environment for wildlife, AndrewsAg switched to the Integrated On-Farm Drainage Management (IFDM) farming system, which was first pioneered at Red Rock Ranch in Fresno County.

IFDM is an integrated agricultural water management system by which subsurface drainage water is applied sequentially to increasingly salt-tolerant crops. Drainage water from irrigating salt-sensitive crops can be reused at a given level of salinity to irrigate salt-tolerant crops. The number of steps comprising the reuse sequence can vary, as can the crops to which the drainage water is applied at each stage of the sequence. Once the drainage water becomes too salty to grow any crops, the remaining drainage effluent from the final stage in the sequence of reuse is evaporated in a solar evaporator, leaving crystallized salts behind. In the solar evaporator, the concentrated drainage water is distributed using timed sprinklers or other equipment that sets and adjusts the discharge rate so that water does not pond on the surface of the solar evaporator. The dry salt mixture may contain chemicals of commercial value that can be harvested.

Figure A AndrewsAg Integrated On-Farm Drainage Management System

AndrewsAg has been using the IFDM system on 1,200 acres for about 10 years, and has successfully managed drainage water, salt, and selenium in an ecologically sound way to grow a variety of high-value crops. The AndrewsAg

IFDM system starts with low salinity water to irrigate salt-sensitive, high-value fruit and vegetable crops and alfalfa. For many years, subsurface drainage water from this low-salinity zone was applied to salt-tolerant crops, such as cotton, and the subsurface drainage water collected from this first reuse was applied to a high-salinity zone of salt-loving plants called halophytes. Both applications reduce the volume of drainage water and take up the salt and selenium. Finally, drainage water from the high-salinity zone is evaporated by the solar evaporator. Most recently, AndrewsAg installed a high efficiency drip irrigation system, which eliminates the first reuse step on the IFDM system.

The figure illustrates the layout of the IFDM system on the AndrewsAg farm. Salt-tolerant crops (halophytes) are in the northwest corner. The solar evaporator is in the northeast corner within the area of the former evaporation pond, and only occupies 20 percent of the area within the former evaporation pond. Fruit and vegetable crops and alfalfa are grown on approximately 1,140 acres (95 percent), halophytes are grown on 40 acres (3.3 percent), and the solar evaporator occupies 20 acres (1.7 percent).

Box 19-3 Case Study 3: San Joaquin River Water Quality Improvement Project — A Regional Solution to Salinity

The Grassland Drainage Area (GDA) is an agricultural region on the west side of the San Joaquin Valley. The land is productive, but the soils contain high levels of naturally occurring salts and trace elements, such as selenium and boron. The salts and trace elements are leached from the soil when the fields are irrigated and accumulate in the shallow groundwater collected in drainage pipes commonly called tile drains. Farmers have installed tile drains in fields to protect crops from waterlogging conditions. Until the 1990s, drainage water from the GDA that contained high concentrations of selenium, salts, and other constituents discharged directly to waterways that delivered water to wetland areas and the San Joaquin River.

In 1996, several irrigation and drainage districts formed the Grassland Area Farmers (GAF), a drainage entity of about 97,000 acres of irrigated farmland. The GAF's challenge was to maintain agricultural production in a region with shallow groundwater and naturally occurring salts, and to reduce and then eliminate all farm drainage discharge from the region.

To manage and reduce the drainage discharge to the San Joaquin River, the GAF has made several irrigation and infrastructure improvements, such as pumping groundwater above the Corcoran clay layer and using that groundwater for irrigation to lower the perched water table in order to reduce the amount of groundwater entering the subsurface drains; installing more high-efficiency drip and micro-sprinkler irrigation systems; and rerouting drainage around wetland supply channels. An additional regional improvement is the San Joaquin River Water Quality Improvement Project (SJRIP).

In 2001, the GAF initiated the SJRIP by purchasing 4,000 acres for the reuse area; planting salt-tolerant crops, including Jose Tall Wheatgrass, Bermuda and fescue pasture, pistachio trees, and alfalfa; and constructing distribution facilities that irrigated 1,821 acres with drainage water and/or blended water. Subsurface drainage systems were installed in 2002. The SJRIP continued to expand, and by 2010 the total acreage had increased to more than 6,000 acres, with approximately 5,100 developed to salt-tolerant crops for drainage reuse. Approximately 12,400 acre-feet (af) of drainage water was reused on the SJRIP in 2010, by continuing to recycle the drainage to more salt-tolerant crops and blending the tile drainage back into the supply system. This reuse contributed to the significant reductions in drainage water volume documented for the entire GDA. By 2010, the amount of drainage water released from the GDA had been reduced 75%, from more than 57,500 af to 14,400 af. During that period, the amounts of selenium, salt, and boron had dropped 87%, 72%, and 64%, respectively.

The drainage volumes and associated salts and trace elements are expected to continue to decrease as more reuse area is developed. Although substantial progress has been made, additional work is required to achieve the ultimate goal of zero discharge. The final step for the remaining drainage water will be to collect the brine from the reuse area for further treatment and disposal by non-agricultural processes.

The actions taken by the GAF have led to significant salt and selenium load reductions. Two water bodies (Salt Slough and the San Joaquin River below the Merced River) — as well as over 90 miles of wetland water supply channels in the Grassland Watershed that were listed as impaired because of the high selenium levels — have been de-listed by the State

Box 19-4 Case Study 4: Salt Management in the Santa Ana Watershed Requires Regional Salt Disposal Options

The Inland Empire Brine Line has allowed us to use groundwater from salt-degraded aquifers and capacity in that line will be the limiting factor in our future groundwater recovery and recycling efforts.

— Don Galliano, Board Member, Western Municipal Water District

Salt concentrations in the region's underground aquifers have increased over time as a result of historic agricultural and industrial practices and the use of high-salinity imported water. In some instances, high salt concentrations limit the potential to make use of local groundwater sources. For this reason, brackish groundwater desalination facilities have been constructed in the watershed to remove salt and provide needed drinking water sources, but desalination results in a concentrated stream of high-salinity brine that requires disposal outside of the watershed. Furthermore, the establishment of certain types of water-intensive industries, such as power plants, food processors, and technology businesses in the watershed, also requires a vehicle for the safe disposal of concentrated salt water that cannot go to sanitary sewers.

The Inland Empire Brine Line, also known as the Santa Ana River Interceptor (SARI) system, was constructed in phases over a period of 20 years, stemming from a vision of a salt-balanced watershed articulated in the early 1970s. The SARI is a complex system of 93 miles of pipelines that collects high-salinity flows throughout the watershed and conveys them to an Orange County Sanitation District treatment facility prior to discharge to the Pacific Ocean.

The regional brine line provides the following benefits:

- Allows the use of groundwater resources from aquifers with too much salt or other contaminant(s) for use.
- Protects and improves groundwater quality through salt and contaminant removal.
- Allows industry to take advantage of Inland Empire opportunities and meeting salt discharge standards for water used in industrial process.
- Protects Orange County groundwater aquifers, which then do not need additional desalting.
- Provides a cost advantage compared with trucking brine out of region (Santa Ana Watershed Project Authority 2012).

Construction of this infrastructure was the result of a cooperative approach requiring coordination of several water agencies:

- San Bernardino Valley Municipal Water District.
- Eastern Municipal Water District.
- Western Municipal Water District.
- Inland Empire Utilities Agency.
- Orange County Sanitation District.

Original map and GIS data courtesy of Santa Ana Watershed Project Authority

The construction of this extensive system could not have been implemented by a single agency. Using a novel partnership model, the SARI was constructed with loans that were repaid using revenue generated from the sale of capacity in the system to those anticipating desalting needs. Operation and maintenance continues to be funded with revenue and capital reserves generated from rates. In addition, capital-intensive improvements may be funded through debt financing.

East Bay Municipal Utility District has a local brine disposal facility that receives trucked brine with the capacity to develop regional brine lines further. The local systems primarily serve local or regional industry producing high salinity wastewaters, which may not require or be suitable for traditional municipal wastewater treatment. Agencies and groups in the Calleguas Creek watershed are pursuing a variety of options in their salt management plan that begin at source control and lead to large scale desalting and disposal including a brine line and ocean outfall. The SWRCB is in the process of amending the Water Quality Control Plans for Ocean Waters and Enclosed Bays and Estuaries to address desalination facilities and brine disposal.

Real-time Salinity Management

Real-time salinity management is a strategy for meeting downstream salinity objectives by making use of a river's assimilative capacity and improving coordination of upstream constituent loading from point and non-point sources with dilution flows (Quinn, Karkoski 1998). The concept is being evaluated as a management alternative in the San Joaquin River basin to ensure water quality is protected while allowing excess salt to be transported out of the basin via the river itself. The assimilative capacity for a pollutant such as salinity in a water body is defined as the maximum loading of that contaminant that can be accommodated by the water body without exceeding water quality objectives or standards. These objectives are typically defined at a downstream compliance monitoring location. In the Lower San Joaquin River, changes in the natural hydrology (replacing natural headwaters with more saline Delta imports) have led to a river system dominated by agricultural drainage with limited dilution flows during much of the year. These conditions lead to seasonally elevated salinity levels in the river and southern Delta. Real-time management attempts to time the saline discharges with periods of greater dilution flows. Technical advances in data acquisition and information dissemination technologies will be necessary for implementing a real-time salinity management program. Real-time salinity management relies on continuously recording sensors that form the backbone of a monitoring network, simulation models that forecast flow and water quality conditions in the receiving water body, and the tributary watersheds that contribute flow and salt load to the river. The concept of mass balance is fundamental to all flow and water quality simulation models. Models can extrapolate the results of system monitoring since it is impossible to collect data for every drainage outlet and stream tributary in the basin. Dividing hydrologic basins into smaller drainage subbasins each with a monitoring station at their outlet can provide an efficient means of characterizing salt export loading from the watershed to surface water bodies such as rivers. This is the basis for the sort of control necessary to meet salt loading objectives at the basin-scale. Implementing the principles of real-time salinity management is underway in a USBR-funded study in the Grasslands Ecological Area. This is a 140,000-plus acre tract of seasonally managed wetlands containing state and federal waterfowl refuges and privately owned duck clubs. The real-time monitoring, data sharing, and modeling needed at the basin-scale are being developed at the subbasin scale as proof-of-concept (Quinn 2009; Quinn et al. 2010).

Salt Recycling

Agricultural subsurface drainage water and concentrate from desalination facilities contains a mixture of salts as well as other dissolved minerals that have leached from the soil. In much of the San Joaquin Valley, sodium sulfate and sodium chloride are the dominant salt compositions. Salts such as calcium carbonate, calcium chloride, calcium sulfate (gypsum), and magnesium chloride are also present, but to a lesser extent. Because of the number and types of constituents in drainage water, treatment of drainage water to produce fresh water is complex and requires a high-energy demand. Disposal of the salts and brines from the treatment processes also is costly. However, today's treatment technologies are being developed that use less energy, and methods are being explored to recycle economically the salts removed from the concentrated drainage.

There are available processes that separate purified salt products (e.g., sodium sulfate, gypsum, or sodium chloride) for commercial markets and the sale of product-generated revenues can potentially offset the cost to treat the drainage water. The U.S. Geological Survey (USGS) Mineral Commodity Summary prices for 2010 of some of these salts are shown in Table 19-2. The prices are in dollars per short ton (2,000 pounds).

Sodium sulfate has solubility characteristics that offer the potential to recover purified sodium sulfate for commercial markets. The USGS estimates of U.S. sodium sulfate uses in 2010 were soaps and detergents (35 percent), glass (18 percent), pulp and paper (15 percent), textiles (4 percent), carpet fresheners (4 percent), and miscellaneous (24 percent). Gypsum or calcium sulfate is another mineral that can be recycled. It is commonly used in agriculture. For example, San Joaquin Valley farmland uses an average of 850,000 tons of gypsum per year (California Department of Food and Agriculture 2009).

Once purified, salts from the drainage water could also be further processed to make other useful products. For example, sodium sulfate can be converted to sodium hydroxide (caustic soda) and sulfuric acid using electrochemical technologies, both of which can be sold. The sodium hydroxide can also be used to capture and convert carbon dioxide, a GHG, into carbonates such as soda ash and other high-value chemicals.

In 2010, the chemical industry consumed about 40 percent of total sodium chloride (salt) sales and salt for highway de-icing accounted for 38 percent of U.S. demand (U.S. Geological Survey 2012). However, the most economical use of sodium chloride removed from agricultural drainage brine is likely reuse in the drainage water treatment process, e.g., softening water using ion exchange treatment. Any surplus could be sold.

After the drainage water is treated and salts and other constituents are recycled or disposed, the cleaned water can be used for irrigation or other beneficial uses. As noted in the "Collection and Storage" section above, treatment costs including removal and disposal of unwanted chemicals must be balanced with potential income to determine feasibility.

Adaptation

A very commonly employed but ultimately unsustainable management strategy is adaptation to increasingly saline conditions. This situation exists in the Tulare Lake Basin that does not have a reliable natural outlet. In the absence of some mechanism to remove and dispose salts, salt imported into the basin in irrigation water, in soil amendments, for water softening, and for other purposes remains in the basin. The Water Quality Control Plan for the Tulare Lake Basin recommends constructing a drain to remove the excess salts from the basin to begin correcting the problem. This option is not being pursued at this time because of cost and political considerations. Therefore, the plan also includes a strategy of controlled degradation to extend the beneficial uses of the water in this basin and the environmental, economic, and social infrastructure those uses support for as long as possible. Some land in this basin has already been

Table 19-2 Value of Reclaimed Water and Recyclable Salts Present in a Typical Agricultural Drainage Water Sump in the San Joaquin Valley[a]

Water Composition					
	% Weight	Weight (ton)	Value ($/ton)	Unit Value ($)	% Value
Water [H_2O]	98.77%	1,359	0.25	340	13.83%
Calcium Bicarbonate [$Ca(HCO_3)_2$]	0.03%	0.34	50	17	0.12%
Calcium Sulfate [$CaSO_4$]	0.18%	2.41	33	79	3.57%
Boron as boric acid [$B(OH)_3$]	0.01%	0.18	360	64	3.75%
Sodium Chloride [NaCl]	0.42%	5.73	35	201	7.08%
Magnesium Chloride [$MgCl_2$]	0.08%	1.14	300	342	14.38%
Sodium Nitrate [$NaNO_3$]	0.05%	0.70	390	274	10.40%
Potassium Chloride [KCl]	0.00%	0.01	600	8	0.09%
Selenium [Se]	0.00%	0.001	70,000	96	4.35%
Sodium Sulfate [Na_2SO_4]	0.47%	6.41	140	897	42.43%
TOTAL	**100.00%**			**$2,319**	**100.00%**

Sources: U.S. Geological Survey, Mineral Commodity Summaries (2009) and ICIS Chemical Business (2009).

Notes:

[a] Drainage water volume, af: 1

Drainage water weight, tons: 1,359

Conductivity, dS/cm: 15,735

Total dissolved salts, mg/l: 11,733

Salt volume, tons: 16

abandoned due to salinization. There is additional discussion of land retirement in Chapter 32, “Other Strategies,” in this volume.

Potential alternatives must be evaluated in mind of other resource and environmental needs in order to develop the best strategy for California’s variety of regions. For example, an evaluation of the impacts of evaporation basins should be weighed against possible alternatives such as constructing a brine line. Water conservation efforts in the Salton Sea watershed must be balanced with overall salt management for surrounding lands and potential impacts to the sea. Salt storage, while expensive and often environmentally problematic, should be researched further and new strategies for interim and long-term salt storage and salt disposal should be developed.

These debates are beginning now, partially because of the 2009 Recycled Water Policy adopted by the State Water Resources Control Board. This policy includes a requirement that local water and wastewater entities, together with local salt/nutrient contributing stakeholders, prepare salt and nutrient management plans, complete those plans, and propose them for adoption by the regional water quality control boards within five years. The State Water Resources Control Board also committed to seek state and federal funds to cost share in the preparation of these plans (see also Chapter 12, "Municipal Recycled Water"). The resulting plans will be able to build on the case studies in this chapter, which illustrate current approaches to address problem salinity in various parts of the state. The local studies range from urban to agricultural and include collaborative efforts between regulators and stakeholders to develop and implement regional plans that encompass multiple salinity sources and an array of management options. A larger regional collaborative effort known as CV-SALTS is described in Box 19-5, containing Case Study 5, and will have spillover benefits for areas beyond the region.

Potential Benefits

A number of benefits that salt management will provide can be grouped under beneficial use protection, increased useable water supplies, and economic stability.

- **Beneficial Use Protection.** As discussed earlier, the beneficial uses most sensitive to excess salt include agricultural irrigation/stock watering, municipal and domestic supply, and processing. However, other uses may be impacted as well. A selection of the ongoing and emerging threats which would be minimized by salt management are listed below.
    - *Salt loads containing nitrates*. Dairy waste management, septic systems, and fertilizer use can all contribute to groundwater degradation by nitrate. Excessive nitrate salts in groundwater is a human health issue. Chapter 16, "Groundwater/Aquifer Remediation," in this volume has additional information on nitrate contamination. Excessive nutrient salts in surface water can spur explosive, unwanted algal growth that not only impacts aquatic life but also interferes with recreational and commercial use of water bodies.
    - *Seawater intrusion*. Seawater intrusion into the Delta has a significant impact on the quality of water exported from the Delta. Coastal aquifers are at risk of seawater intrusion when there is more fresh water withdrawn than is recharged into the aquifer. Aquifers and surface water are vulnerable to rising sea levels and seawater brought in by storm surges. Due to climate change, such storm surges may increase in intensity or frequency. Seawater intrusion threatens drinking water and water used for irrigation.
    - *Soil and groundwater salinization*. Salinization occurs when salts are allowed to accumulate over time in soil or groundwater. Soil salinization results in a loss of soil productivity due to a chronically unfavorable balance of salt and water in the soil profile (see Figure 19-3 for the statewide current status). Groundwater salinization results in the loss of utility of an aquifer, meaning that the water no longer supports municipal or agricultural uses. Both processes are virtually irreversible.
    - *Salinization of water bodies*. Water bodies with no natural outlet are primarily sustained by inflowing water and evaporation. As water evaporates, dissolved salts are left behind and begin to concentrate. These water bodies may see further increases in salinity if inflows are reduced and/or if the inflows have a high TDS concentration. Both factors are contributing to the salinity problem in the Salton Sea. The Salton Sea Species Conservation Habitat Project draft environmental impact statement/environmental impact report (EIS/EIR) reports that an environmental impact of increased salinity is an adverse effect on fish that, in turn, affects the birds that feed on them.

Box 19-5 Case Study 5: Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS)

Nowhere in California is salinity a more significant threat to sustainability than in the Central Valley. Salinity threatens the long-term reliability of water supplies and community water quality as groundwater basins are impacted and farmland goes out of production.

In 2007, area stakeholders, the Central Valley Regional Water Quality Control Board, and State Water Resources Control Board initiated a unique collaborative salinity management effort partially modeled on the Santa Ana Watershed approach described in Case Study 4, Box 19-4 only on a much grander scale.

The Central Valley region is comprised of three major basins and covers a 60,000 square mile area that extends from the Tehachapi Mountains in the south to the Oregon border in the north. The Central Valley Salinity Alternatives for Long-term Sustainability (CV-SALTS) is an initiative that addresses salinity throughout the region and the Delta in a comprehensive, consistent, and sustainable manner through the development of a Salt and Nitrate Management Plan for the Central Valley region. Similar to the Santa Ana Watershed Project Authority (SAWPA), CV-SALTS encourages stakeholder-initiated actions and leadership that can accomplish management that the Regional Water Quality Control Boards are unable to require, but which will make it possible to achieve and maintain sustainable salinity management in the region.

Several organizations are currently active in the CV-SALTS initiative. The Water Boards provided initial support and continue to play key advisory roles. The Central Valley Salinity Coalition, a strong initial and ongoing funder of the CV-SALTS initiative, includes members from statewide and regional associations, agricultural coalitions, cities, counties, and special districts representing a majority of the Central Valley. The Executive Committee charged with the governance of this broad-reaching initiative has representatives from the Central Valley Salinity Coalition, as well as representatives from state and federal agencies, local governments, and from nongovernment, environmental justice, and industry organizations. The Technical Advisory Committee includes top researchers and consultants in the field to review scientific and technical issues and economics. Other committees made up of stakeholders serve as technical reviewers of management practices, conduct outreach, review economic and technical studies, and related efforts.

These efforts will develop the science and policy required to review and update the Water Quality Control Plans for the Sacramento and San Joaquin River basins, the Tulare Lake basin, and the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.

More information is available on the CV-SALTS committees and the Central Valley Salinity Coalition at http://cvsalinity.org/.

- **Increased Useable Water Supplies.** Salt management does not simply reduce the salt loads impacting a region; it can also improve water supplies. In some regions, dilution with low salinity water is the primary means used to manage salinity. Dilution in the right place may provide some side benefits due to increased flow (e.g., supporting aquatic life), but more often water used for dilution is water that is unavailable for other purposes at other times. Climate change will undoubtedly alter the way California manages water and altered weather patterns will likely impact the volume, location, and timing of available low salinity flows in many, if not all, parts of the state. Therefore, sustainable salt management is a key component of securing, maintaining, expanding, and recovering usable water supplies. Recovered water supplies would include recycled wastewater and brackish water desalination projects. Some water authorities in Southern California use both strategies. The issues related to recovering usable water supplies are further discussed in Chapter 12, "Municipal Recycled Water," in this volume.

- **Economic Stability.** As a somewhat silent and long-term threat, salinity is seldom considered a key component to California's economic stability. However, the population requires reliable drinking water sources and industries, particularly agriculture, suffer as salinity levels increase. The reality is although some communities reclaim brackish water at great expense, most California water users cannot afford to do this. Despite contributing $31.4 billion to California's economy in 2006, several of the most productive farming regions of the state (including the Imperial, Salinas and San Joaquin Valleys) are vulnerable to soil and/or groundwater salinization. Statewide economic benefits from providing a sustainable salt and nutrient management plan for the Central Valley alone have been estimated at $10 billion by 2030 (Howitt et al. 2009).

The local benefits of sustainable salinity management mirror the statewide benefits: 1) restoring and maintaining beneficial uses of water within the basin, 2) securing and, in some cases, improving the reliability of the water supply, and 3) providing local economic stability by providing reliable drinking water sources and water quality that supports local industries. Out-of-basin benefits can also be substantial. Due to the complex water transport infrastructure in California, sustainable salt management in any hydrologic region of the state protects water resources that may be serving multiple purposes in multiple regions. For example, salinity control in the Sacramento River basin may have a relatively small direct benefit in this watershed, which normally receives high rainfall and therefore usually has adequate dilution flows to maintain salinity at acceptable levels. However, Sacramento River water flows into the Delta and reducing salt loads in tributary rivers to the Delta could provide significant benefits to those receiving water through the California Aqueduct (much of Southern California) and the Delta-Mendota Canal (approximately 1.6 million acres in the San Joaquin Valley). These benefits are higher quality drinking water, avoided costs, continued ability to produce food and fiber, habitat maintenance, and reduced pre-treatment costs for industries requiring low salinity water supplies.

Another example of an out of basin benefit is the Colorado River. Water from the Colorado River serves several states, including California, and the river carries a significant salt load. Programs currently in place to reduce salt inputs in the upper watershed benefit all downstream water users. Continued upstream salt load reductions provide continued reduction of salt imported into parts of the California where opportunities for export, treatment, or storage are limited. Any time salinity treatment can be avoided there will be significant energy savings benefits as well.

Potential Costs

Several studies have confirmed that the cost for treating the resulting problem is greater than up-front planning to avoid the issue. The stakeholder-led Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) developed a five-year work plan in 2009 that identified costs as high as $50 million to characterize and develop a sustainable salt and nutrient management plan for 40 percent of California's surface area and 70 percent of its managed water supply (Central Valley Salinity Coalition and CV-SALTS 2009). The primary costs are:

- Characterizing source and fate of salinity.
- Ensuring appropriate beneficial use designation and associated water quality objectives.
- Validating industry management practices.

- Determining implementation alternatives and priorities.
- Developing a long-term monitoring network for adaptive management.

Even though the cost for the overall plan does not include implementing the projects needed to manage salts, benefits from salinity management in the Central Valley would extend to the rest of the state through improved water exports from the Delta to Southern California and the Central Coast. Due to the complexity of salt management and limited funding, the stakeholders are currently revising the priority activities for the first phase (through approximately 2014) and future efforts. Stakeholders are also coordinating with the integrated regional water management plan (IRWMP) planning and other regional efforts to assist regional planning and implementing salt management projects.

Some examples of the costs for industries and regions currently addressing salt control and/or management are highlighted below.

- Rubin, Sundig, and Berkman (2007) investigated the cost of managing TDS in the Central Valley. At food processing plants, costs for removing dissolved solids by various means ranged from $258 to more than $8,000 per ton. For the wine industry, costs ranged from $269 to $2,300 per ton. For the dairy industry, costs ranged from $193 to $3,200 per ton. The report also estimated that the dairy and wine industries would spend up to $2,500 per ton of salt removal to use a brine line to the ocean.
- Tulare Lake Drainage District (TLDD) has investigated numerous desalination technologies for drainage water including reverse osmosis, polymer pretreatment, and distillation to develop a new source of water supply from subsurface agricultural drainage water. Numerous selenium removal technologies have also been evaluated. TLDD recently completed an enhanced evaporation spray field trial using high-pressure spray nozzles to increase natural solar evaporation. The total cost expended exceeded several million dollars.
- The Santa Ana Watershed Project Authority (SAWPA) with the help of state low interest loans and grants committed well over $100 million to construct a regional brine line serving all areas of the Santa Ana River watershed (see Box 19-4). Additionally, stakeholders in the watershed spent several million dollars and more than 10 years developing a basin-wide salt and nutrient management plan to provide for sustainable management. The plan uses the brine line and continued building of more than 10 ground water desalters to remove salts and nitrates from the groundwater. Most desalters have an initial capital cost of $20-40 million.
- The City of Dixon (population 18,000) located on the west side of the Central Valley recently completed a study to reduce the city's wastewater chloride load to the groundwater by 30 percent (City of Dixon 2011). Key findings include:
  - All else being equal, 20 percent conservation can result in 25 percent concentration. Average household costs to mitigate this amount appear to range from approximately $3 to $60 per month.
  - Impacts of residential communities and agriculture are roughly equivalent acre for acre with the same water source.
  - Source control and land fallowing are roughly equivalent on a cost basis and both are an order of magnitude (10 times) less expensive than salt removal treatment.

Table 19-3 lists the estimated cost to Dixon by project.

Table 19-3 Incremental Costs to Remove or Mitigate Approximately 30 Percent of the City of Dixon's Municipal Wastewater Chloride Load to Local Groundwater

Project Description	Capital Cost (in million $)	Annual O&M Cost (in million $)	Total Cost[a] (in million $)
Public education, source characterization studies, residential water softener ban/incentive program	$0.42	$0.16	$2.8
Fallowing of farmland that relies on low quality tailwater and/or groundwater for irrigation	$1.5	$0.10	$3.0
Injecting high quality surface water into groundwater	$3.6	$0.20	$6.6
Blending high quality surface water with wastewater treatment plant effluent	$6.3	$0.18	$9.0
Change wastewater treatment process to activated sludge (high rate/bubble aerated) treatment	$9.5	$0.14	$12
Chloride removal from groundwater by reverse osmosis	$9.0	$0.35	$14
Chloride removal from the wastewater treatment plant effluent by electrodialysis reversal	$20	$0.49	$27
Change drinking water source of supply from groundwater to surface water	$45	$0.70	$55
Install water softeners at drinking water well sites	$32	$2.0	$62

Sources: City of Dixon DRAFT Wastewater Facilities Plan, August 2011, Stantec (conceptual peer review by Brown and Caldwell), Web site: http://www.ci.dixon.ca.us/index.aspx?nid=190, Technical Memorandums for City of Dixon, ECO:LOGIC, and Stantec, personal communications with city staff and commercial dischargers.

Notes:

[a] Total costs presented as 20 year present worth, assuming 3 percent net interest rate.

It is extremely difficult to estimate the cost of a statewide strategy for sustainable salt management apart from water management itself. Ideally, salinity control should be, and most often is, incorporated into broader efforts to protect or expand water supplies, optimize water use, offset land subsidence, protect fisheries, or store water for future use. Salt management methods vary in effectiveness and cost depending on a variety of factors, including:

- Volume and concentration of salts.
- Type of salts and stability of salt stream.
- Other materials or contaminants present.
- Desired salt concentration after management.

- Use of the water after treatment.
- Disposal of salt removed as part of a treatment process.
- Type of salt management strategies used:
  - Prevention.
  - Salt minimization.
  - Salt removal from process.
  - Salt removal from groundwater or environment.

Disposal of salt is a particular concern in inland areas that use desalinated water as a part of their water supply portfolio and have no access to an ocean outfall line. Two major strategies for brine disposal for these areas include 1) deep well injection and 2) evaporation basins. Several other strategies for using waste brine have been proposed, including irrigation of salt tolerant plants and brine shrimp harvesting. Such approaches have been limited and tend not to be applicable to very large volumes of wastewater. Recovery of inorganic salts with potential commercial value has also been suggested, but has not demonstrated economic viability to date.

While cost variability is high, multiple salt management options are often necessary because the least-cost salt management options appropriate for a given area may be inconsistent with sustainability when considered in a broader context of local, regional, or statewide salt management, energy consumption, water availability, or other resource issues.

Major Implementation Issues

Major issues facing successful salt and salinity management in California include the lack of:

- A common understanding of the need.
- Regional framework to address management issues on a holistic scale.
- Consolidated/validated water flow and quality data for sound decisions.
- Feasible treatment alternatives.
- Stable funding.

Climate change must be considered when addressing these major issues.

Common Understanding

Historically, salinity has not been a high profile issue to the general public although the local impacts of salinity have been severe in certain parts of California such as in the Salinas Valley, the Tulare Lake basin, the Lower San Joaquin River basin, the Colorado River basin, and the Santa Ana River watershed. Damage to the soils and groundwater from salt generally occurs over decades rather than hours, days, or months as occurs with many toxic constituents. Californians increasingly recognize that high quality water is a limited resource that once salinity concentrations become excessive the available and technically feasible recovery options are likely to be very expensive, adaptation to increasing salinity is an interim measure at best, and that water quality protection is more cost-effective and has a greater chance of success than water quality remediation. Salinity concentrations and loads can be impacted by most of the resource management strategies discussed in this chapter and must be considered as an integral component in all resource management strategies.

Understanding the need for salt management is only a first step. California has additional major challenges to implement sustainable salt management.

Regional Framework

Each hydrologic region has its own priorities and limitations on the resources available to address those priorities. Salt management has not kept up with emerging salt problems in many parts of California. As a general rule, salt management has been reactive rather than proactive in many parts of the state. Problem salinity emerges and a plan is formulated to deal with it; or problem salinity is anticipated and a plan is formulated, but the plan is not implemented completely or is not flexible enough to adjust to changing conditions like ecosystem or other water quality priorities. Sustainable salt management will require a more concerted, coordinated, and proactive planning effort than most communities or regions of the state have been able to achieve to date. This planning should be integrated with other water management alternatives and it could result in efficiencies and cost reductions for salt management. In particular, salt management strategies should be included in integrated regional water management planning efforts.

Effective salt management may also be constrained by federal, state, and local policies crafted to serve other needs. This inadvertent constraint is a similar problem to the funding issues discussed below. Very few public policies were developed with salt management in mind. As a result, water use and reuse, prioritization of resources, pollutant control, land use, and habitat management policies, to name a few, may be inconsistent with optimal salt management. Also, vis-à-vis, optimal salinity management may impact numerous other resources and management strategies. Historically, water management decisions have been driven primarily by water use efficiency policies, often with no consideration of the salinity issues. Consumptive use of water always results in the concentration of the total salt load in that water. As California uses water more efficiently, supplies will tend to become more saline unless policies and practices are intentionally implemented to maintain salinity at acceptable concentrations. Compromises between efficiency and quality will likely be needed to ensure a sustainable water supply for future generations.

Salinity problems often stem from decisions and actions taken elsewhere, but the costs to manage salt are generally borne by the receiving basin, watershed, community, or individual water user. Salt problems are rarely attributable to a single cause, but rather reflect a suite of decisions, conditions, conflicting water needs, and shifting state and local priorities. Problem salinity in California, as in other parts of the country and other parts of the world, can often be traced back to decisions that did not take into account the long-term impacts of salinity. A significant example of this is the operation of the Central Valley Project (CVP) and the State Water Project (SWP), which move water and the associated salt loads from one basin to another around the state in order to meet water supply needs while operating to Delta water quality objectives set by the SWRCB (Figure 19-3). A few additional examples follow.

- The Hetch Hetchy and Pardee Reservoirs serve as a water supply for San Francisco and East Bay Municipal Utility District respectively, diverting high quality water supplies from their basin of origin. These flows would otherwise assist in salt management by diluting the concentrations of salts downstream in the San Joaquin River basin and Delta, though the potential trade-off may be increased salinity in Bay Area water supplies.

- Planning for drainage facilities in the San Joaquin Valley began in the mid-1950s. Drainage service was initially considered at the time the USBR first studied the feasibility of supplying water to the San Luis Unit. By 1975, an 82-mile segment of the San Luis Drain, ending at Kesterson Reservoir, had been completed and 120 miles of collector drains were constructed in a 42,000-acre area of the northeast portion of the Westlands Water District. In 1983, the discovery of embryonic deformities of aquatic birds at Kesterson Reservoir due to high selenium in drainwater significantly changed the approach to drainage solutions in the San Joaquin Valley. Discharges to Kesterson Reservoir were halted and feeder drains leading to the San Luis Drain were plugged. Multiple lawsuits later, the San Luis Drainage Feature Reevaluation Plan Formulation Report in 2002 and draft EIS in 2005 (U.S. Bureau of Reclamation 2002; 2009) identified the In-Valley Disposal/Water Needs Land Retirement Alternative as the proposed action to provide drainage service based on cost, implementation, and other environmental information. In May 2003, the Westside Regional Drainage Plan was developed as a collaborative effort between the San Luis Unit water districts and the San Joaquin River Exchange Contractors Authority to provide drainage relief in portions of the Unit and adjacent areas (San Joaquin River Exchange Contractors Water Authority et al. 2003). The Westside Regional Drainage Plan is currently being implemented by its proponents and with the assistance of state and federal funding. However, salt loads are continuing to accumulate in the basin.
- Los Angeles basin biosolids are exported and applied to land in Kern County. In the process of providing agricultural benefits (porosity, soil tilth, etc.), this activity is also relocating salt to the Tulare Lake basin that is already under salt stress.
- In Southern California, only about half of the region's salt comes from local sources. The rest is brought in with imported water (Figure 19-4). The Colorado River Aqueduct imports the highest volume of salt to the South Coast hydrologic region with an average concentration of approximately 640 mg/L TDS, measured at Parker Dam. Water imports from the SWP and California Aqueduct have better water quality than other imports, but still have higher salt levels than many local basins. Elevated salt concentration leads to water scaling problems for indoor plumbing appliances and equipment in homes, business, and industries, which contributes to a consumer choice to install water-softening equipment, exacerbating the overall problem.
- Imported water from the Colorado River in the Imperial and Coachella Valleys has a high salinity concentration averaging 745 mg/L TDS measured at Imperial Dam. This brings an estimated 3.1 million tons of salt annually to these valleys.

Consolidated/Validated Flow and Water Quality Data

Salinity monitoring in surface and groundwater in most regions is under-funded, insufficiently coordinated, and has inadequate coverage to properly indicate the salt situation in most regions. Coordinated monitoring is the only way to assess salt impairment, track the rate of salinity degradation or improvement, and determine the effectiveness of salt management actions. Coordinating efforts not only lowers the costs of monitoring, but can also assist to make sure that all components needed to develop realistic water and salinity budgets are properly estimated. Sometimes overlooked is the fact that a reliable water budget is necessary to develop a useful salinity budget. Measuring or estimating the hydrologic components of seepage, evapotranspiration, inflow, and outflow for a region of interest can be exceedingly difficult but is necessary since the water budget is the basis of all hydrologic simulation models used for decision-making.

Figure 19-4 Movement of Salts in California from the Major Federal and State Water Projects

Source: Department of Water Resources and the U.S. Bureau of Reclamation

Data needs for decision tools have increased as models are formulated with greater precision, demanding greater spatial and temporal resolution. Fortunately, environmental monitoring technology has become progressively less expensive during the past decade and allows discrete sampling technologies to be replaced by continuous sensors and inexpensive telemetry systems to obtain real-time access to data. While the multi-agency California Water Quality Monitoring Council, established in 2009, attempts to move toward broader coordination, limited resources have been made available for the effort.

Feasible Treatment Alternatives

Environmentally and economically feasible options for sustainable salt collection, storage, and disposal do not currently exist for many parts of the state. Supporting beneficial uses when water is becoming increasingly saline often means that salt must be harvested from the water periodically and then disposed. Treatment technologies, like reverse osmosis or distillation, generate a highly saline solid or liquid waste product. Some areas, such as the Santa Ana River watershed, have pipelines that take brine from inland areas, treat the brine, and discharge it to the ocean where it mixes with the salt already present. However, many of California's interior valleys do not have this option. A few facilities use deep-well injection to sequester saline wastewater and some areas use low-tech solutions such as evaporation basins to isolate and store collected salt. Both of these alternatives are expensive and can be used only in areas where the geology and soil structure support this type of management. In addition, evaporation basins require significant land area and may have environmental impacts requiring mitigation. Other areas are investigating strategies such as Integrated Farm Drainage Management, which applies saline water progressively to more saline-tolerant crops. Case Study 2 (Box 19-2) is a farm-level example that ultimately disposes the remaining drainage in a solar evaporator, while Case Study 3 (Box 19-3) is a regional system that blends drainage with freshwater for reuse. Although these systems show promise at the regional scale, long-term salt accumulation is still a major issue for any reuse approach. Some saline discharges simply cannot be managed feasibly, sustainably, or economically with the management tools currently available.

Stable Funding

Funding to support salt management planning, project development, project operation and maintenance, and salinity monitoring has been insufficient in most parts of the state. With very few exceptions, public funding dispersed through grants or loans to agencies and organizations has excluded or severely limited funding for salinity planning efforts. Salt management on the scale needed for sustainability in California will require a lot of coordinated planning at the local and regional levels.

Grants and loans targeting project development and operation also often fail to support salt management, since the programs are usually competitive and award caps may favor multiple small projects over a smaller number of larger coordinating projects. This strategy is effective for some purposes (e.g., funding irrigation efficiency improvements on multiple farms across a large geographic area), but may be counterproductive for salt management which is often more cost-effectively achieved at a sustainable level through community-, watershed-, and regionally-scaled efforts (see Case Studies 1, 3, and 5, in Boxes 19-1, 19-3, and 19-5, for various examples).

Project maintenance and closure is often overlooked in budgeting for salt management. However, like the example of the incomplete San Luis Drain (discussed above in "Regional Framework"), the unforeseen environmental consequences of incomplete or abandoned salt management projects can result in greater hazards than if the project had never been undertaken. Sustainable salt management will need sufficient funding to ensure that salt management projects are maintained and closed properly and adapt to unforeseen environmental issues that may occur. Timely and adequate investments in salt management will ensure that salt control projects do not exacerbate existing salt conditions.

These examples above illustrate California's need for long-term planning to deal with the ultimate disposal or long-term sequestration of salt and equitable distribution of salt management costs. Salt disposal and relocation are not simply local engineering problems, but may potentially pose economic, social justice, or environmental problems as well as opportunities for the state.

California's communities, watersheds, and regions can only achieve a sustainable salt balance if the salt leaving the area equals or, in the case of many areas with basins already out of balance, exceeds the amount of salt received. The state's "plumbing" — the natural and constructed conveyance systems that move water and drainage around the state — is not optimized for salt management. It may not be possible to achieve sustainable salt management solely through conveyance system changes, but there should be studies conducted to quantify the benefits of optimizing conveyance systems for the additional purpose of salt management.

Climate Change

Climate change projections indicate that the Pacific Ocean level along the California coast will rise by 14 inches on average by 2050 and as much as 55 inches by 2100 (State of California Sea-Level Rise Task Force 2010). Sea level rise and associated storm surges and tidal flows will increase seawater intrusion in coastal groundwater basins and in the Delta. Furthermore, increased temperatures will increase evapotranspiration rates, leading to changes in crop planting and salt deposition from fertilizer use.

Adaptation

The Delta and coastal groundwater basins can be protected by counterbalancing seawater intrusion with freshwater flows. For the Delta, this means allowing more freshwater to flow into the Delta from upstream. Nevertheless, using upstream freshwater flows for protecting against seawater intrusion could have legal and economic implications for downstream water rights holders. For coastal groundwater basins, it means reducing pumping, moving pumping inland, and creating intrusion barriers with low-salt recycled water similar to Orange County. Reducing application of salts in agricultural and industrial processes will also protect groundwater basins for continued use. Moreover, desalination of brackish water may help manage salt accumulation in some areas.

Mitigation

Protecting coastal groundwater basins as water supply sources can reduce the need to rely upon more energy-intensive forms of water supply, minimizing GHG emissions. Creating seawater intrusion barriers and brackish desalination can be high-energy processes that negatively impact climate change mitigation efforts. In inland areas, salinity management could involve more high-energy treatment techniques. Alternately, reduced application of fertilizer could lower GHG emissions from fertilizer production.

Recommendations

Salt and salinity management is a long-term commitment for California. Recommendations have been broken into two parts: short-term (5-10 years) to provide a solid framework on which to build and long-term/on-going to support regional/statewide management and implementation alternatives. Since the success will depend on a stable funding base, a separate recommendation for potential funding alternatives is included in Chapter 7, "Finance Planning Framework," in Volume 1. The following recommendations are complementary to other water quality resource management strategy recommendations because salt and salinity management is strongly tied to all elements.

Short-Term (5-10 Years)

1. **Address Priority Concerns.** Legislature should identify and prioritize planning and implementation funding to areas where salt and nitrate management have immediate and/or widespread benefits including:

    A. Areas with impacts to drinking water as identified in State Water Resources Control Board's Report to the Legislature on Communities that Rely on Contaminated Groundwater (Assembly Bill 2222, Statutes of 2008) and State Water Resources Control Board's Report to the Legislature on Addressing Nitrate in California's Drinking Water with a Focus on Tulare Lake basin and Salinas Valley Groundwater (Senate Bill X2 1).

    B. The Central Valley where improvements would benefit not just the valley, but also significant portions of California receiving water exported from the Delta.

2. **Support Regional Management.** Existing programs, such as the IRWM Grant Program and others, should prioritize funding to groups updating regional plans that include salt and nutrient management components or implementation projects, giving higher funding preference to areas with disadvantaged community participation, areas identified in Recommendation No. 1 above, and small water systems and individual wells with documented contamination. In addition, multi-state cooperative salinity management efforts, such as the Colorado River Salinity Forum, should be encouraged and supported at a State level.

3. **Centralize Validated Water Quality and Flow Data.**

    A. State agencies should provide support and funding for the California Water Quality Monitoring Council as it continues to evaluate and promote coordinated monitoring and data management throughout the state.

    B. As financially feasible, projects receiving state money for salt management should be required to follow appropriate quality assurance protocols and submit salt data to a publicly accessible database.

    Improved hydrological and water quality database management tools are critical to facilitate easier access and data sharing necessary for the success of basin-wide salinity management. Decision support requires timely and accurate data that will require a greater degree of collaborative sharing than exists at present. Discrete flow and water quality data is no longer sufficient for decision-making. Maintaining high quality continuous sensor data will require a significant investment in state-of-the-art information technologies such as screening and data quality control software that runs on web-based data servers. Adopting common data platforms, or at the very least, agreeing on hydrologic data management conceptual protocol, would go a long way to encourage data sharing and improve data access.

4. **The State should review its funding guidance and policies for consistency with sustainable salt management and make revisions where necessary.** Specifically:

   A. Since salt is ubiquitous throughout the environment and a conservative element, management options appropriate in one area may not be sustainable when considered in broader context of local, regional, or statewide management, energy consumption, water availability or other resource issues. Legislated grant and loan programs (including Proposition 84) should address salt management differently than other constituents and favor projects that coordinate with a regional salt management plan and are supported by the entities maintaining the regional salt plan.

   B. When not explicitly prohibited by statute, public funding proposal solicitations should welcome projects with community-, watershed-, and regional-scale planning (specifically salt management planning) and water quality monitoring components.

   C. Award caps should be consistent with implementation of community-, watershed- , and regional-scale salt management projects.

   D. All salt management projects receiving public funding should be required to provide the awarding agency with an assurance that sufficient funding will be available to maintain the project during its life. These salt management projects should close in an environmentally acceptable manner based upon what can be foreseen at the time of project proposal.

Long-Term and Ongoing Needs

5. **Salt Storage and Other Research and Implementation.** Additional options for salt collection, salt treatment, salt disposal, and long-term storage of salt should be developed. University researchers should work with regulatory agencies and stakeholders to identify environmentally acceptable and economically feasible methods of closing the loop on salt for areas that do not currently have sustainable salt management options. Funding for this sort of research should be prioritized to ensure that areas with the greatest needs (i.e., high salt and few or no feasible management options) are targeted first (see recommendation No. 1). Specifically:

   A. Invest in research and development of environmentally acceptable means of storing salts for extended periods (decades) and sequestering salts (100+ years). Research should include identifying areas where such facilities can be sited with the least environmental impacts.

   B. Encourage additional research into more feasible means of using collected salt.

   C. Continue to evaluate an out-of-valley conveyance for the Central Valley such as a regulated brine line similar to the Santa Ana River Interceptor (SARI) system.

6. **Policies.** Entities with water policy-making authority should review existing policies, including those related to water use efficiency and funding of water projects, for consistency with sustainable salt management. Revisions should be made where necessary to ensure consistency with long-term sustainability objectives for multiple resources (e.g., water and energy). Effective salt management is not a stand-alone strategy and it should be integrated with other strategies. Every water use, water reuse, and waste disposal decision should include consideration of how the decision may affect the local and regional salt balance. Projects that propose to introduce saline water that may eventually mix with groundwater

should be evaluated in the context of the basin's assimilative properties, California's Antidegradation Policy, and potential impacts on a broader holistic scale to allow for a systems management approach.

When developing new policies and long-term strategies consideration must be given to policies adopted as the basis for ongoing activities. A good example is the policy to develop a Central Valley Drain to mitigate salt import and drainage impacts when extensive water supplies were provided through the Central Valley Project (CVP).

7. **Planning.** DWR and the USBR should actively participate in the Central Valley Salinity Alternatives for Long Term Sustainability (CV-SALTS) and other regional planning groups to develop regional salinity management plans that would include their respective water projects. These regional plans should include:

    A. An assessment of salt sources, loads, and timing.

    B. Current and projected regional water use with a description of projects.

    C. An assessment of conveyance flexibility to minimize/maximize exportation of salts.

    D. Land use planning based on regional/state projections.

    E. A regional implementation strategy, which could include offsetting/reducing salt loads relocated to salt-stressed interior basins as a result of water project operations. For example, USBR and the Central Valley Regional Water Quality Control Board entered into a Management Agency Agreement in December 2008 to address salinity brought into the San Joaquin basin via the Delta Mendota Canal. After 2008, USBR will implement its Action Plan to quantify offsets from current mitigation projects and continue to implement existing projects.

    F. A funding strategy that supports the implementation strategy, including providing funding and staff to participate in and support the CV-SALTS initiative and other regional planning groups.

    G. A stakeholder participation process to increase the likelihood of achieving plan goals and to ensure transparency in project planning and implementation.

    H. A monitoring program to track the success of the implementation strategy.

    I. An adaptive management strategy that ensures the plan can be modified to respond to drought, emergencies, climate change, and other changes and needs appropriately.

    Also, federal, state, and local entities with planning authority should review their planning documents (i.e., integrated regional water plans, basin plans, general plans) for consistency with sustainable salt management balanced with other resource management decisions and make revisions where necessary. Plans serving areas where salt accumulation in groundwater is currently unavoidable should address options for extending the life of the aquifer including, but not limited to, source control strategies and construction of salt disposal or long-term storage facilities. These plans are living documents. Therefore, salt management sections should be updated in accordance with salt management actions that have been taken (or in response to expanded salinity problems due to actions not taken) as well as other resource management activities since the previous review.

8. **Federal Coordination.** The federal government should ensure that all federal facilities are contributing their fair share to mitigate any federal facility's impact to salt imbalances

in California's communities, watersheds, and regions and participate in regional salt management efforts where appropriate.

9. **Expanding Coordinated Monitoring and Standardization.** Federal, state, tribal, local, non-government, and private stakeholders should work collaboratively to fund, develop, and operate a monitoring network or an array of compatible networks capable of identifying emerging salinity problems and tracking the success of ongoing salinity management efforts where such networks do not already exist. New or expanded networks should build upon and remain compatible with existing statewide monitoring programs such as the Surface Water Ambient Monitoring Program (SWAMP) and Groundwater Ambient Monitoring and Assessment (GAMA) program. Data should be made available to the public through a web-based user interface such as the Integrated Water Resources Information System (IWRIS). Many water districts and agencies, such as the U.S. Fish and Wildlife Service, have chosen commercial data platforms such as WISKI (developed by Kisters North America) to collect, maintain, and share data. This software provides a high level of security allowing these water districts and agencies to share data on their own web servers. This data may be valuable to other water districts and outside agencies and this software prevents universal access to more sensitive data. If widely adopted, this technology may have an important role in eliminating some of the current monitoring redundancy and optimizing use of scarce monitoring program funds.

   The tools and data resources currently available to assess salt balance are inadequate as previously discussed. Salt balance analyses should be based on calibrated regional surface and groundwater hydrology models where possible, since these models supply a standardized conceptual schema for defining basin, hydrologic, and institutional boundaries and provide a widely accepted protocol for defining layer boundaries with aquifer depth. Having this degree of standardization will allow valid comparisons to be made between salt balance, between regions, and will support more creative approaches using visualization techniques to convey the concepts of salt balance, rates of change, and long-term sustainability to stakeholders and the public.

Conclusion

Salt moves with water statewide. Therefore, effective salinity management should address the routes water takes within and between basins. All entities that make decisions with a bearing on water management should participate in regional salt management planning, monitoring, and implementation projects. In specific arid areas of the state, salt may also be displaced by air (e.g., Owens Valley) and such potential displacement must also be considered during planning efforts. Salinity stakeholder groups should conduct outreach aimed at educating specific target audiences with the ability to influence salinity decisions (Legislature, state and local agencies, interest groups, general public) about the need for sustainable salinity management.

Effective and sustainable salt management decisions rest in the hands of a wide range of water managers, regulators, facility operators, policy makers, landowners, and other stakeholders in any given watershed. These entities should strive to coordinate their efforts where possible in order to use resources efficiently, develop regional solutions to regional problems, optimize funding opportunities, and achieve a salt balance in the basin as quickly as possible.

Californians can continue paying for salt management reactively as rates increase, equipment wears out prematurely, food costs soar (loss of farmland means higher transportation costs for imported food), fish and wildlife habitat is lost, and business and development opportunities disappear as operations leave the area for states with more favorable water conditions. Alternatively, Californians can pay proactively through adequate continuous funding of sustainable salt management. With so much at stake on statewide, community, and personal levels, funding for salt management cannot be solely a state or federal responsibility.

Salt and salinity management is intertwined with almost all other resource management strategies. California cannot afford to wait to address this overarching issue.

References

References Cited

Ayers RS, Wescot DW. 1994. *Water Quality for Agriculture*. FAO Irrigation and Drainage Paper 29 Rev. 1. Rome (Italy): Food and Agriculture Organization of the United Nations. Viewed online at: http://www.fao.org/DOCREP/003/T0234E/T0234E00.HTM#TOC. Accessed: Nov. 16, 2009.

Bookman-Edmonston Engineering, Inc. 1999. *Salinity Management Study, Final Report: Long-term Strategy and Recommended Action Plan*. Los Angeles (CA): Prepared for Metropolitan Water District and U.S. Bureau of Reclamation.

California Department of Food and Agriculture. 2009. *California Agricultural Resource Directory 2008-2009*. Sacramento (CA): California Department of Food and Agriculture. [Web site.] Viewed online at: http://www.cdfa.ca.gov/statistics/. Accessed: Jan., 2010.

Central Valley Salinity Coalition. 2009. "Central Valley Salinity Coalition and CV-SALTS." Sacramento (CA): Central Valley Salinity Coalition. [Web site.] Viewed online at: http://cvsalinity.org. Accessed: Nov. 16, 2009.

City of Dixon. 2011. *City of Dixon Draft Wastewater Facilities Plan*. Dixon (CA): Prepared by: Stantec Consulting Services Inc. Prepared for: City of Dixon. Viewed online at: http://www.ci.dixon.ca.us/index.aspx?nid=190.

Diamond JM. 2005. *Collapse: How Societies Choose to Fail or Succeed*. New York, NY. Viking. [Book.] 575 pp.

Howitt RE, Kaplan J, Larson D, MacEwan D, Medellín-Azuara J, Horner G, Lee NS. 2009. *The Economic Impacts of Central Valley Salinity. Final Report to the State Water Resources Control Board*. Sacramento (CA): Prepared by: University of California, Davis. Prepared for: State Water Resources Control Board. Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/library_reports_programs/econ_rpt_final.pdf.

Imperial Irrigation District. 2010. 2010 Annual Water Report Imperial Irrigation District. Imperial (CA): Viewed online at: http://www.iid.com/Modules/ShowDocument.aspx?documentid=5057.

Quinn NWT. 2009. " Information technology and innovative drainage management practices for selenium load reduction from irrigated agriculture to provide stakeholder assurances and meet contaminant mass loading policy objectives." Agricultural Water Management. [Journal.] Volume 96(3): 484-492, Mar. 2009.

Quinn NWT, Karkoski J. 1998. "Real-time management of water quality in the San Joaquin River Basin, California." American Water Resources Association. [Journal.] Volume 34(6).

Quinn NWT, Ortega R, Rahilly PJA, Royer CW. 2010. "Use of environmental sensors and sensor networks to develop water and salinity budgets for seasonal wetland real-time water quality management." Environmental Modeling and Software. [Journal.] Volume 25:1045-1058.

Rubin Y, Sundig D, Berkman M. 2007. *Hilmar Supplemental Environmental Project. Executive Summary*. Sacramento (CA): State Water Resources Control Board. 16 pp. Order No. R5-2006-0025. Viewed online at: http://www.berkeleyeconomics.com/HilmarExSum.pdf.

Salton Sea Authority. 2009. Salton Sea Authority. La Quinta (CA): [Web site.] Viewed online at: http://www.saltonsea.ca.gov/. Accessed: Nov. 16, 2009.

San Joaquin River Exchange Contractors Water Authority, Broadview Water District, Panoche Water District, Westlands Water District. 2003. *Westside Regional Drainage Plan*. Sacramento (CA): State Water Resources Control Board. 23 pp. Viewed online at: http://www.waterboards.ca.gov/rwqcb5/water_issues/salinity/library_reports_programs/westsd_regnl_drng_plan_may2003.pdf.

Santa Ana Watershed Project Authority. "Brine line. How much does it cost?" Santa Ana Watershed Project Authority. Riverside (CA): [Web site.] Viewed online at http://www.sawpa.org/brine-line/how-much-does-it-cost/. Accessed: Dec., 2012.

State of California Sea-Level Rise Task Force, Coastal and Ocean Working Group of the Climate Action Team. 2010. *State of California Sea-level Rise Interim Guidance Document*. Sacramento (CA): State of California Sea-Level Rise Task Force, Coastal and Ocean Working Group of the Climate Action Team. Viewed online at: http://www.slc.ca.gov/Sea_Level_Rise/SLR_Guidance_Document_SAT_Responses.pdf.

State Water Resources Control Board. 1968. *Resolution No. 68-16. Statement of Policy with Respect to Maintaining High Quality of Waters in California*. Sacramento (CA): State Water Resources Control Board. 2 pp. October 28. Viewed online at: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1968/rs68_016.pdf.

———. 1988. *Resolution No. 88-63. Adoption of Policy Entitled Sources of Drinking Water*. Sacramento (CA): State Water Resources Control Board. 3 pp. May 19.Viewed online at: http://www.waterboards.ca.gov/board_decisions/adopted_orders/resolutions/1988/rs1988_0063.pdf.

———. 2009. *Resolution No. 2009-0011: Adoption of a Policy for Water Quality Control for Recycled Water*. Sacramento (CA): State Water Resources Control Board. 3 pp. Viewed online at: http://www.swrcb.ca.gov/board_decisions/adopted_orders/resolutions/2009/rs2009_0011.pdf. Accessed: Nov. 19, 2012.

U.S. Bureau of Reclamation. 2002. *San Luis Drainage Feature Re-evaluation Plan Formulation Report*. Sacramento (CA): U.S. Bureau of Reclamation. 160 pp. Viewed online at: http://www.usbr.gov/mp/sccao/sld/docs/plan_form_rpt/complete_rpt.pdf.

———. 2009. "San Luis drainage feature re-evaluation program documents." Sacramento (CA): U.S. Bureau of Reclamation. [Web site.] Viewed online at: http://www.usbr.gov/mp/sccao/sld/docs. Accessed: Nov. 16, 2009.

———. 2012. *Colorado River Accounting and Water Use Report, Arizona, California, and Nevada, Calendar Year 2011*. Boulder City (NV): U.S. Bureau of Reclamation. 48 pp. Viewed online at: http://www.usbr.gov/lc/region/g4000/4200Rpts/DecreeRpt/2011/2011.pdf.

U.S. Geological Survey. 2012. *Mineral Commodity Summaries 2012*. Washington (DC): U.S. Geological Survey. 198 pp. Viewed online at: http://minerals.usgs.gov/minerals/pubs/mcs/2012/mcs2012.pdf.

Additional References

CALFED Water Quality Program. 2006. *CALFED Water Quality Program Stage 1 Final Assessment. Final Draft*. Sacramento (CA): California Bay-Delta Authority. 202 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/Draft_Final.pdf.

California Department of Water Resources. 2006. *Progress on Incorporating Climate Change into Management of California's Water Resources*. Technical memorandum report. Sacramento (CA): California Department of Water Resources. 339 pp. Viewed online at: http://baydeltaoffice.water.ca.gov/climatechange/DWRClimateChangeJuly06.pdf.

———. 2012. *Municipal Water Quality Investigations – Real Time Data and Forecasting Report*. Sacramento (CA): California Department of Water Resources. Viewed online at: http://www.water.ca.gov/waterquality/drinkingwater/rtdf_rprt.cfm.

Central Valley Regional Water Quality Control Board. 1998. *Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins*. Fourth edition. Revised October 2011 with approved amendments. Sacramento (CA): State Water Resources Control Board. Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/sacsjr.pdf.

———. 2004. *Water Quality Control Plan for the Tulare Lake Basin*. Second edition. Sacramento (CA): State Water Resources Control Board. 70 pp. Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/tlbp.pdf.

———. 2006. *Salinity in the Central Valley An Overview*. Sacramento (CA): State Water Resources Control Board. 133 pp. Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/centralvalley_salinity_alternatives_archives/initial_development/swrcb_02may06_ovrvw_rpt.pdf.

———. 2009. "Central Valley salinity alternatives for long term sustainability initiative (CV-SALTS)." Sacramento (CA): Central Valley Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/salinity. Accessed: Nov. 16, 2009.

———.2009a. "Drinking water policy." Sacramento (CA): Central Valley Regional Water Quality Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/drinking_water_policy. Accessed: Nov. 16, 2009.

Drainage Reuse Technical Committee. 1999. *Drainage reuse. Task 1 Final Report*. Sacramento (CA): Prepared by San Joaquin Valley Drainage Implementation Program and University of California Salinity/Drainage Program. 83 pp. Viewed online at: http://www.water.ca.gov/pubs/groundwater/drainage_reuse_final_report_-_san_joaquin_valley_drainage_implementation_program/03-reuse.pdf.

Gordus AG, Shivaprasad HL, Swift PK. 2002. "Salt toxicosis in ruddy ducks that winter on an agricultural evaporation basin in California." Journal of Wildlife Diseases. 38(1):124-131. Viewed online at: http://www.jwildlifedis.org/content/38/1/124.full.pdf+html.

Izbicki JA, Metzger LF, McPherson, KR, Everett RR, Bennett V GL. 2006. *Sources of High-Chloride Water to Wells, Eastern San Joaquin Ground-water Subbasin, California*. Sacramento (CA): U.S. Geological Survey. 8 p. Open File Report 2006-1309. Viewed online at: http://pubs.usgs.gov/of/2006/1309/pdf/ofr2006-1309.pdf.

Los Angeles Regional Water Quality Control Board. 2008. *Upper Santa Clara River Chloride TMDL Reconsideration and Conditional Site Specific Objectives*. Staff Report. Los Angeles (CA): Los Angeles Regional Water Quality Control Board. 54 pp. Viewed online at: http://www.farmbureauvc.com/pdf_forms/USCR_Chloride_Staff_Report.pdf.

Santa Ana Watershed Project Authority. 2009. Riverside (CA): "Santa Ana Watershed Project Authority." [Web site]. Viewed online at: http://www.sawpa.org/. Accessed: Nov. 16, 2009.

Salt Utilization Technical Committee. 1999. *Utilization of Salt and Selenium Harvested from Agricultural Drainage Water*. Sacramento (CA): Prepared by San Joaquin Valley Drainage Implementation Program and University of California Salinity/Drainage Program. 81 pp. Viewed online at: http://www.water.ca.gov/pubs/groundwater/salt_utilization_final_report__san_joaquin_valley_drainage_implementation_program/tc8030399.doc.

U.S. Geological Survey. 2012. "USGS surface-water data for California. Washington (D.C.): U.S. Geological Survey. [Web site.] Viewed online at: http://waterdata.usgs.gov/ca/nwis/sw. Accessed: Dec. 5, 2012.

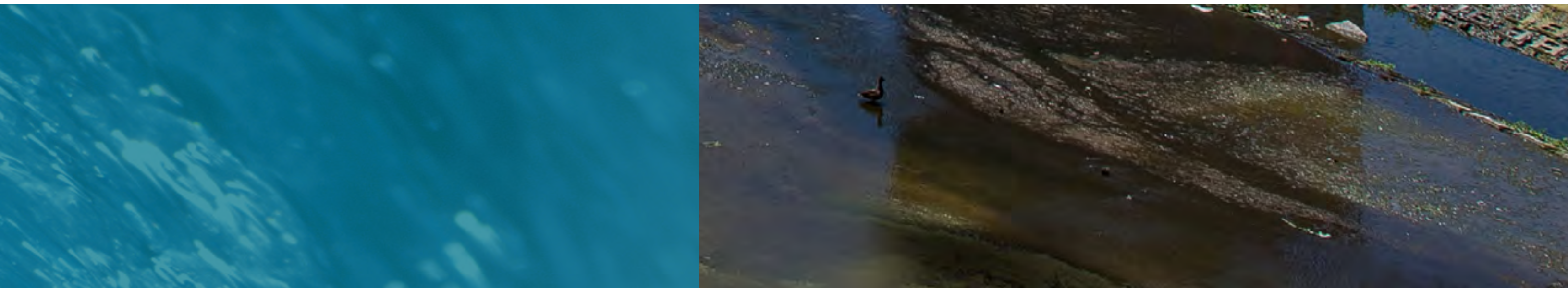
Westside Resource Conservation District. 1999. *Integrated System for Agricultural Drainage Management on Irrigated Farmland*. Final Report for Grant Number 4-FG-20-11920. Five Points (CA): Westside Resource Conservation District.

———. 2005. *A Technical Advisor's Manual Managing Agricultural Irrigation Drainage Water. A Guide for Developing Integrated On-farm Drainage Management Systems*. Fresno (CA): Prepared by Westside Resource Conservation District and Center for Irrigation Technology, California State University, Fresno. Viewed online at: http://www.water.ca.gov/pubs/drainage/integrated_on-farm_drainage_management__a_technical_advisors_manual/ifdm_tmanl.pdf. Accessed: Nov. 16, 2009.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 20

Urban Stormwater Runoff Management



San Jose, CA. Flood control infrastructure near downtown San Jose.

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Chapter 20. Urban Stormwater Runoff Management

Urban stormwater runoff management is a broad series of activities to manage both stormwater and dry-weather runoff. Dry-weather runoff occurs when, for example, excess landscape irrigation water flows to the storm drain. Traditionally, urban stormwater runoff management was viewed as a response to flood control concerns resulting from the effects of urbanization. Concerns about the water quality impacts of urban runoff have led water agencies to look at watershed approaches to control runoff and provide other benefits (see Box 20-1). As a result, urban stormwater runoff management is now linked to other resource management strategies covered in this volume, including Chapter 3, “Urban Water Use Efficiency”; Chapter 9, “Conjunctive Management and Groundwater Storage”; Chapter 12, “Municipal Recycled Water”; Chapter 18, “Pollution Prevention”; Chapter 24, “Land Use Planning and Management”; Chapter 25, “Recharge Area Protection”; and Chapter 27, “Watershed Management.”

Urban Stormwater Runoff Management in California

The traditional approach to runoff management views urban runoff as a flood management problem in which water needs to be conveyed as quickly as possible from urban areas to waterways in order to protect public safety and property. Consequently, precipitation-induced runoff in urban areas has been viewed as waste, and not a resource.

Urbanization alters flow pathways, water storage, pollutant levels, rates of evaporation, groundwater recharge, surface runoff, the timing and extent of flooding, the sediment yield of rivers, and the suitability and viability of aquatic habitats. The traditional approach to managing urban and stormwater runoff has generally been successful at preventing flood damage, but it has several disadvantages. In order to convey water quickly, natural waterways are often straightened and lined with concrete, resulting in a loss of habitat and impacts on natural stream physical and biological processes. Urbanization creates impervious surfaces, meaning stormwater does not infiltrate into subsurface aquifers. These impervious surfaces collect pollutants that are washed off to surface waters when it rains. The impervious surfaces also increase runoff volumes and velocities, resulting in streambank erosion, and potential flooding problems downstream. Because of the emphasis on removing the water quickly, the opportunity to use storm-generated runoff for multiple benefits is reduced.

A watershed approach for urban stormwater runoff management tries to emulate and preserve the natural hydrologic cycle that is altered by urbanization. The watershed approach consists of a series of best management practices (BMPs) designed to reduce the pollutant loading and reduce the volumes and velocities of urban runoff discharged to surface waters. Some BMPs include facilities to capture, treat, and recharge groundwater with urban runoff; public education campaigns to inform the public about stormwater pollution, including the proper use and disposal of household chemicals; and technical assistance and stormwater pollution prevention training.

Methods for recharging groundwater with urban runoff include having roof runoff drain to vegetated areas; draining runoff from parking lots, driveways, and walkways into landscaped areas with permeable soils; using dry wells and permeable surfaces; and collecting and routing

Box 20-1 Objectives of Urban Stormwater Runoff Management

- Protection and restoration of surface waters by minimizing pollutant loadings and negative impacts resulting from urbanization.
- Protection of environmental quality and social well-being.
- Protection of natural resources (e.g., wetlands and other important aquatic and terrestrial ecosystems).
- Minimization of soil erosion and sedimentation problems.
- Maintenance of predevelopment hydrologic conditions.
- Protection and augmentation of groundwater supplies.
- Control and management of runoff to reduce or prevent flooding.
- Management of aquatic and riparian resources for active and passive pollution control.

stormwater runoff to basins. Infiltration may require the use of source control and pretreatment before infiltration. Infiltration enables the soil to naturally filter many of the pollutants found in runoff and reduces the volume and pollutant load of the runoff that is discharged to surface waters. An example is the Elmer Avenue Neighborhood Retrofit Demonstration Project (see Box 20-2). The watershed approach will not prevent, nor should it prevent, all urban runoff from entering waterways. Elements of the traditional conveyance and storage strategy are still needed in order to protect downstream beneficial uses, protect water right holders, and protect the public from floods. In addition to infiltration of stormwater, other BMPs include the use of rain barrels and cisterns to “harvest” stormwater for later use (e.g., irrigation), and the use of structural controls that are designed to capture stormwater runoff and slowly release it into streams in order to mimic the natural hydrograph that existed before development occurred. In Los Angeles, the nonprofit TreePeople organization constructed a 216,000-gallon cistern in Coldwater Canyon Park to collect and store stormwater from building rooftops and parking lots for irrigation use during the dry months (see Box 20-3).

Urban stormwater runoff management has become more important and more controversial over the last two decades as municipal governments have been held increasingly responsible for pollutants washed from developed and developing areas within their jurisdictions into the storm sewer system and discharged into waterways. Unlike pollution from industrial and sewage treatment plants, pollutants in urban runoff and stormwater runoff come from many diffuse sources (see Box 20-4) and typically are not treated prior to being discharged to surface waters. It should be noted that in a few locations, dry weather urban runoff is diverted to the sanitary sewer system where it is treated at a local wastewater treatment plant. As rainfall or snowmelt moves over the urban landscape, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and, potentially, groundwater. Pollution associated with discharges from a storm sewer system can occur outside of storms also, from landscape irrigation flows, improper disposal of trash or yard waste, illegal dumping, and leaky septic systems.

Runoff in the urban environment, both storm-generated and dry weather flows, has been shown to be a significant source of pollutants to the surface waters of the nation. As a result, the 1987 amendments to the federal Clean Water Act (CWA) required that discharges from municipal

Box 20-2 Elmer Avenue Neighborhood Retrofit Demonstration Project

The Elmer Avenue Neighborhood Retrofit Demonstration Project is part of the Los Angeles Basin Water Augmentation Study, led by the Council for Watershed Health (formerly the Los Angeles and San Gabriel Rivers Watershed Council) and including multiple stakeholders. The project was designed to capture and infiltrate the runoff generated by a 0.75-inch design storm within the 40-acre residential catchment that fed surface flow to the 5800 block of Elmer Avenue. This block is a residential area with 24 single-family homes, located in the San Fernando Valley that was susceptible to floods due to the absence of storm drains and sidewalks. The project improves drainage and groundwater recharge and provides stormwater quality mitigation through the application of multiple low-impact development strategies on both public and private lands (Los Angeles and San Gabriel Rivers Watershed Council 2010).

A wide range of integrated management strategies and practices are part of the demonstration, from individual rain barrels (cisterns) on single-family homes to wide-scale infiltration trenches that were constructed underground along roadways. All of the systems are a focus of an extensive monitoring program under way that provides knowledge about the physical and social effectiveness of the installed systems.

The project was designed to provide 16 acre-feet (af) of groundwater recharge annually. Measurements and estimates suggest that in 2010-2012 the systems infiltrated about 40 af over the two years, exceeding the groundwater recharge design goal. Two large infiltration systems are under the roadway and handle the bulk of the recharge. Bio-swales are used to capture flow from the residential parcels. The project included retrofits to individual homes, with features such as porous pavement, rain barrels, native planting, and rain gardens.

Photo A Elmer Avenue Infiltration Galleries Under Construction

Source: Council for Watershed Health

Photo B Elmer Avenue Curbside Bio-Swale Filled by Half-Inch Rainstorm

Source: Council for Watershed Health

Box 20-3 Stormwater Cistern, Coldwater Canyon Park, Los Angeles

In an effort to reduce demand for imported water supplies and cost, the nonprofit organization TreePeople designed and constructed a 216,000-gallon cistern, underground stormwater storage tank, in Coldwater Canyon Park in Los Angeles. This innovative runoff management strategy captures and stores stormwater runoff to use on-site for irrigation during the dry months. The installation includes a stormwater storage and collection system to capture stormwater that falls on nearby building rooftops and a parking lot. Stormwater that falls onto the parking lot flows into a centralized gravel trench drain, which filters it. The water then seeps into pipes and is carried to the cistern. The buildings are also fitted with rain barrels in order to provide additional storage for rainwater. These barrels can be used to water urban watershed gardens that help allow for more infiltration of water on-site (TreePeople 2012a).

In 2010, the TreePeople facility captured more than 70,000 gallons from a three-day Los Angeles storm. A TreePeople Web page (TreePeople 2012b) states, “This solution prevents local flooding, helps keep beaches clean and if implemented widely, could stimulate the economy. … Last year, despite the declared drought emergency, TreePeople’s cistern captured enough rainwater to meet most of Coldwater Canyon Park’s irrigation needs, greatly minimizing the nonprofit’s dependency on the L.A. City water grid.”

Photo A TreePeople’s 216,000-Gallon Cistern Under Construction

Source: TreePeople 2012a

Photo B TreePeople’s Parking Lot with Storm Drains Piped to Cistern

Source: TreePeople 2012b

Box 20-4 Examples of Pollution in the Urban Environment

- Herbicides and pesticides from landscaped areas (residential and commercial), golf courses, city parks, etc.
- Oil, grease, and heavy metals from normal vehicle use (automobiles, trucks, and buses) that accumulate on streets, roads, highways, driveways, and parking lots (leaks and drips, brake pad dust, tire wear, etc.).
- Sediment from improperly managed construction activities.
- Litter and green waste.
- Bacteria from improperly maintained septic systems, encampments, and waste from pets and wildlife.
- Nutrients from the application of excess fertilizers on landscaped areas (home, commercial, parks, etc.).
- Illegal dumping of material into the storm sewer system (used crankcase oil, antifreeze, pesticide container rinse water, etc.).
- Atmospheric deposition.
- Natural catastrophes.
- Building maintenance (pressure washing of lead-based paints, rinsing of walkways, etc.).
- Sanitary sewer overflows.
- Illegal cross connections with the sanitary sewer systems.

separate storm sewer systems serving a population of 100,000 or more must be in compliance with requirements contained in National Pollutant Discharge Elimination System (NPDES) permits. The U.S. Environmental Protection Agency (EPA) promulgated regulations for these discharges in 1990. These regulations were subsequently amended in 1999 to require that municipal separate storm sewer systems that served populations fewer than 100,000 and were located in an urbanized area were subject to requirements contained in an NPDES permit. In California, the authority to regulate urban and stormwater runoff under the NPDES system has been delegated by the EPA to the State Water Resources Control Board (SWRCB) and the nine regional water quality control boards (RWQCBs).

Under the initial NPDES permits issued in the 1990s, municipalities were required to develop and implement a plan to reduce the discharge of pollutants into waterways, including the discharges from areas of new development and significant redevelopment. For the new development and redevelopment projects, the permit requirements were generally met by implementing BMPs that addressed discharges taking place during the construction activity but did not address discharges occurring after construction was completed (post-construction controls). Since the first municipal stormwater permits were adopted, and with continued beach closures and other pollution problems associated with urban runoff, it has become clear that post-construction controls, retrofit, and more advanced measures will be required in some areas to comply with water quality regulations (see Box 20-5).

The SWRCB and RWQCBs seek opportunities for managing urban runoff that will result in multiple benefits. Low-impact development (LID) is one such collection of management

Box 20-5 Implementation Plan for Urban Stormwater Runoff Management Programs

Implementation of urban stormwater runoff management programs will require local agencies to:

- Promote coordination of interagency programs that protect water quality from urban runoff pollution.
- Reduce the potential for contamination of surface water and groundwater that results from uncontrolled or poorly controlled urban runoff practices.
- Develop tools to assess the effectiveness of urban water pollution programs.
- Increase the availability of regulatory and guidance documents and instructional workshops to demonstrate effective urban runoff pollution control programs and policies.
- Reduce the number of uncontrolled urban runoff pollution sources by increasing the number of municipalities, industries, and construction sites that use non-point source management measures and fit under the permitted State Storm Water Program.
- Develop and implement watershed-based plans, including total maximum daily loads and stormwater management programs in order to identify and address impacts from urban land use.

techniques that has multiple benefits. LID is a sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional stormwater management, which collects and conveys stormwater runoff through storm drains, pipes, or other conveyances to a centralized stormwater facility, LID takes a different approach by using site design and stormwater management to maintain the site's predevelopment runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall. LID has been a proven approach in other parts of the country and is seen in California as an alternative to conventional stormwater management. The SWRCB and RWQCBs are advancing LID in California in various ways.

LID can be used to benefit water quality, address the modifications to the hydrologic cycle, and be a means to augment local water supply through either infiltration or water harvesting. In light of this, the SWRCB and RWQCBs are incorporating the principals of LID into the permits now being issued and are funding projects that highlight LID using the various voter-approved bond funds.

The SWRCB and RWQCBs are also required under the federal CWA Section 303(d) and federal regulations (Code of Federal Regulations [CFR] Title 40, Section 130) to prepare a list of water bodies requiring total maximum daily loads (TMDLs) because they do not meet water quality standards and set priorities for these water bodies. The Section 303(d) list was last revised in 2010 and is currently being updated for 2012. Federal regulations require the Section 303(d) list to be updated every two years. TMDLs represent the total pollutant load a water body can assimilate before the water body's beneficial uses are considered to be impaired and water quality standards are no longer met. Through the process of establishing the Section 303(d) list of impaired water bodies, it has often been found that urban runoff is a source of pollutants contributing to the impairment.

NPDES permits now issued to local agencies for discharges of stormwater require the implementation of specific measures to reduce the amount of pollutants in urban runoff. Permits for discharge to listed water bodies having a TMDL must be consistent with the waste load allocations in a TMDL. Under California law, TMDLs include implementation plans for meeting water quality standards. The implementation plans allow for time to implement control strategies to meet water quality standards.

Potential Benefits

The primary benefits of urban stormwater runoff management are to reduce surface water pollution and improve flood protection. Additional benefits may be to increase water supply through groundwater recharge in areas with suitable soil and geological conditions. Pollutants in urban stormwater runoff have the potential to degrade groundwater quality. However, good stormwater management practices can minimize these impacts and should be implemented. Groundwater recharge and stormwater retention sites can also be designed to provide additional benefits to wildlife habitat, parks, and open space.

Underground facilities can store runoff and release it gradually to recharge a groundwater aquifer or release it to surface waters in a manner that mimics the natural hydrologic cycle. Captured stormwater can also be used as a source of irrigation water rather than using potable water. For instance, a school campus can solve its flooding problem and develop a new sports field at the same time. These may provide secondary benefits to the local economy by creating more desirable communities. By keeping runoff on a site, storm drain systems can be downsized, which could reduce the installation and maintenance costs of such systems. A watershed planning approach to managing urban runoff allows communities to pool economic resources and obtain broader benefits to water supply, flood control, water quality, open space, and the environment.

Statewide information on the benefits of increased management of urban runoff is not available, but examples from local efforts exist. The Fresno-Clovis metropolitan area has built an extensive network of stormwater retention basins that not only recharges more than 70 percent of the annual stormwater runoff (17,000 acre-feet [af]) and removes most conventional stormwater pollutants, but also recharges excess Sierra Nevada snowmelt during the late spring and summer (27,000 af). Los Angeles County recharges an average 210,000 af of storm runoff a year, which reduces the need for expensive imported water. Agencies in the Santa Ana watershed recharge about 78,000 af of local storm runoff a year. The Los Angeles and San Gabriel Watershed Council (now known as the Council for Watershed Health) has estimated that if 80 percent of the rainfall that falls on just a quarter of the urban area within the watershed (15 percent of the total watershed) were captured and reused, total runoff would be reduced by about 30 percent. That translates into a new supply of 132,000 af of water per year or enough to supply 800,000 people for a year.

The City of Santa Monica is an example of a municipality that is taking a watershed approach to managing urban runoff. Santa Monica's primary goal is to treat and reuse all dry-weather flows. This turns a perceived waste product into a local water resource so that beach water quality is protected and the local nonpotable water supply is augmented. However, if dry-weather discharges are necessary, the City's secondary goal is to release only treated runoff into waterways. Both goals improve water quality of the Santa Monica Bay. The City's goals promote development such that urbanization works with nature and the hydrologic cycle.

At the "lot" or home-owner level, LID techniques and practices can be used to reduce the amount of runoff being generated and slow its release to the storm sewer system or surface waters. Captured runoff can be harvested and stored for later use on-site. LID techniques and practices include rain barrels, cisterns, rain gardens, swales, trench drains, land grading, permeable pavers, tree-box filters, and green roofs. For further information, see Volume 3, Chapter 24, "Land Use Planning and Management." An analysis aimed at quantifying the benefits of LID techniques was conducted by the Natural Resources Defense Council and University of California, Santa Barbara (2009), and is summarized in Box 20-6; the full report is included in Volume 4.

Potential Costs

Information about statewide costs to implement urban stormwater runoff management activities is not available. The SWRCB contracted with the Office of Water Programs at California State University, Sacramento, to survey six communities to estimate the costs of complying with their NPDES stormwater permits (California State University, Sacramento, 2005). Although this may address the cost for a municipality to comply with specific programmatic elements of an NPDES permit, it may not be the most applicable for looking at watershed programs seeking multiple benefits. In addition to this project, the Southern California Water Committee Stormwater Task Force has also initiated the development of a database of stormwater capture projects in Southern California that includes some preliminary cost information (Southern California Water Committee 2013).

The City of Santa Monica illustrates the costs of managing urban runoff from the perspective of treating dry-weather flows. The City has a stormwater utility fee that generates about $1.2 million annually and has been in place since 1995. The funds are used for various programs to reduce or treat runoff. They go to the City's urban runoff management coordinator for the maintenance of the storm drain system and to help support other City staff that conduct runoff work. Additional funds are spent by other divisions to perform runoff management efforts, such as street sweeping, some trash collection, sidewalk cleaning, and purchasing and maintaining equipment. The City has also received five grants totaling more than $3.5 million for the installation of structural BMP systems, all of which will require long-term maintenance and monitoring by the City. The culmination of the City's program is the $12 million Santa Monica Urban Runoff Recycling Facility (SMURRF), a joint project of the City of Santa Monica and the City of Los Angeles. The SMURRF project is a state-of-the-art facility that treats dry-weather runoff water before it reaches Santa Monica Bay. Up to 500,000 gallons per day of urban runoff generated in parts of the cities of Santa Monica and Los Angeles can be treated by conventional and advanced treatment systems at the SMURRF.

Major Implementation Issues

Lack of Integration with Other Resource Management Strategies

Land use planning is not conducted on a watershed basis. Many agencies spend millions of dollars annually addressing urban runoff problems with very little interagency coordination (both within the municipality and with other neighboring municipalities) even though downstream communities can be affected by activities upstream. In other words, internal communications within local government can be improved to ensure that the program goals and direction of

Box 20-6 Efforts to Quantify Benefits of Low-Impact Development

Low-impact development (LID) practices that emphasize infiltrating stormwater to recharge groundwater supplies or capturing rooftop runoff in rain barrels and cisterns for on-site use can be used to increase access to safe and reliable sources of water for end users, while reducing the amount of energy consumed and the greenhouse gas (GHG) emissions generated by supplying the water. Analysis by the Natural Resources Defense Council and University of California, Santa Barbara (2009) demonstrates that implementing LID practices at commercial and residential development and redevelopment, in urbanized Southern California and limited portions of the San Francisco Bay area, has the potential to increase water supplies by 229,000-405,000 acre-feet (af) per year by 2030. The water savings at these locations translate into electricity savings of 573,000-1,225,500 megawatt-hours (MWh), avoiding the release of 250,500-535,000 metric tons of carbon dioxide per year, as the increase in energy-efficient local water supply from LID results in a decrease in need to obtain water from energy-intensive imported sources of water, such as the State Water Project or energy-intensive processes such as ocean desalination.

The study analyzed geographic-information-system-based land use data, water supply patterns, and the energy consumption of water systems in California in order to estimate the water supply, energy use, and GHG emissions benefits of LID on a regional basis, under a conservative set of assumptions. The ranges presented for each benefit reflected a set of variables and input values used to create low and high estimates of potential savings. The study considered the percentage of impervious surface cover in the landscape; the density of development; the average annual rainfall; the soil type and infiltrative capacity; residential and commercial development rates; the energy intensity of current imported and local water supply sources; the effects of evapotranspiration; and local conditions, such as the presence of contamination or of shallow groundwater that may affect groundwater recharge.

Because the study included only a subset of urban areas within California, and incorporated only residential and commercial development, the true value of LID is likely higher than the results indicate. For example, expanding the use of LID to include industrial, government, public use, and transportation development in Southern California alone would have the potential to yield an additional 75,000 af of water savings per year by 2030, with corresponding reductions in energy use and carbon dioxide emissions. Finally, opportunities to implement LID practices that infiltrate or capture stormwater exist statewide. Even greater overall water supply, energy use, and GHG emissions reductions benefits would result from full application of LID and other green infrastructure techniques throughout all of California.

The Natural Resources Defense Council and University of California, Santa Barbara, research demonstrates that LID offers important opportunities to address vital issues of water quality and quantity, while simultaneously addressing climate change and its impacts on California. The results from this analysis suggest that LID is a worthy investment to meet many of the challenges faced by local agencies and communities.

one branch do not conflict with those of another; and local governments need to communicate with one another to ensure that land use planning on a regional level is complementary across jurisdictional boundaries.

Solutions to managing urban runoff are closely tied to many interrelated resource management strategies, including land use planning, watershed planning, water use efficiency, recycled water, protecting recharge areas, and conjunctive management. How and why water is used in the urban environment needs to be considered comprehensively within a watershed.

Climate Change

Climate change models project more frequent flood-producing storm events. These storms may overwhelm existing urban stormwater infrastructure, resulting in more localized flooding. During drought periods, additional landscape irrigation could create higher levels of runoff. In addition, contaminant buildup during extended dry conditions could result in increased impacts on coastal areas when large storms flush those contaminants out to coastal water bodies or the ocean.

Adaptation

Urban planning and development that incorporates opportunities to capture and infiltrate rainwater will assist cities in adapting to higher-precipitation storm events. Landscape design elements such as xeriscaping, drought-tolerant gardens, and bioswales can improve water capture and infiltration. Minimizing impervious areas, using regionally appropriate landscaping features, and seeking opportunities for harvesting rainwater for on-site use or infiltrating rainfall into ground water aquifers in new development will help protect against flooding from stronger storms.

Mitigation

Harvesting rainwater at the site level and infiltrating it on a regional scale can result in reducing localized flooding, as well as increasing local water supply through groundwater recharge. Harvesting when combined with the use of regionally appropriate landscaping can also reduce the amount of water needed to be delivered to the home for landscape irrigation. These activities can reduce the demand for energy-intensive water supplies, thus reducing the amount of greenhouse gas emissions produced from urban water supply.

Lack of Funding

The two main aspects of implementing urban stormwater runoff management measures are source control, including education, and structural controls. In highly urbanized areas, major costs for structural controls include purchasing land for facilities and constructing, operating, and maintaining treatment facilities. Local municipalities have limited ability to pay for retrofitting existing developed areas within existing budgets. The provisions of Proposition 218 have limited local municipalities' ability to increase fees to pay for services required to implement robust urban stormwater runoff management programs. Additional information on Proposition 218 is available in Volume 4, *Reference Guide.*

Effects of Urban Runoff on Groundwater Quality

The movement of pollutants in urban runoff is a concern. Urban runoff contains chemical constituents and pathogenic indicator organisms that could impair water quality. Studies by the EPA (U.S. Environmental Protection Agency 1983) and the U.S. Geological Survey (Schroeder 1993) indicate that all monitored pollutants stayed within the top 16 centimeters of the soil in the recharge basins. The actual threat to groundwater quality from recharging urban runoff depends on several factors, including soil type, source control, pretreatment, solubility of pollutants, maintenance of recharge basins, current and past land use, depth to groundwater, and the method of infiltration used.

Nuisance Problems/Other Concerns

The presence of standing water in recharge basins and other drainage and storage structures can lead to vector problems, such as mosquitoes and the transmission of West Nile virus. The California Department of Public Health has developed guidelines that address the issue of vector control in basins. These same concerns also apply to the on-site capture of runoff for later use.

A number of state agencies are encouraging infiltration and have found it to be an effective means of dealing with surface water pollution and the excess volumes and velocities of runoff created in the urban environment. However, it is also acknowledged that infiltration is not appropriate in all circumstances. Examples of this would be the widespread use of infiltration in a hazardous substance release site or brownfield development or infiltrating large amounts of water in hillside developments where slope stability may be an issue.

Protecting Recharge Areas

Local land use plans often do not recognize and protect groundwater recharge and discharge areas. Areas with soil and geologic conditions that allow groundwater recharge should be protected where appropriate. If development does occur in these areas, the amount of impervious cover should be minimized, and infiltration of stormwater should be encouraged on both a regional scale as well as at the "lot" level. In 2010, the Los Angeles and San Gabriel Rivers Watershed Council (now known as the Council for Watershed Health) prepared a water augmentation study that looked at the results of stormwater infiltration and the impact on groundwater (Los Angeles and San Gabriel Rivers Watershed Council 2010). Refer to Volume 3, Chapter 25, "Recharge Area Protection," for additional information.

Misperceptions

There are many misperceptions about urban runoff and its management. Urbanization changes the native landscape and creates many sources of urban runoff pollution. Urbanization brings about increases in impervious surfaces that do not allow precipitation to infiltrate into the ground, causing increased runoff volume and velocity that changes streams to become more "flashy." In addition, the traditional way that the urban environment has been landscaped (lawns) has called for the use of lawn care products to keep lawns green and free from weeds and other unwanted vegetation. The use of lawn care products creates a pollutant source when excess watering washes products off and into the storm sewer system. Likewise, the transportation system creates sources of runoff pollution.

Storm sewer systems have been designed to carry water away from the urban environment in order to reduce localized flooding during storm events. The systems have worked well in this regard, which has led to the public often times viewing runoff as a waste. However, with increasing demands on a limited water supply (surface water and groundwater) and climate-induced changes in precipitation patterns, water that otherwise would run off and be discharged to surface waters is being viewed as a resource. Changes in how new developments are planned and built, and changes in how we manage the existing urbanized areas, can create opportunities to capture runoff for future use.

Existing Codes

There are current codes and ordinances within State and local government that could conflict with some of the goals of managing urban runoff. Dry-weather flows have been shown to be significant sources of pollution, with one of the primary dry-weather flows being runoff associated with landscape irrigation and lawn watering. Reduction/elimination of these flows not only provides a water quality benefit, but also reduces the amount of potable water that is being used in a community. However, some municipalities have "green lawn" ordinances, and compliance oftentimes leads to runoff. Other codes require minimum street widths that can inhibit the minimization of impervious surfaces.

Recommendations

State

State agencies should:

1. Coordinate their efforts to decide how urban stormwater runoff management should be integrated into their work plans.

2. Coordinate their efforts to develop a single message to the public and local government regarding managing urban runoff through the use of LID techniques.

3. Coordinate their efforts to develop appropriate site design requirements that can be incorporated into either local building codes or statewide building standards.

4. Lead by example by incorporating LID into projects to showcase the use, utility, and cost of the features. Site design should be given the same attention that indoor environmental quality, energy usage, etc., are given in the design, funding, and construction of public projects.

5. Encourage public outreach and education about the benefits and concerns related to funding and implementation of urban runoff measures.

6. Provide leadership in the integration of water management activities by assisting, guiding, and modeling watershed and urban runoff projects.

7. Work with local government agencies to evaluate and develop ways to improve existing codes and ordinances that currently stand as barriers to implementing and funding urban stormwater runoff management.

8. Provide funding and develop legislation to: support development of urban runoff and watershed management plans; enable local agencies and organizations to pursue joint-venture, multipurpose projects; and collect information on regional urban stormwater runoff management efforts.

9. Assist agencies with developing recharge programs with appropriate measures to protect human health, the environment, and groundwater quality.

10. Work with federal policymakers and industry to create research and development incentives and to develop standards to reduce urban runoff from transportation-related sources, including lubricant systems, cooling systems, brake systems, tires, and coatings.

11. Maintain a publicly accessible clearinghouse of information regarding practices that can be used to address water quality issues associated with urban stormwater runoff management.

12. Work with local government to seek legislative solutions to the limitations imposed by Proposition 218.

Regional and Local Agencies and Governments

Local agencies and governments should:

13. Design recharge basins to minimize physical, chemical, or biological clogging; periodically excavate recharge basins when needed to maintain infiltration capacity; develop a groundwater management plan with objectives for protecting both the available quantity and quality of groundwater; and cooperate with vector control agencies to ensure the proper mosquito control mechanisms and maintenance practices are being followed.

14. Seek opportunities to include LID techniques in public works projects.

15. Work with the development community to identify opportunities to address urban stormwater runoff management, including LID, in development and redevelopment projects.

16. Develop urban stormwater runoff management plans, integrating the following practices into the development process:

    A. Understand how land use affects urban runoff.

    B. Communicate with other municipalities regarding how land use will change the hydrologic regime on a regional basis and how this change is being addressed.

    C. Look for opportunities to require features that conserve, clean up, and reduce urban runoff in new development and in more established areas when redevelopment is proposed.

    D. Be aware of technological advances in products and programs through communications with other municipalities, branches of local government, and professional organizations.

    E. Learn about urban runoff and watershed ordinances already in place. For example, the City of Santa Monica and the Fresno Metropolitan Flood Control District already have extensive urban stormwater runoff management programs in place.

    F. Integrate urban stormwater runoff management with other resource management strategies covered in this volume, including pollution prevention, land use planning and management, watershed management, urban water use efficiency, municipal recycled water, recharge area protection, and conjunctive management and coordinate both within and across municipal boundaries.

G. Be sensitive to the fact there are going to be sites where it is not appropriate to infiltrate urban runoff and stormwater flows.

H. Integrate urban stormwater runoff management with development goals and strategies in the community.

17. Communicate with citizens about pollution of urban runoff and what can be done about it.

18. Create lists of locally accepted practices that could be used at the homeowner level to address urban runoff.

19. Review codes and ordinances to determine whether there are impediments to managing urban runoff and amend these as needed or as is appropriate.

20. Coordinate urban stormwater runoff management with local water purveyors to ensure the goals and activities of each complement each other rather than conflict.

21. Seek opportunities to provide incentives for the installation of LID features at the lot level for new and existing developments.

References

References Cited

California State University, Sacramento, Office of Water Programs. 2005. *NPDES Stormwater Cost Survey: Final Report*. Sacramento (CA): California State University, Sacramento. 296 pp. Contract 02-189-250-0. Prepared for: State Water Resources Control Board. Viewed online at: http://www.owp.csus.edu/research/npdes/costsurvey.pdf. Accessed: Oct. 29, 2012.

Los Angeles and San Gabriel Rivers Watershed Council. 2010. *Water Augmentation Study: Research, Strategy, and Implementation Report*. Los Angeles (CA): Los Angeles and San Gabriel Rivers Watershed Council. 75 p. Viewed online at: http://watershedhealth.org/Files/document/522_WAS_StrategyDocument_web.pdf. Accessed: Nov. 1, 2012.

National Resources Defense Council and University of California, Santa Barbara. 2009. *A Clear Blue Future: How Greening California Cities Can Address Water Resources and Climate Challenges in the 21st Century*. New York (NY): National Resources Defense Council. 53 pp. Technical report. Viewed online at: http://www.nrdc.org/water/lid/files/lid.pdf. Accessed: Oct. 29, 2012.

Schroeder RA. 1993. *Potential for Chemical Transport Beneath a Storm-Runoff Recharge (Retention) Basin for an Industrial Catchment in Fresno, California*. Sacramento (CA): U.S. Geological Survey. 38 pp. Water-Resources Investigations report No. 93-4140.

Southern California Water Committee. 2013. "Costs and Benefits of Multi-Benefit Stormwater Projects in So. California (SCWC Database Project)." [Web site.]. Viewed online at: http://www.socalwater.org/images/11_Costs_and_Benefits_of_Multi_Benefit_Stormwater_Projects_in_So_Ca_-_Sim_Tyrrell_West.pdf.

TreePeople. 2012a. "Cistern." Beverly Hills (CA): TreePeople. [Web site.] Viewed online at: http://www.treepeople.org/cistern. Accessed: Oct. 29, 2012.

———. 2012b. "Collect the Rainwater." Beverly Hills (CA): TreePeople. [Web page.] Viewed online at: http://www.treepeople.org/collect-rainwater. Accessed: Oct. 29, 2012.

U.S. Environmental Protection Agency, Water Planning Division. 1983. *Results of the Nationwide Urban Runoff Program: Volume 1 — Final Report*. Washington (DC): U.S. Environmental Protection Agency. 198 pp. EPA No. 832R83112. Viewed online at: http://www.epa.gov/npdes/pubs/sw_nurp_vol_1_finalreport.pdf. Accessed: Oct. 29, 2012.

Additional References

Dallman S, Piechota T. 1999. *Stormwater: Asset Not Liability*. Los Angeles (CA): Los Angeles and San Gabriel Rivers Watershed Council. 41 pp. Funded by: U. S. Environmental Protection Agency Region 9 and the Union Bank of California. Viewed online at: http://www.lasgrwc.org/publications/Stormwater.pdf. Accessed: Oct. 29, 2012.

Kayhanian M, Johnston J, Yamaguchi H, Borroum S. 2001. “Caltrans Storm Water Management Program.” Stormwater 2(2). [Journal.] Viewed online at: http://www.stormh2o.com/SW/Articles/3273.aspx. Accessed: Oct. 29, 2012.

Lehner P, George P, Aponte C, Cameron DM, Frank AG. 2001. *Stormwater Strategies: Community Responses to Runoff Pollution*. Chapter on low-impact development added in October 2001; report originally published in 1999. San Francisco (CA): Natural Resources Defense Council. Viewed online at: http://www.nrdc.org/water/pollution/storm/stoinx.asp. Accessed: Oct. 29, 2012.

LowImpact Development Center. 2007. *A Review of Low-Impact Development Policies: Removing Institutional Barriers to Adoption*. Sacramento (CA): State Water Resources Control Board Stormwater Program and the Water Board Academy. 27 pp. Project officer: Greg Gearheart, professional engineer.

Pitt R, Clark S, Parmer K. 1994. *Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration.* Project Summary. Cincinnati (OH): U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory, Office of Research and Development. 7 pp. EPA/600/SR-94/051. Viewed online at: http://purl.access.gpo.gov/GPO/LPS35032. Accessed: Oct. 29, 2012.

Santa Ana Watershed Project Authority, Planning Department. 2005. *Santa Ana Integrated Watershed Plan 2005 Update*. Riverside (CA): Santa Ana Watershed Project Authority. 183 pp.

City of Santa Monica Urban Watershed Management Program. 2005. *Working for a Cleaner Bay*. Santa Monica (CA): City of Santa Monica. 16 pp. Viewed online at: http://www.swrcb.ca.gov/water_issues/programs/climate/docs/resources/sm_2005runoffbrochure.pdf. Accessed: Oct. 29, 2012.

City of Santa Monica Office of Sustainability and the Environment. 2009. *Stormwater Best Management Practices for New Developments, Major Retrofits and Tenant Improvements: A Stormwater Design Primer for Developers, Architects and Builders*. Santa Monica (CA): City of Santa Monica. 2 pp. [Pamphlet.] Viewed online at: http://www.swrcb.ca.gov/water_issues/programs/climate/docs/resources/sm_bmpbrochurejan09.pdf. Accessed: Oct. 29, 2012.

State Water Resources Control Board, California Coastal Commission, and Nonpoint Source Interagency Coordinating Committee. 2003. *State of California Nonpoint Source Program Five-Year Implementation Plan: July 2003 Through June 2008*. Sacramento (CA): State Water Resources Control Board. 423 pp. Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/nps/docs/5yrplan/nps5yrplan_20032008.pdf. Accessed: Oct. 29, 2012.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 21

Agricultural Land Stewardship


Yuba County. Pasture land near Beale Air Force Base, approximately 3 miles east of Marysville, CA.

Contents

Chapter 21. Agricultural Land Stewardship

This resource management strategy focuses primarily on private land in agriculture including cultivated land and rangeland. Agricultural land in California comprises about 31.6 million acres (California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program 2008). About 12.4 million of these acres are cultivated, while the remaining 19.2 million acres are rangeland (California Department of Forestry and Fire Protection 2010). (Information about forest land can be found in Chapter 23, "Forest Management," in this volume.)

Agricultural systems in California are varied in the way resources are used, ranging from intensive conventional agriculture (irrigated crop cultivation) to more extensive systems such as livestock grazing, each with a different relationship to natural resources. They also affect and are affected by surface hydrology and groundwater recharge in different ways. Stewardship of this land requires constant balancing among natural constraints, market forces, and ever-changing social expectations. Institutions and policies have been developed in response to these challenges. Public investment in water infrastructure (reservoirs, canals, drains, levees, dykes) has been in the forefront of these. This chapter focuses on agricultural land stewardship (ALS) strategies that can be incorporated into relevant adaptive management of agricultural land at different levels, including landscape, regional and project.

> ”Agricultural land stewardship” means farm and ranch landowners — the stewards of the state's agricultural land — producing public environmental benefits in conjunction with the food and fiber they have historically provided while keeping land in private ownership.
>
> *California Water Plan Update 2005*
> Agricultural Land Resource Management Strategy

Land managers practice ALS by conserving and improving land for food, fiber, biofuel production, watershed functions, and soil, air, energy, plants, animals, and other conservation purposes. ALS also protects open space and the traditional characteristics of rural communities, as well as open space within urban areas. Moreover, support for public benefits from ALS activities helps landowners maintain their farms and ranches in the face of expanding urban development.

ALS continue to be a leading priority in implementing *California Water Plan Update 2013*. Conversion of agricultural lands to developmental other uses (i.e., urban, industrial) can compromise a landscape's ability to provide ecosystem services to the public. Working landscapes will increasingly be relied on for flood management and water storage and conservation, as well as providing critical habitat at key locations and sequestering carbon, while maintaining ongoing primary productivity of food and fiber. It is also anticipated that difficult decisions will need to be made with regard to taking some productive agricultural land out of production to provide land for ecological functions, to fulfill the goals of flood management, reliable water supplies, and functional ecosystems. Questions persist about the appropriate role of the State in the purchase of development easements and the custodianship of these easements in light of the financial failure of land trusts around the country. Conversion of agricultural lands to developmental other uses (e.g., urban, industrial), can compromise a landscape's ability to provide ecosystem services to the public. For a more detailed discussion of this emerging issue, see the discussion on ALS later in this chapter.

Laws and Programs Relating to Agricultural Land Stewardship in California

Article 13, Section 8 of the California Constitution

Article 13, Section 8 of the California Constitution restricts taxation of open space land, including farmland, to promote conservation, preservation, and continued existence of this necessary resource.

California Land Conservation (Williamson) Act of 1965

Underscoring the economic importance of agricultural land, California lawmakers enacted the California Land Conservation Act of 1965 (Williamson Act) in order to protect agricultural land and open space from premature conversion to urban uses. The Williamson Act program is administered through the California Department of Conservation (DOC) Division of Land Resource Protection (DLRP), to promote land use planning decisions, which conserve farmland to the greatest extent feasible. About 16 million acres, roughly half of the farmland in California (cropland and rangeland), is covered by long-term contractual protections under the Williamson Act. At the time of this writing, the State no longer funds subvention payments to counties, which places this program and its inherent benefits at substantial risk. Permanent protection of farmland through agricultural easements is partially funded by matching fund grants administered by DLRP, as part of the California Farmland Conservancy Program (CFCP).

The Watershed Coordinator Grant Program

Also administered by DLRP, the Watershed Coordinator Grant Program supports projects implementing integrated resource management. This program works with landowners by building relationships to build better, healthier watersheds. The projects include water conservation, erosion prevention, and public education for water quality, best management practices (BMPs), science, and planning in watershed management. Other institutions supporting ALS include resource conservation districts (RCDs), University of California Cooperative Extension offices (UCCE), Natural Resource Conservation Service field offices (NRCS), county Agriculture Commissioners, and the California Department of Food and Agriculture (CDFA).

California Department of Food and Agriculture Environmental Farming Science Panel

CDFA organized the Environmental Farming Act Science Advisory Panel in August 2011 (see http://www.cdfa.ca.gov/environmentalstewardship). The panel is working toward the development of a market-based trading system to incentivize growers to implement management practices that contribute to the overall environmental quality of their working lands. Working toward that end, CDFA and the Science Panel have developed a definition of ecosystem services, developed a Qualitative Assessment Model, and released the Ecosystems Services database.

The Ecosystem Services database is collected from various sources including voluntary submission from growers and ranchers. The database is a communication tool to show the many social and environmental benefits offered by growers and ranches in California, including food production. To date, nearly 400 farms and ranches are included.

The California Ag Visions Reports and Ag Vision Advisory Committee

CDFA sponsored an Ag Vision Advisory Committee that lead to the development of the California Agricultural Vision Reports (see the *California Agricultural Vision: Strategies for Sustainability Report* and the *California Agricultural Vision: From Strategies to Results Report*, at http://www.cdfa.ca.gov/agvision/docs/Ag_Vision_Final_Report_Dec_2010.pdf and http://www.cdfa.ca.gov/agvision/docs/Ag_Vision_Progress_Report.pdf, respectively).

The Farm Security and Rural Investment Act of 2012

The reauthorized federal 2008 Farm Bill provided several new and traditional agricultural conservation programs that exemplify an ALS strategy. All programs are voluntary. Many programs may include technical assistance, financial incentives, or temporary and permanent set-aside payments for various purposes. At the time of this writing, the current reauthorization of the Farm Bill (2012) awaits action by Congress.

California Agricultural Water Stewardship Initiative (CAWSI)

CAWSI raises awareness about approaches to agricultural water management that support the viability of agriculture, conserve water, and protect ecological integrity in California. This effort of the multi-stakeholder group, the California Roundtable on Water and Food Supply, includes an online resource center of agricultural water stewardship practices and a host of additional useful resources. (See the California Water Stewardship Initiative at http://www.agwaterstewards.org/.)

California Roundtable on Water and Food Supply

The California Roundtable on Water and Food Supply (http://aginnovations.org/roundtables/crwfs/) is a forum for select leaders at the intersection of agriculture and water management to uncover obstacles, identify strategic and widely accepted solutions, and generate recommendations to ensure a reliable, long-term supply of water to California's specialty crop producers while optimizing other beneficial uses of water. The Roundtable is a forum where these thoughtful and committed leaders can engage in a facilitated, off-the-record dialogue where creativity and wisdom can flourish and new thinking and paths forward for sound water management can emerge. Recent publications can be found on their Web site.

California Rangeland Water Quality Management Plan

In 1990, California's range livestock industry led by the California Cattlemen's Association developed a program of voluntary compliance with the Federal Clean Water Act, federal and State coastal zone regulations, and California's Porter-Cologne Act. This initiative led to the development of the California Rangeland Water Quality Management Plan (CRWQMP) for nonfederal rangelands, which was approved by the State Water Resources Control Board in 1995. The management plan provides for development and implementation of ranch water quality plans on a voluntary basis. In 1994, the University of California Cooperative Extension (UCCE) and NRCS began to develop education programs to support landowners in the development of individual water quality management plans. These plans focused on non-point-source assessment, development of water quality protection objectives, implementation of practices, and monitoring in the short- and long-terms. Several workshops targeting landowners have been conducted throughout the state by UCCE. The program has been effective; the majority of ranchers who developed management plans went on to implement BMPs.

Payments for Watershed Services

These are new and voluntary market-based mechanisms that fund conservation easements and/or conservation practices on private lands for watershed services (i.e., to protect water sources and maintain and improve water quality). These programs include one or several buyers (e.g., public agencies, private companies, non-profits, consumers). Several of these programs are being implemented in the United States and in California.

Agricultural Land Stewardship Strategies

California Water Plan Resource Management Strategies

The size and terrain of California allows for a diverse agriculture sector that includes extensive and intensive systems. This comes with costs, not the least of which are the large amounts of capital and land needed for water capture, storage, transport, and disposal (i.e., Lower Klamath Lake, Salton Sea). Other resource management strategies requiring significant land resources may be compatible or conflict with ongoing agricultural uses. Among these are flood management, ecosystem restoration, watershed management, forest management, economic incentives, water transfers, agricultural water use efficiency, and land use management. Although this narrative does not discuss the overlap with these other strategies in any detail, the interrelationship among these strategies highlights the need for integrated water management that takes into consideration the land that is affected by these strategies.

Agricultural Land Stewardship Approaches

ALS is not a new concept. Under various names, it has been practiced by many farmers and ranchers and encouraged by the California Department of Conservation's programs and the U.S. Department of Agriculture (USDA) through the NRCS and various nongovernmental entities for many years. The California RCDs and other entities specialize in working with private landowners in watershed management and coordination strategies. There are many ways that agricultural land can provide conservation benefits and be profitably managed. Cropland and rangeland can be managed to reduce or avoid streambank erosion or rapid stormwater runoff. Streambank stabilization may include a buffer strip of riparian vegetation, which slows bank erosion and filters drainage water from the fields. Measures such as these can minimize or reduce the effects of agricultural practices on the environment and help meet governmental regulatory requirements while also reducing long-term maintenance problems for the landowner and providing environmental co-benefits.

California's 19.2 million acres of privately held rangeland strongly differ from cropping systems in their impacts on water, and the management strategies to enhance water quality and quantity. Eight of California's 12 major drainage basins are dominated by vegetation types that are commonly grazed rangeland, which occurs on roughly 20 ecosystems in California. These have a rich diversity of species. Two-thirds of the major reservoirs in the state are located on public and private rangeland. The location of rangeland, between the forested areas and major river systems, means that almost all surface water in California passes through rangeland. Rangeland plays a key role in ensuring watershed function in California. A recent publication from the NRCS provides the additional background on the practices and benefits of rangeland management. (United States Department of Agriculture, Natural Resources Conservation Service 2011) Investment in naturally occurring, "green" infrastructure is a cost-effective way of protecting and maintaining healthy watersheds in California. This is accomplished through rangeland conservation programs that aim to secure beneficial land uses through conservation easements and BMPs, in order to protect both water supplies and water quality.

A range of private and public programs and initiatives already exist that fit the stewardship model (see *California Water Plan Update 2009* for a list of these programs). Many public programs provide technical assistance on what crops to plant and how to plant, cultivate, and irrigate them. Similarly, programs in rangelands enhance water quantity and quality, and other ecosystem services by providing information on grazing intensity and timing, and strategies for fencing and developing infrastructure to provide water to livestock. Other programs provide technical help on wildlife-friendly farming and ranching techniques for terrestrial and aquatic ecosystems. Additional types of programs cover soil, water, and habitat conservation planning. These efforts can identify suitable areas for farming and habitat management, and identify key rangelands and croplands that should be protected from development due to the multiple services they can provide. Urban planning programs can also be used to avoid agricultural land fragmentation and permanent loss of valuable agricultural land because of urban development (see the Land Use Planning and Management resource management strategy).

More recently, there are programs that limit or cease commercial agricultural use to promote flood management or to protect and restore wetlands and other wildlife sensitive areas. In the past, these programs have not affected a large portion of agricultural land. Now, however, several large programs anticipate taking a significant amount of land out of production. Although governmental land acquisition programs may not be considered ALS programs when they take farmland out of production, ALS is being increasingly considered by governmental and nongovernmental organizations (NGOs) as a way to avoid taking agricultural land out of production, where possible, and for protecting natural resources while keeping the land in productive private ownership.

Update 2009 provides an Annotated List of Agricultural Land Stewardship Best Management Practices, by Resource Issue Addressed and Hydrologic Regions of Greatest Applicability (see Update 2009 Resource Management Strategies, Chapter 20, "Agricultural Land Stewardship," at http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2c20_aglands_cwp2009.pdf).

Governmental land acquisition programs do not constitute agricultural stewardship when they take farmland out of production. These programs have been limited, because they have affected only a small portion of agricultural land. More recently, several large programs, such as the Bay Delta Conservation Program (BDCP) and the Central Valley Flood Protection Program, anticipate taking a significant amount of land out of production. ALS is being increasingly considered by governmental and NGOs as a way to avoid taking agricultural land out of production where possible and for protecting natural resources while keeping the land in productive private ownership.

Agricultural Land Stewardship and Planning in the Delta

The State and other entities are pursuing multiple activities in the Delta that could affect Delta farmland. These include near-term projects of the State and federal water projects to meet current endangered species requirements and future projects under the BDCP. The conversion of important farmland to other uses may be significant and result in mitigation under the California Environmental Quality Act (CEQA) depending on the nature and quality of the lands to be converted. In addition, conversion of important farmland may adversely affect habitat for native terrestrial species.

CEQA focuses on the environmental impact, not the economic impact of a project — a distinction that is sometimes difficult to make in the context of agricultural resources. Farmland conversion may have impacts in terms of changes to high quality soils, changes to land use, and loss of habitat. After avoidance and minimization, the conventional mitigation approach for these types of impacts has been to acquire conservation easements over existing farmlands elsewhere near the project area, usually on lands that are in the path of urban development.

In 2012, an interdisciplinary, interagency workgroup developed a concept paper describing a proposal that would explore with the agricultural community an ALS approach to the conversion of agricultural land that would offer a more integrated and collaborative effort using a variety of ALS principles and strategies. An underlying premise of the discussion was to work on developing an approach that strives to minimize impacts to the agricultural land resources in the Delta and to avoid long-term cumulative impacts to the agricultural economy and/or to wildlife that depends on farmland for habitat. It does not attempt to distinguish between environmental or economic impacts, but rather focuses on maintaining the viability of Delta agriculture.

The approach takes into account the desire of individual Delta farmers to continue working on their land, the long-term viability of regional agricultural economies, the economic health of local governments and special districts, and the Delta as an evolving place. This approach is designed to encourage early planning that will result in multiple benefits and long-term partnerships with local interests with a goal of developing projects with sustainable outcomes that benefit both the environmental and social-economic communities in the Delta. Finally, the approach recognizes that local interests, including Delta farmers, have unique and specialized knowledge and would seek to involve these interests in the process.

The workgroup received positive input as a result of discussions on the concept paper and in early 2013 began work on describing in more detail different ALS strategies and developing a framework for ALS planning that integrates the strategies. As the work progressed, it became clear that most of these strategies have broader applicability statewide and can be used in considering ways to reduce the negative impacts of many land use decisions on agricultural productivity.

Agricultural Land Stewardship Framework for Planning

ALS planning can provide an integrated and collaborative approach for addressing the use of farmland for project purposes and the conversion of farmland to different uses, especially uses that continue an open space use of the land.

It encourages exploration of a voluntary framework for project proponents to pursue that is consistent with State and regional polices and that would provide the environmental and habitat benefits that are part of the project while maintaining agricultural and economic viability in the area where the project is located and supporting the stability of local government and special districts.

A comprehensive tool box of ALS strategies and a framework for considering them can help develop informed ALS activities at different levels of planning, including landscape, regional and project. It can also be useful for making funding decisions.

At its core, it can be used by project proponents in developing projects that affect agricultural land through an agricultural land stewardship plan (ALSP). To the extent they apply, the ALS strategies should be considered in developing the ALSP. Not all of the ALS strategies will apply to a specific project. In fact, some of them provide different approaches that are not compatible. The framework for developing an ALSP first suggests that the parties evaluate the extent to which the project can be part of or complement existing or planned land uses for the area involved, including mitigation and enhancement relating to aquatic and terrestrial habitat, agricultural use, recreation, agritourism, ecotourism, and flood management. As a threshold issue, this means thinking about ways to prevent or avoid farmland loss. To the extent that impacts to farmland cannot be avoided, consideration should be given to developing working landscapes on project lands that take into account the possibility of multiple benefits. If a project cannot avoid agricultural impacts, then project proponents should consider different strategies for mitigation of environmental, as well as economic, impacts.

The primary responsibility for preparing and implementing an ALSP would be with the project proponent. Entities such as the local counties or regional entities may want to consider developing a regional plan that can help identify places where special attention should be given to preserving agricultural land for a variety of reasons, including that it is in the path of development, is unique, or is critical to preserving important infrastructure. To the extent that there are regional conservation plans, they can also be considered. If the farmer is involved in carrying out the project, a more specific agreement may be involved that sets for the responsibilities of the farmer. Part of this may be a requirement that the farmer propose and carry out more specific implementing ALSPs.

Agricultural land stewardship planning should involve the local community in the planning process, along with local, State and federal agencies. At its core is involvement of the landowner and the county where the property is located, recognizing that local interests have unique and specialized knowledge. In addition to the landowner and/or farmers affected, at a minimum, the following organizations or types of organizations should also be consulted: local government, Sacramento Area Council of Governments, and other councils of government; federal, State resource and regulatory agencies; organizations with a regional focus; RCDs; local colleges and universities, including agricultural extension; local labor and farm worker organizations; Economic Development Corporations; NGOs representing farmers; and NGOs representing entities that promote habitat protection and restoration activities.

The framework for ALS, the ALS strategies, and other information, including samples of proposed or actual ALSPs can be found on the ALS Web site at https://AgriculturalLandStewardship.water.ca.gov/.

Potential Benefits of Agricultural Land Stewardship

ALS should be included as an integral component of regional integrated resource planning, including watershed planning and implementation. ALS can use stewardship practices to protect the health of environmentally sensitive land, recharge groundwater, improve water quality, provide water for wetland protection and restoration, reduce costs to the State for flood management, and aid riparian reforestation and management projects. Land can also be managed to improve water management, urban runoff control, water storage, conveyance, and groundwater recharge. These stewardship practices are attractive since they do not rely on construction of major facilities and provide a range of environmental co-benefits.

Agricultural Land Stewardship as Part of a Regional Strategy of Urban Growth Management

Agricultural land provides public benefits for floodplain management, scenic open space, wildlife habitat, and defined boundaries to urban growth. Stewardship provides the rural counterpart to urban efforts to encourage more water efficient development patterns. It also can minimize fragmentation of agricultural land by development that can decrease productivity and decrease the provision of ecosystem services. Maximizing co-benefits, while respecting private property rights of owners of agricultural land, landowner incentives, including payments for watershed services, need to be expanded carefully.

Update 2009 provides an Annotated List of Agricultural Land Stewardship Best Management Practices, by Resource Issue Addressed and Hydrologic Regions of Greatest Applicability (see Update 2009 Volume 2, *Resource Management Strategies*, Chapter 20, “Agricultural Land Stewardship,” at http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v2c20_aglands_cwp2009.pdf).

Climate Change

Climate change is anticipated to increase average temperatures and cause changes to hydrology, which will have many direct and indirect impacts on agriculture in California. These impacts include a reduced snowpack, decreased water availability, increased evapotranspiration, and more intense flood events and droughts (California Department of Water Resources 2008). Climate change will lead to increased evapotranspiration and moisture deficits during potentially longer drought periods, concurrent with increased water demand (California Department of Water Resources 2008). ALS provides potential benefits in relation to climate change, including both mitigation (reduction of overall impact) and adaptation (preparation for unavoidable changes).

Adaptation

Stewardship of agricultural soils improves capacity to retain water and promotes resilience to dry periods. Likewise, soils that are rich in organic matter absorb water better which will be beneficial during unusually high rainfall events that are anticipated under a changing hydrologic regime. Increasing flexibility in cropping patterns will be important in a more variable climate, which may yield fewer freeze days and a longer growing season. The protection of small patches of wildlife habitat on portions of cultivated or fallowed land would provide multiple climate adaptation benefits such as providing habitat for pollinators and refugia for other species that may need to migrate across the landscape to find suitable habitat. Higher temperatures and dryer conditions will lead to increased wildfires in some parts of California. Grazing and brush management on rangelands can be used to reduce the risks of wildfire and subsequent impacts to watersheds and downstream agricultural land.

Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas (GHG) emissions in an effort to lessen contributions to climate change. ALS is a valuable mitigation tool. Energy conservation measures associated with ALS lead to a direct reduction in the production of GHG emissions, and practices that encourage soil sequestration take carbon out of the atmosphere while protecting soils that will be subjected to an increasingly variable hydrologic regime in the future. On-farm management of green waste and other soil-building practices can retain carbon and nitrogen within the soil, benefitting both tilth and overall soil health while sequestering GHGs. Enhancing soil organic matter also increases water retention in soils, thereby reducing additional energy spent through irrigation. Conservation tillage reduces on-farm energy use, while improving soil organic content and carbon sequestration. On-farm power generation through anaerobic digestion, photovoltaic panel installation, and wind turbines reduces the use of GHG-intensive fossil fuels. Developing on-farm water sources, such as ponds, reduces the energy required for pumping groundwater. Management practices in rangelands, such as prescribed grazing and management of woody vegetation, have the potential to increase carbon.

Climate Change Impacts on Rangeland

More than 16,000 acres of rangelands are converted every year in California, primarily due to urbanization and irrigated agriculture (California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program 2008). Climate change will pose a new threat to rangelands by changing water availability and species distributions. Climate modeling scenarios showed that a loss of rangelands will lead to loss of biodiversity, impaired water quality, less carbon sequestration, less groundwater recharge, and in some cases, less input to food production. Ecosystem services (resources and processes supplied by natural ecosystems) provided by rangelands include wildlife habitat, groundwater recharge, and carbon sequestration. Recent studies have attempted to access potential threats to rangeland ecosystems services and to quantify the economic costs and benefits. The key threats for ranching in the future include limited availability of grazing land for lease, fragmentation of grazing land, declining forage quality and quantity, and high start-up investment cost. Economic analysis of ecosystem services included 1) identifying affected ecosystem services and their economic importance, 2) compiling a provisional estimation of costs-and-benefits-by-scenario impact, and 3) identifying economic incentives to maintain rangeland habitats.

In September 2013, CDFA's Climate Change Consortium released a report that outlines climate change impacts and discusses strategies for resilience. The paper focuses on California's significant specialty crop sector (see http://www.cdfa.ca.gov/environmentalstewardship/pdfs/ccc-report.pdf).

Potential Economic Costs of Agricultural Land Stewardship

Governmental and nongovernmental entities are seeking ways to secure funds for conservation practices that can be part of stewardship. In general, there is agreement by economists on three questions:

- What are the direct costs for supporting stewardship programs?
- What are the common ways to measure the costs for the wide range of environmental values?
- What current level of investment is needed to sustain stewardship for the long term?

Developing stewardship costs is similar to estimating costs of managing land to avoid environmental impacts such as air and water pollution, or to provide wildlife habitat or secure food and fiber production. Stewardship is a way of doing business and should be a part of an economic model that shows a return on investment by placing a value on healthy communities and their quality of life. In addition, ALS helps avoid costs associated with urban land use. Typically, landowners pay for conservation practices out of their own pockets, with cost-share programs offsetting a fraction of these costs for landowners willing to access government funding. It is difficult to quantify the costs that are prevented by ALS. Not only are there cost savings by avoiding expansion of infrastructure, but also there are avoided costs for flood damage reduction measures and urban runoff. These costs have not been quantified for broad reference and application.

There are at least three ways to deal with costs of implementing ALS.

1. Actual costs of BMPs that have been documented in recent studies or projects, or by conservation or agricultural agencies, such as the USDA NRCS. Costs would be expressed in terms of dollars per acre or mile, for example, or for installation of a structure.

2. A range of costs based on past experience or range of levels of implementation of an ALS practice or strategy. An example would be the cost of agricultural easement acquisition, which would vary from place to place, and would also vary based on the extent of property interests purchased by an easement agreement (e.g., just development rights, or development rights plus flowage rights including restrictions on crops that can be planted under the easement agreement).

3. Cost estimates in reports and studies of solving a resource issue in a region or statewide. An example might be a State agency's estimate of the current cost of installing riparian buffers to protect water quality on high-priority water bodies in a particular regional water quality control board's area.

Major Implementation Issues

There are major issues related to improving ALS, include mixing economic endeavors with environmental goals, economic markets, and land conversion. Increased focus on this strategy is necessary to implement regional integrated resource planning and management, and to demonstrate to the public the measurable benefits of stewardship. Land use change is a critical issue, as conversion from agriculture to urban and industrial land use can result in irreversible loss of a landscape's potential to provide food and multiple ecosystem services that benefit the public. Every year about 20,000 acres of rangelands are converted to other uses, which negatively impacts water provisioning, conservation of biodiversity, and open space (California Department of Conservation, Division of Land Resource Protection, Farmland Mapping and Monitoring Program 2008).

Landowner Confidentiality and Privacy Protection

Many environmental regulatory programs understandably require information from working landowners about the effectiveness of grant funding made to help landowners comply with regulations. The issue has at least two facets. First, agencies have a responsibility to account for the expenditure of public funds to achieve resource protection and conservation. Second, there is an enforcement-related and scientific need for data on the effectiveness of funded ALS practices. These data are necessary to document compliance and to document value of ALS practices to the conservation objectives of the regulatory agency. For example, the State Water Resources Control Board has required farm-specific information as part of the public record of its agricultural water quality grant programs. Besides the vulnerability that farmers and ranchers feel from other regulatory programs that might use the information, the requirement conflicts with USDA's conservation assistance programs and may prevent better leveraging of funds and coordination among agencies with similar goals of ALS.

Leadership

Most states maintain a State council or similar leadership and coordinating body that provide guidance to federal, State, and local programs to achieve ALS. Some have regulatory or oversight authority over local conservation work that uses State and federal funding; others simply set state goals for conservation and serve as a venue for coordination and problem-solving for State programs as well as local conservation entities, especially RCDs.

California once supported a governor-appointed Resource Conservation Commission that served primarily in the former capacity. The commission failed to keep pace with the changing paradigms of conservation, including the definition of conservation, with the move from structural solutions to bioengineering technologies. The Commission, though still authorized in statute, has ceased to operate due to a lack of funding and commissioner appointments. The California Association of Resource Conservation Districts, among others, has called for the re-creation of at least a State conservation advisory council. Based in part on the positive experience with the former CALFED Bay Delta Program Working Landscape Subcommittee, the secretaries of the California Natural Resources Agency (CNRA) and the CDFA explored the creation of a working land stewardship council made up of stakeholders and agencies to identify and pursue coordinated initiatives in support of ALS. To date, no such State leadership body exists. It is recommended that CDFA follow up on forming a council to fill this gap.

Underserved Agricultural Land Stewardship Stakeholders, Communities, and Regions

For a variety of reasons, including language barriers, the remoteness and size of communities that affect their capacity to be heard, some landowners, communities, and regions may not receive the share of ALS resources that is warranted by their ALS resource problems.

Regulatory Barriers to Agricultural Land Stewardship, the Burden of Bureaucracy, and Regulatory Assurances

There is an ongoing need for interagency coordination and alignment of policies and regulations to clarify regulatory barriers, reduce unnecessary burden of multiple bureaucracies, and provide greater regulatory assurances to landowners that complying with one agency's programs will not put them at fault with another agency's regulations. In December 2010, the California Roundtable on Agriculture and the Environment (CRAE) members reached consensus on a set of recommendations to facilitate the permitting processes for on-farm environmental restoration projects. These recommendations are detailed in the CRAE report, *Permitting Restoration: Helping Agricultural Land Stewards Succeed in Meeting California Regulatory Requirements for Environmental Restoration Projects* (see http://aginnovations.org/images/uploads/Permitting_Restoration.pdf).

Federal, State, and local regulations and permits may present crippling barriers to ALS. The issue may simply be the time, complexity, and cost of complying with regulations relative to the ALS benefits to be achieved. The issue may be the costs and bad fit of regulations resulting from the application of regulations intended for urban land uses and settings to the rural conditions of the agricultural working landscapes. In at least a few circumstances, the application of one ALS practice may place a landowner in jeopardy with another environmental protection standard. The application of a conservation practice that could result in the incidental take of listed Endangered Species Act species is one example.

Landowners often do not pursue available conservation financial assistance because of the amount of paperwork and the process that they must go through to receive funding. This issue is often a problem of striking a balance between funding accessibility and the need to be accountable to the public for the effective and legal expenditure of funds. The liability that administrators face can lead to a cumbersome bureaucracy that is not commensurate with level of assistance being offered. In addition, farmers and ranchers may have an inherent mistrust of government entities, which prevents them from participating in stewardship programs.

As previously noted, divulging personal or site-specific information to a granting agency can open a landowner to further regulatory liability. Similarly, there remains an issue that "no good deed goes unpunished" among some landowners who fear that on-farm conservation, for example, can lead to the improved health in the population of a listed species, leaving the landowner at greater risk of Endangered Species Act sanctions. If a landowner improves the protection of listed species, and the species become more abundant on their land, regulators have been known add greater restrictions onto the landowner to protect the now-abundant local population. The issue is the need for more and easier-to-employ opportunities for regulatory assurances that good conservation deeds will not be punished, but will be rewarded.

Outreach and Demonstration

Due to cutbacks in the UCCE, the NRCS Environmental Quality Incentives Program (EQIP) education and demonstration funding and authority, among other reductions in conservation programs, there are many untold success stories and how they were achieved. Too few working landowners are aware of the technical and financial assistance that is available to them. There are too few opportunities for landowners to see what their neighbors are doing to save natural resources while saving money. Farm tours, tailgate sessions, workshops, and meetings out on the working landscape are needed to spread information and inspiration. There are good examples that could be replicated with funding and staff assistance. Otherwise, insufficient outreach, education, demonstration, and storytelling opportunities are barriers to ALS.

Some examples include stories of stewardship published by the USDA NRCS, RCDs, California Farm Bureau Federation, wildlife conservation agencies and organizations like Farming for Wildlife, the California Cattlemen Association, the California Rice Commission, and the California Rangeland Conservation Coalition, to name a few. Also, there are a growing number of ALS-consistent workshops and training sessions being sponsored sporadically around the state, such as by the University of California Small Farm Program, county-level farm marketing associations such as PlacerGROWN in Placer County, the EcoFarm Conference in Asilomar each winter, the California Association of Resource Conservation Districts and member RCDs, and others.

Measuring Performance of Conservation

There is a need to develop metrics and standards to measure and evaluate the efficiency and efficacy of stewardship practices. Metrics need to balance the need for accuracy (i.e., scientifically based) and practicality so they are simple to use and are inexpensive to generate. The previously cited NRCS Conservation Effectiveness Assessment Program (CEAP) has been launched to address this need. See http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/.

Documenting Performance of Conservation

There should be a focus on the need for information that makes it clear to funding organizations and landowners that ALS practices are worth the investment, in part because the practice will clean up the water enough to meeting regulatory standards or the personal stewardship goals of the landowner. Priority for this investment has been given to practices that deliver multiple benefits and in areas of higher conservation value.

Food Safety and Co-Management

The September 2006 outbreak of *E. coli* O157:H7 in the Salinas Valley galvanized the grower community and the food processing industry to orchestrate intensive efforts to prevent crop contamination by developing and implementing rigorous food safety programs. However, some food safety programs conflict with environmental goals by targeting the elimination of wildlife and habitat, and removal or discouragement of conservation practices intended to improve and protect water quality by attenuating sediment, nutrients, and pesticides in tailwater and stormwater runoff (e.g., vegetative filters, grassed waterways, constructed wetlands, etc.). State and federal public funds have supported growers' efforts to develop farm water quality plans and implement conservation practices (e.g., Farm Bill/Environmental Quality Incentives Program, Clean Water Act — Section 319 Nonpoint Source Program grants). Many farmers are required to comply with regulatory mandates (e.g., the regional water quality control boards' Irrigated Lands Regulatory Program) and implement BMPs to reduce, control, or prevent pollution. The U.S. Food and Drug Administration is expected to promulgate federal food safety regulations in 2012, which places emphasis on the co-management of food safety and environmental requirements to avoid conflict.

Energy Crops and Climate Change

Market forces encourage growers to plant energy crops, such as corn and soybeans. While these crops have increased the farming profitability in many regions, the new cropping patterns can also lead to increased cultivation of new land, higher use of fertilizers and volatile organic carbons for pest management, and thus increasing energy use and GHG emissions. Cropping and ranching practices that sequester carbon, on the other hand, are best suited to the production of cellulosic ethanol, whose technology is not yet developed for commercial-scale use. Carbon sequestration in rice cultivation and wetland production has been demonstrated to have immediate potential benefits.

Floodplain Protection and Farming

The working landscape approach to agriculture often advocates the use of agricultural conservation easements to keep land in private ownership and management, while permanently removing the development rights from the land and altering farming and ranching practices to those compatible with floodplain management. Among the common easement restrictions is the limitation on types of crops grown to crops that will not impede flood flows or lead to excessive crop loss claims. As such, flood easements often prohibit the planting of high-value and flow-impeding permanent tree and vine crops. Farmers who may otherwise be interested in flood easements may be reticent to participate knowing that their "palette" of crops available to respond to market opportunities will be limited. Increased implementation of "flood-friendly farming" can reduce the inherent conflicts between floodway easements and reliable crop production. Additional information on floodplain protection can be found in Chapter 4, "Flood Management," in this volume.

Water Conservation and Water Rights

The conservation of water on agricultural land, depending on the nature of water contracts and rights, could result in the loss of water availability. For example, conservation of water could lead to a base of water use that may be used in the future for calculating cutbacks in water allocations.

Water Transfers

Idling of agricultural land for the temporary or permanent transfer of water or water rights is a strategy to meet urban and environmental water needs in times of shortage. This has become an increasingly normal condition with climate change and population growth. Idling of cropland can result in a degradation of soils from salt accumulation absent the leaching fraction component of irrigation, erosion, or invasive plant species. Strategies are needed that integrate water transfers with crop rotation/agronomic fallowing, and soil-building schemes that also provide conjunctive wildlife habitat benefits. Additional information about water transfers can be found in Chapter 2, “Agricultural Water Use Efficiency,” and in Chapter 8, “Water Transfers,” in this volume.

Agricultural Conservation Easements Are Forever

There is a growing awareness of the need for agricultural conservation easements to protect land from the fragmentation of agricultural landscapes into parcels that are too large to mow and too small to farm. Yet, producers often loathe giving up their future “retirement account” of subdivision potential forever. There are available ways to enable producers to use easements as an aid to financial and estate planning, but too few producers know about them. One example is the use of clustering development to gain development value income while protecting the bulk of the land for agriculture in ways that do not impede surrounding agricultural uses or exacerbate the provision of urban services by cash-strapped counties.

Farm Market and Economic Considerations

The three legs of sustainability include economic, environmental, and social equity sustainability. A growing body of environmental, labor, food safety, land use, and other regulations has increased the cost of doing business in California. Land costs have increased as demands for housing and open space compete for land. Trade liberalization and international competition from developing countries with lower labor costs and regulatory standards have driven up the prices California producers can command in the marketplace. These issues and other factors make choices to invest in ALS practices difficult. Finding market value for the environmental services that Californians demand from agriculture is one key to keeping the California working landscapes profitable and sustainable. These services include:

- Spreading floodwater during high flows.
- Settling sediment during flood flows.
- Improving wildlife habitat and recreational opportunities, scenic places, and open space.
- Harvesting renewable energy.
- Sequestering carbon and providing clean air.
- Recharging groundwater.
- Providing clean and more abundant water supplies.

Landowner Concerns

Landowners are concerned that environmental programs that help them improve habitat might attract more threatened and endangered species affecting landowners’ use of land. Thus, some landowners are reluctant to be involved with government agencies, even though some of these agencies might help landowners to comply with regulatory requirements.

Federal Endangered Species Act assurances can be granted only by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. To determine what type of species must be covered and the possible protective measures that may be required, surveys are necessary to determine what species are present. This only increases landowner concerns that they will be subject to increased restrictions if the presence of endangered species is verified on their property.

Some landowners question how they can adequately maintain their privacy and, at the same time, satisfy the public need for information of farm activities supported by public resources. In addition, there is landowner confusion regarding what type of assurances can be provided. One perspective is that the economic return from certain land stewardship programs may often be less than the return from other options for land use, especially when urban development is an option.

Lack of Information

There is a lack of scientific, economic, social, and environmental studies and monitoring of ALS programs to evaluate their merits for ecosystem restoration, water quality, and agricultural economics for large and small agricultural operations. Reports conflict about the compatibility of certain ALS and ecosystem restoration programs. Investment in research to address these issues is much needed. To justify public investment in stewardship, there must be accountability in terms of monitoring.

Complex Regulations and Programs

Institutional regulations and programs are complex and sometimes conflict. Agricultural landowners may be discouraged when developing a stewardship program for multiple purposes, such as water and soil conservation, ecosystems restoration, floodplain and wetlands management, water quality, and land use planning. The regulations may seem intrusive to the private landowner, but are essential for those government agencies and others responsible for environmental protection and restoration programs.

Federal Funding

California has received proportionately less funding traditionally from the federal Farm Bill's conservation provisions relative to its agricultural standing, the value of the threatened resources, the population served, and the interests of the landowner community. Although California farmers and ranchers provide more than 13 percent of the nation's food and fiber, historically they receive less than 3 percent of federal farm conservation funding. Commodity support programs influence stewardship management. California is dominated by specialty crops rather than traditional price-supported commodity programs. The funding inequities of the Farm Bill will become increasingly apparent in the future as production of California cotton, alfalfa, irrigated pasture, and possibly rice decreases and as production of specialty crops increases.

Regional Cooperation

The effectiveness of ALS depends on having a sufficient number of landowners implementing conservation practices within a watershed. Without regional cooperation, private landowners may be frustrated in reaching their management goals by adjacent operations or watershed activities that do not contribute to better management for environmental functions and values. These values include protecting and re-establishing riparian corridors or water quality within a watershed.

Watershed stewardship is an approach that can help build partnerships, increasing overall success of conservation practices within a watershed. Chapter 27, "Watershed Management," in this volume addresses these concepts in greater detail.

Public Perception of State Policy Goals

In general, land use is a local planning issue subject to local regulation. Statewide planning goals or restrictions may be seen as an intrusion on local governmental powers. When there is a conflict between private property and public commitments, many landowners prefer such programs as the Williamson Act because these are temporary land-use restrictions from which landowners can ultimately "opt out," if they later decide to sell land to development and the asking price justifies the cancellation penalty. As a result, many landowners are wary that they may lose future economic opportunities by committing to permanent restrictions. Likewise, the public may be unwilling to fund the necessary incentive (e.g., rental, technical assistance) programs essential to successful stewardship without a clear understanding of long-term benefits from such programs.

Changing Demographics of Farmers and Farms

As agricultural land stewards age, and lacking a new generation of farmers to take the reins, there is a shift away from mid-sized farms toward large and small farms; the former sometimes held and managed by commercial interests with non-resident managers, and the latter being a collection of smaller boutique farming operations. Meanwhile, mid-size, owner operated farms are vanishing. At the same time, some farming families are diversifying, creating a vertical integration of production, processing, packaging, marketing, with the new generation filling both the administrative and farming roles.

Recommendations to Promote and Facilitate Agricultural Land Stewardship

I. Recommendations for State Action

A. Institutional and Leadership Recommendations

1. The secretaries of the CNRA and the CDFA, in consultation with the California State Board of Food and Agriculture, U.S. Environmental Protection Agency, U.S. Department of Interior, USDA, U.S. Department of Commerce, and the National Oceanic and Atmospheric Administration, should assess ALS assistance, information and regulatory programs, their effectiveness, and level of coordination. The performance measure is the completion of the assessment report that addresses the issues listed below.

    A. The assessment should address the need for better coordination between regulatory and assistance programs, as well as between assistance and information programs, of State and federal agencies. Recommendations should include mechanisms for improving coordination among State assistance programs, and opportunities for leveraging State, federal, and local resources to address ALS issues on a local and regional basis. Recommendations should also address ways for voluntary assistance programs to help producers better meet State resource regulatory mandates. The latter recommendations should include actions for better coordination between State and federal assistance and regulatory programs.

B. The assessment should address the need for a statewide ALS leadership and coordination entity, such as a governor-appointed council or re-establishing the former Resource Conservation Commission.

C. Measures to ensure implementation of findings should be included in assessment mandate.

D. State and federal agencies should work with stakeholders to develop and implement payments for ecosystem services programs that compensate landowners for their stewardship while reducing the cost of regulatory compliance and delivering measurable conservation benefits

B. Regulatory and Process Recommendations

2. State funding and staff should be made available through collaboration with the USDA NRCS, State RCDs, and appropriate non-profit conservation organizations to develop a one-stop shop for local and regional-level permit coordination and assistance programs. The California Environmental Protection Agency and the CNRA should implement this recommendation through use of bond funds, redirection of staff, and use of existing local capacity-building programs, such as the Department of Conservation's Watershed Coordinator Program. This recommendation should be implemented immediately. Performance measures include reduced cost, time, and liability for landowners to implement ALS practices and strategies.

3. State resource protection regulations should be amended to allow qualified third-party verification that grant funding to assist landowners in complying with regulations is spent appropriately and effectively. Regulations should also be amended to support collection of monitoring data in a manner that protects landowner confidentiality and enables federal participation in conservation actions that assist with regulatory compliance and the development of data on the effectiveness of ALS practices. Regulatory agencies, particularly the California Air Resources Board (ARB), the regional water quality control boards, and the California Department of Fish and Wildlife should assess regulations and the need for amendments in the near-term, and propose changes for mid-term achievement of this recommendation. Performance measures would include greater State and federal collaboration in assisting landowners in meeting regulatory requirements, providing sufficient data on the effectiveness of ALS practices in meeting resource protection regulatory requirements, and an increased level of participation among private landowners in State grant programs intended to assist regulatory compliance.

4. The CNRA is facilitating the development of the BDCP and the California Department of Fish and Wildlife's Natural Community Conservation Plan to provide regulatory assurances and incidental take permits for water agencies to pump water from the Delta while also implementing a conservation plan to protect Endangered Species Act-listed fish species. The CNRA and CDFA should offer similar leadership as needed to implement Integrated Regional Water Management Plans where ALS is a key component of the regional plans. This is a mid-term recommendation pending adequate staff resources and bond funding availability. A performance measure would be increased implementation of ALS practices that improve terrestrial and aquatic habitat and species diversity.

5. Responses should be integrated with regard to the overlap of existing and forthcoming regulations on climate change, flood control, air and water quality, biodiversity protection, etc., to achieve greater compliance and efficiencies.

C. Financial and Technical Assistance Recommendations

6. A partnership between the CNRA, the CDFA, and the USDA NRCS should be formalized to build on existing needs assessments to perform a gap analysis of ALS needs and existing program resources to meet them. The analysis would become the basis for developing a strategy for the use of existing and new bond measure funding, existing General Fund conservation programs, and federal conservation programs to fill the identified gaps. The analysis and strategic funding plan should be conducted under the leadership structures recommended in 1A above. The analysis and strategy should be conducted pursuant to an executive directive or via a legislative proposal, or both, immediately with results provided before the next California Water Plan update. The performance measures would be increased funding for ALS top priority resource issues, increased State and federal coordination of funding, and better information on which to allocate available funding to meet the most important ALS needs of California.

7. The CNRA, the CDFA, and the California Environmental Protection Agency should establish a Farm Bill Interagency Agreement under which California establishes an ongoing presence in the debate over conservation provisions of reauthorized Farm Bills, and in the annual appropriations of funding for conservation to meet the needs of California as identified by the assessment and strategy of recommendation (6), above. This recommendation should be carried out after consultation with the NRCS, appropriate farm and conservation interest groups, and non-profits. In this spirit, a collaborative, interagency letter was prepared and submitted regarding the pending 2012 Farm Bill.

8. The governor should establish a coordinated conservation easement acquisition program based on a preference for maintaining working land in private ownership by using conservation easements. Currently, there are a number of State and federal easement programs for wildlife, agricultural land, grasslands, forestlands, floodplains, and scenic and recreational open space. These programs need better coordination to ensure that the highest priority resource lands are protected and that the protected lands are conserving multiple values simultaneously. The funding gap analysis and strategic plan should include an identification of needs for resource land acquisition programs and seek State bond and federal farm, highway, and wildlife easement funding to acquire the highest priority agricultural land (among other types of land), which would also help to accomplish drought preparedness and flood management goals. This executive action should occur immediately, tied with the implementation of recommendation 6 above.

9. Funding for ALS programs should be made available on a voluntary participation basis, but with funding allocation based on priority conservation needs (recommendation 6 above) and regulatory compliance needs. Financial and technical assistance should be in the form of grants, cost-share, regulatory relief, and tax incentives. Most financial and technical assistance should be contingent on a meaningful and feasible level of landowner contributions.

10. Relevant agencies should explore the feasibility of a coordinated statewide effort to develop on-farm irrigation ponds that provide offstream capture of winter stormwater for summer

use. Evaluate current pilot pond projects, obstacles to broader adoption, and benefits for economic viability, local water supply, watershed management, flood control, groundwater recharge, mitigation of climate change, wildlife habitat, etc. Pilot projects for these efforts have been investigated by the California Roundtable for Water and Food Supply, as well as the California Roundtable for Agriculture and the Environment. Sustainable Conservation is one group that has been a leader in carrying out pilot projects (e.g., Pine Gulch Creek in west Marin County).

D. Data and Research Recommendations

11. The USDA's Agricultural Resource Service, UCCE, and the USDA Economics Research Service should conduct cost-benefit analyses for ALS practices, in particular for new and emerging strategies such as keylines and dry farming. California government leaders should request that funding be directed or appropriated from the federal and State budgets to conduct such research. This is essential research for effectively spending limited conservation assistance funding. Further, if a regulatory approach to working landscapes natural resource issues is intended to be collaborative, depending on conservation planning and the use of certified BMPs, regulators should ensure that practices employed to improve water and air quality or improve biodiversity are documented as effective. Recently, the University of California, Davis, and the USDA NRCS have collaborated to document the costs and benefits of conservation tillage systems. This research should be implemented immediately. Performance measures should include increased confidence in ALS practices as exemplified by greater State and federal funding to support their use by growers, and increased use of certification programs to assist growers in complying with environmental regulations.

12. Agricultural, conservation, and food safety organizations and agencies should continue to identify and support needed research on the causes of food contamination to determine the extent to which ALS practices may play a role in causing or resolving the contamination. When research identifies food contamination risks from conservation practices, further research should be supported to adapt existing or develop alternative conservation practices that protect water and air quality, for example, while lowering the risk to food safety. Identification of research needs should be continued under the leadership of the University of California and industry and there should be funding found immediately to support research and extension. Performance measure should include both known risks and known benefits of common conservation practices, and should measure increased, widespread adoption of conservation practices that contribute to food safety.

13. The USDA, CDFA, California Energy Commission, ARB, and other agencies should support research of ALS practices and strategies with respect to net GHG emissions and carbon sequestration, including the cultivation of alternative biofuel crops and use of agricultural residues. This research should be conducted immediately for application to ALS practices by the next California Water Plan update. Performance measures are the application of ALS practices that reduce GHG emissions and increase carbon retention in the soil.

14. Periodic inventory of soil organic carbon content can be performed with existing technologies. DWR should partner with the CDFA and the ARB to develop a program employing these technologies. Performance measures are protocols and a program to measure soil organic carbon content.

E. Climate Change

15. Recommendations of the Agricultural Working Group of the Climate Action Team (AgCAT) should be incorporated into financial and technical assistance programs, particularly those of the Farm Bill's conservation programs. Assistance programs should support only agricultural practices and crop systems that result in lower GHG emissions as determined by a life-cycle analysis of the carbon budget of a practice. For additional information, see the AgCAT page of the Climate Action Team Web site (http://www.climatechange.ca.gov/climate_action_team/agriculture.html).

F. Floodplain Management and Agricultural Land Stewardship

16. The Legislature and Congress should appropriate bond and Farm Bill funding, respectively, to continue floodplain protection easement programs that allow conjunctive agricultural uses. This should allow as much flexibility for crop selection under easement agreements as possible to avoid limiting grower response to market signals, thereby limiting farming profitability. At the same time, growers should assume the risk of growing high value, permanent crops on flood easement-restricted cropland. The latter recommendation may require immediate changes to statutory or regulatory rules affecting floodplain easement programs. Performance measure is increased participation by growers in floodplain corridor protection grant programs. Chapter 4, "Flood Management," in this volume provides additional details about this topic.

G. Water Conservation, Water Rights, and Water Transfers

17. State and federal water providers should reward conservation by their customers through the use of conservation incentives in water delivery contracts, such as by increasing the water delivery priority to those producers practicing water conservation and ALS measures.

18. DWR and U.S. Bureau of Reclamation should establish a water transfer oversight entity that ensures water transfers do not result in a long-term negative impact on the state's food production capacity, or have an adverse impact on rural community economics. The protection of soil health and enhancement of wildlife habitat should be considerations in approving water transfers. For example, temporary crop idling for water transfers should be designed to contribute to a crop rotation system that includes fallowing to build soil moisture and organic carbon content, and to provide conjunctive wildlife habitat for such species as the giant garter snake (*Thamnophis gigas*). Transfers should reserve sufficient water on transferring land in order to establish a cover crop. Performance measures are acres of land in rotational conservation fallow programs, and the amount of water not used (saved) for those acres during fallow periods.

H. Education, Demonstration, and Outreach

19. The federal Farm Bill should be amended, and appropriations should be made to support a return to farmer-to-farmer education, demonstration, and outreach on successful conservation programs. The Environmental Quality Incentives Program once included funding for such work. This authority and needed funding should be returned to the NRCS as part of its conservation operations and technical assistance budgets. Every Farm Bill conservation program should include funding to document not only program effectiveness, but also to

share information about the programs and their supported practices with other growers through educational materials, field demonstrations, and workshops. This recommendation should be implemented immediately in the near- and long-term as USDA's budget appropriations are made each year, and as Farm Bill reauthorizations occur every five or so years. Although current demand is about three times the amount of current funding, performance measures for this recommendation would be greater demand for USDA's conservation program funding and technical assistance, and greater awareness among working landowners of conservation programs.

20. State grants that support ALS should likewise include a requirement that each grantee document project success and share lessons learned and successes with other growers and granting agency managers. This recommendation should be implemented, as bond authorities allow, immediately. As with demand for federal funding, current demand for State grants exceeds available resources. Performance measures for this recommendation would be greater demand among stakeholders and agencies for funding of effective ALS practices and strategies, and the requirement that such funding includes funding for demonstration and outreach.

21. The Department of Conservation Farmland Conservancy Program's funding for planning grants should be expanded in support of recommendations 22 and 23 below. The Governor's Office should work with the Legislature to acquire bond measure appropriations that support the Farmland Conservancy Program, specifically for its planning grants. This recommendation should be implemented immediately and in the long term as new bond measures are placed on the ballot. See the performance measure for recommendation 22.

22. The CDFA and the Department of Conservation should seek funding to support an interagency technical outreach team to facilitate the transfer of technology with respect to agricultural land protection via agricultural conservation easements. The team would work with county planners and agricultural commissioners by sharing information on innovative farmland protection programs and ordinances in other counties. The team would also educate landowners about the tax relief, estate planning, and other benefits of agricultural conservation easement. This recommendation could be implemented immediately through an interagency agreement and a minor reallocation of staff resources. Performance measures for this recommendation would be transfer of successful agricultural land protection programs to other counties, and a greater demand for agricultural conservation easements and the funding to purchase them.

II. Recommendations for Local Action

23. Integrated regional water management plan (IRWMP) applications for funding should embody ALS components where the region addressed by the plan includes agricultural land. Criteria, incentives, and education should focus on these goals. This recommendation should be implemented immediately, if it has not already. Performance measure involves IRWMPs being comprehensive and integrated, and containing supportive ALS measures and strategies, where appropriate.

24. Where appropriate, cities and counties should consider adding agricultural land preservation policies to their general plans and designating supportive agricultural districts that enhance ALS on high-priority, productive agricultural land. These districts should focus on regulatory assistance through county agricultural ombudsmen. These districts should also be the focus

of local agricultural infrastructure investment, marketing assistance, and the development of ALS practices and strategies in cooperation with local, State, and federal agricultural conservation entities. Districts should also be the focus of land protection instruments, such as the Williamson Act, and agricultural conservation easements. Other strategies to enhance agricultural resources locally should engage such resource organizations as RCDs, the American Farmland Trust, and Ag Futures Alliances (via Ag Innovations Network), and be integrated with IRWMP and habitat conservation plans, where appropriate. This recommendation should be implemented over the long term as each county general plan is updated. Performance measure is the number of general plans that include comprehensive plans for sustaining local agricultural working landscapes.

25. Local entities should look for alternative sources of funding for ALS, such as payments for watershed services.

References

References Cited

Briske DD (editor) 2011. *Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps*. Washington (DC): United States Department of Agriculture, Natural Resources Conservation Service. 429 pp. Viewed online at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?&cid=stelprdb1045811.

California Department of Conservation. 2008. *California Farmland Conversion Report 2006-2008*. Sacramento (CA): California Department of Conservation, Division of Land Resource Protection. Farmland Mapping and Monitoring Program. 108 pp. Viewed online at: http://www.consrv.ca.gov/dlrp/fmmp/Documents/fmmp/pubs/2006-2008/fcr/FCR%200608_intro.pdf

California Department of Forestry and Fire Protection. 2010. *California's Forests and Rangelands: 2010 Assessment.* Sacramento (CA): California Department of Forestry and Fire Protection Fire and Resource Assessment Program. 353 pp. Viewed online at: http://frap.fire.ca.gov/assessment2010/pdfs/california_forest_assessment_nov22.pdf.

California Department of Water Resources. 2008. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water*. Sacramento (CA): California Department of Water Resources. 34 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf.

California Roundtable on Agriculture and the Environment. 2010. *Permitting Restoration: Helping Agricultural Land Stewards Succeed in Meeting California Regulatory Requirements for Environmental Restoration Projects*. Sebastopol, (CA): Ag Innovations Network. California Roundtable on Agriculture and the Environment. 20 pp. Viewed online at: http://aginnovations.org/images/uploads/Permitting_Restoration.pdf.

California Roundtable on Water and Food Supply. 2012. *From Storage to Retention: Expanding California's Options for Meeting Its Water Needs*. Sebastopol, (CA): Ag Innovations Network. California Roundtable on Water and Food Supply. 20 pp. Viewed online at: http://aginnovations.org/images/uploads/CRWFS_Storage_to_Retention.pdf.

Additional References

Abberton M, Conant R, Batello C, editors. 2010. Grassland carbon sequestration: management, policy and economics Proceedings of the Workshop on the role of grassland carbon sequestration in the mitigation of climate change. April 2009. Rome, Italy. Food and Agriculture Organization of the United Nations. 342 pp. Viewed online at: http://www.fao.org/docrep/013/i1880e/i1880e.pdf. Accessed: March, 2012.

Allen-Diaz B, Standiford R, Jackson RD. 2007. "Oak woodlands and forests." In: Barbour MG, Keeler-Wolf T, Schoenherr AA, editors. *Terrestrial Vegetation of California*. Berkeley (CA): University of California Press. pp. 313-338.

American Farmland Trust. 2009. Washington (DC): [Web site.] Viewed online at: http://www.farmland.org/. Accessed: Dec., 2009.

Barrett RH. 1980. "Mammals of California oak habitats--management implications." In: *Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks*. USDA Forest Service General Technical Report PSW-44. pp. 275-291.

Bay-Delta Habitat Conservation Plan. 2009. Sacramento (CA): [Web site.] Viewed online at: http://baydeltaconservationplan.com/Home.aspx. Accessed: Dec., 2009.

Bio-Business Support Services. 2009. Charlottesville (VA): [Web site.] Viewed online at: http://privatelands.org/bio/contents.htm. Accessed Nov., 2009.

Briske, DD., editor. 2011. Conservation Benefits of Rangeland Practices: Assessment, Recommendations, and Knowledge Gaps. United States Department of Agriculture, Natural Resources Conservation Service. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/ceap/?&cid=stelprdb1045811.

California Agricultural Water Stewardship Initiative. 2009. Sebastopol (CA): [Web site.] Viewed online at: http://agwaterstewards.org/txp/index.php. Accessed: Nov., 2009.

California Association of Resource Conservation Districts. 2009. Sacramento (CA): [Web site.] Viewed online at: http://www.carcd.org/. Accessed: Dec., 2009. California Department of Conservation. 2006. California farmland conversion report 2002-2004. Sacramento (CA): California Department of Conservation, Division of Land Resource Protection. Farmland Mapping and Monitoring Program. 104 pp. Viewed online at: http://www.conservation.ca.gov/dlrp/fmmp/pubs/2002-2004/Pages/FMMP_2002-2004_FCR.aspx.

California Department of Conservation. 2009. "The Williamson Act." Sacramento (CA): Division of Land Resource Protection. [Web site.] Viewed online at: http://www.conservation.ca.gov/dlrp/Pages/Index.aspx. Accessed: Nov., 2009.

———. 2009. Watershed Coordinator Grant Program. Sacramento (CA): Division of Land Resource Protection. [Web site.] Viewed online at: http://www.conservation.ca.gov/dlrp/wp/grants/Pages/wcgp_intro.aspx. Accessed: Dec., 2009.

———. 2009. Resource Conservation District Assistance. Sacramento (CA): Division of Land Resource Protection. [Web site.] Viewed online at: http://www.conservation.ca.gov/dlrp/rcd/Pages/Index.aspx. Accessed: Dec., 2009.

———. 2009. California Farmland Conservancy Program. Sacramento (CA): Division of Land Resource Protection. [Web site.] Viewed online at: http://www.conservation.ca.gov/dlrp/cfcp/Pages/Index.aspx. Accessed: Dec., 2009.

California Department of Fish and Wildlife. 2009. Sacramento (CA): Natural Community Conservation Planning (NCCP). [Web site.] Viewed online at: http://www.dfg.ca.gov/habcon/nccp/. Accessed: Dec., 2009.

California Department of Food and Agriculture. 2009. Programs and services. Sacramento (CA): Web site. [Web site.] Viewed online at: http://www.cdfa.ca.gov/Programs.html. Accessed: Nov., 2009.

California Department of Water Resources. 2005. *California Water Plan Update 2005*. Volume 2, "Resource Management Strategies", Chapter 2, "Agricultural Lands Stewardship." Sacramento (CA): California Department of Water Resources.

California Floodplain Management Task Force. 2002. *California Floodplain Management Report*. Sacramento (CA): California Floodplain Management Task Force. California Department of Water Resources. Report No. 29.79 pp. [Web site.] Viewed online at: http://www.water.ca.gov/floodmgmt/lrafmo/fmb/fas/specialprojects/taskforce.cfm.

California Green Solutions. 2009. "Solutions For Green." Los Angeles (CA): [Web site.] Viewed online at: http://www.californiagreensolutions.com/. Accessed: Nov., 2009.

Cheatum M, Casey F, Alvarez P, Parkhurst B. 2011. *Payments for ecosystem services: A California rancher perspective*. Washington (DC): Conservation Economics [White paper.] Conservation Economics and Finance Program. Defenders of Wildlife. 65pp.

Cochrane WW. 1993. *The Development of American Agriculture: A Historical Analysis*. 2nd edition. Minneapolis (MN): University of Minnesota Press. 500 pp.

Conant RT, Paustian K, Elliott ET. 2001. "Grassland management and conversion into grassland: Effects on soil carbon." Ecological Applications 11(2): pp. 343–355.

Dahlgren RA, Singer MJ, Huang X. 1997. Oak tree and grazing impacts on soil properties and nutrients in a California oak woodland. Biogeochemistry 39: pp.45-64.

Derner JD, Schuman GE. 2007. Carbon sequestration and rangelands: A synthesis of land management and precipitation effects. Journal of Soil and Water Conservation 62(2): pp. 77-85.

Ecological Farming Association. 2009. Soquel (CA): EcoFarm Conference. Ecological Farming Association. [Web site.] Viewed online at: http://www.eco-farm.org/programs/efc/. Accessed: Dec., 2009.

Gamekeepers - Farming for Wildlife. 2009. West Point (MS): Mossy Oak - Haas Outdoors Inc. [Online magazine.] Viewed online at: http://farmingforwildlife.com/. Accessed: Dec., 2009.

Garrison B, Standiford RB. 1996. "Oaks and habitats of the hardwood rangeland." In: Standiford RB and Tinnin P, editors. *Guidelines for Managing California's Hardwood Rangelands*. Publication no. 3368. Oakland (CA): University of California Division of Agriculture and Natural Resources.

Governor's Office of Planning and Research. 2003. *General Plan Guidelines Update*. Sacramento (CA): Governor's Office of Planning and Research. 290 pp. Viewed online at: http://www.opr.ca.gov/index.php?a=planning/gpg.html.

Johnston WE, McCalla AF. 2004. "A Stylized History of California Agriculture from 1769 to 2000." In: Section II Whither California Agriculture: Up, Down or Out? Some Thoughts About the Future. Berkeley (CA): University of California, Giannini Foundation of Agricultural Economics. 15 pp. Special Report 04-1. Viewed online at: http://giannini.ucop.edu/calag.htm.

Keyline Designs. 2009. Keyline Designs. Queensland (Australia): [Web site.] Viewed online at: http://www.keyline.com.au/. Accessed Nov., 2009.

Kresge L, Mamen K. 2009. *California Water Stewards: Innovative On-farm Water Management Practices*. Davis (CA): California Institute for Rural Studies. 27 pp. Viewed online at: http://www.cirsinc.org/index.php/publications/current-publications.html.

Kroeger T, Casey F, Alvarez P, Cheatum M, Tavassoli L. 2010. *An economic analysis of the benefits of habitat conservation on California rangelands*. Washington (DC): Conservation Economics [White paper.] Conservation Economics Program. Defenders of Wildlife. 91 pp.

Lewis DJ, Atwill ER, Lennox MS, Pereira MDG, Miller WA, Conrad PA, Tate KW. 2010. "Management of microbial contamination in storm runoff from California coastal dairy pastures." Journal of Environmental Quality. 39: pp. 1782–1789.

———. 2009. "Reducing microbial contamination in storm runoff from high use areas on California coastal dairies." Water Science and Technology. 60: pp. 1731-1743.

Lewis DJ , Tate KW, Harper JM. 2000. *Sediment Delivery Inventory and Monitoring: A Method for Water Quality Management in Rangeland Watersheds*. Oakland (CA): Publication 8014. University of California Division of Agriculture and Natural Resources.

Lewis DJ, Atwill ER, Lennox MS, Hou L, B. Karle B, Tate KW. 2005. "Linking on-farm dairy management practices to storm-flow fecal coliform loading for California coastal watersheds." Environmental Monitoring and Assessment. 107: pp. 407-425.

Lewis DJ, Tate KW, Harper JM, Price J. 2001. "Survey identifies sediment sources in North Coast rangelands." California Agriculture. 55(4):32-38

Lewis DJ, Singer MJ, Dahlgren RA, Tate KW. 2000. "Hydrology in a California oak woodland watershed: A 17-year study." Journal of Hydrology. 230: pp. 106-117.

———. 2000. "Applicability of SCS curve number method for a California oak woodland watershed." Journal of Soil and Water Conservation. 55: pp. 226-230.

Majanen T, Friedman, Milder JC. 2011. *Innovations in Market-based Watershed Conservation in the United States*. Washington (DC): EcoAgriculture Partners. 42 pp. Viewed online at: http://www.ecoagriculture.org/publication_details.php?publicationID=362. Accessed: March, 2012.

Marin Carbon Project. 2009. Nicasio (CA): [Web site.] Viewed online at: http://www.marincarbonproject.org/. Accessed: Nov., 2009.

National Governors Association/Center for Best Practices. 2001. *Private Lands, Public Benefits: Principles for Advancing Working Lands Conservation*. Washington (DC): National Governors Association Center for Best Practices. 57 pp. Viewed online at: http://www.nga.org/files/live/sites/NGA/files/pdf/01022PRIVATELANDS.pdf.

Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP). 2009. Washington (DC): U.S. Department of Agriculture, Natural Resources Conservation Service. [Web site.] Viewed online at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/. Accessed: Dec., 2009.

Natural Resources Conservation Service Conservation Effectiveness Assessment Program (CEAP). 2011. Washington (DC): U.S. Department of Agriculture, Natural Resources Conservation Service. [Web site.] Viewed online at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap. Accessed: Feb., 2012.

National Sustainable Agriculture Information Service. 2009. Fayetteville (AR): National Center for Appropriate Technology. [Web site.] Viewed online at: http://attra.ncat.org/intern_handbook/water_harvest.html. Accessed: Nov., 2009.

Pineiro G, Paruelo JM, Oesterheld M, Jobbagy EG. 2010. “Pathways of grazing effects on soil organic carbon and nitrogen.” Rangeland Ecology and Management. 63: pp. 109–119.

PlacerGROWN. 2009. Placer County (CA): [Web site.] Viewed online at: http://www.placergrown.org/. Accessed: Dec., 2009.

Runsten D. 2010. *Why Water Stewardship for Agriculture?* Somis (CA): California Agricultural Water Stewardship Initiative. Ventura County Resource Conservation District. Viewed online at http://www.vcrcd.org/PDFs/WhyWaterStewardshipfor%20Ag.pdf.

Silver WE, Ryals R, Eviner V. 2010. “Soil carbon pools in California’s annual grassland ecosystems.” Rangeland Ecology and Management. 63: pp.128–136.

State Water Resources Control Board. 1995. *California Rangeland Water Quality Management Plan*. Sacramento (CA): State Water Resources Control Board. Division of Water Quality Nonpoint Source Program. 75 pp.

Sustainable Conservation. 2012. San Francisco (CA): [Web site.] Viewed online at: http://suscon.org/pir/pirreport/PIRreport.php. Accessed Feb., 2012.

University.of California Small Farm Program. 2009. Davis (CA): University of California Cooperative Extension, Division of Agriculture and Natural Resources. Viewed online at: http://www.sfc.ucdavis.edu/. Accessed December 2009.

U.S. Environmental Protection Agency. 2009. National Agricultural Center (Ag Center). Washington (DC): [Web site.] Viewed online at: http://www.epa.gov/agriculture/agctr.html. Accessed: Nov., 2009.

USDA Natural Resources Conservation Service. 2009. Electronic Field Office Technical Guide (eFOTG) County Locator (interactive map of California counties). [Web site.] Viewed online at: http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=CA. Accessed Dec., 2009.

Verner J. 1980. “Birds of California Oak Habitats — Management Implications.” In: *Proceedings of the Symposium on the Ecology, Management, and Utilization of California Oaks*. USDA Forest Service General Technical Report PSW-44 . pp. 246-264.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 22

Ecosystem Restoration

Cookhouse Meadow, Sierra Nevada Mountains. In 2005, the U.S. Forest Service initiated a restoration project at Cookhouse Meadow, off State Route 89, redirecting 2,300 feet of creek to restore health to 125 acres of surrounding ecosystem by bringing back wetter perennial plants, attracting migratory birds, and reducing erosion.

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Chapter 22. Ecosystem Restoration

Ecosystem restoration improves the condition of California's modified natural landscapes and biological communities to provide for their sustainability and for their use and enjoyment by current and future generations. Few, if any, of California's ecosystems can be fully restored to their pre-development condition. Instead, efforts focus on rehabilitation of important elements of ecosystem structure and function. Successful restoration increases the diversity of native species and biological communities and the abundance of habitats and connections between them. This can include reproducing natural flows in streams and rivers, curtailing the discharge of waste and toxic contaminants into water bodies, controlling non-native invasive plant and animal species, removing barriers to fish migration in rivers and streams, and recovering wetlands so that they can store floodwater, recharge aquifers, filter pollutants, and provide habitat.

Overview

This strategy focuses on restoration of aquatic, riparian, and floodplain ecosystems because they are the natural systems most directly affected by water and flood management actions, and are particularly vulnerable to the impacts of climate change. Today, water and flood planning must prevent ecosystem damage and reduce long-term maintenance costs. Future water and flood management projects that fail to protect and restore their ecosystems will face reduced effectiveness, sustainability, and public support.

Restoration generally emphasizes recovery of at-risk species and natural communities, usually those whose abundance and geographic range have greatly diminished. These include several fishes, such as delta smelt, longfin smelt, green sturgeon, Chinook and coho salmon, and steelhead rainbow trout. Also included are riparian and wetland habitats and their member species, including valley elderberry longhorn beetle, giant gartersnake, and several migratory bird species. Successful restoration of aquatic, riparian, and floodplain species and communities ordinarily depends upon at least partial restoration of the physical processes that are driven by water. These processes include the flooding of floodplains, the natural patterns of erosion and deposition of sediment, the balance between infiltrated water and runoff, and substantial seasonal variation in stream flow. Another barrier to ecosystem restoration — displacement of native species by exotics — often results from the diminution of these same physical processes.

As an example, nearly all California waterways are controlled to reduce the natural seasonal variation in flow. Larger rivers are impounded to capture water from winter runoff and spring snowmelt and release it in the dry season. Many naturally intermittent streams have become perennial, often from receipt of urban wastewater discharges or from use as supply and drainage conveyances for irrigation water. The Sacramento-San Joaquin Delta (Delta) has become more like a year-round freshwater lake than the seasonally brackish estuary it once was. In each case, native species have declined or disappeared. Exotic species have become prevalent, often because they are better able to use the greater or more stable summer moisture and flow levels than are the drought-adapted natives.

Current Activities

Many important restoration efforts that affect water and flood management occur throughout California and are performed by public agencies, private agencies, non-profits, volunteers, or a combination of all the above. Some examples appear below.

The first example of recovery and restoration planning is in the Delta, where several efforts are under way. Water users are seeking to secure long-term assurances for Delta exports by formulating a Bay Delta Conservation Plan (BDCP). BDCP will identify how to improve the design and operation of the State and federal water projects and restore and manage habitats in the Delta. Once adopted, the BDCP will be implemented over a 50-year period. The Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act) established a Delta Stewardship Council, which has developed and adopted a Delta Plan. State and local agency actions related to the Delta must be consistent with the Plan. The Delta Reform Act also required the State Water Resources Control Board (SWRCB) to develop flow criteria for the Delta ecosystem. The Board approved a staff report on development of flow criteria in August 2010 and submitted it to the Delta Stewardship Council.

Another example of restoration planning is the Central Valley Project Improvement Act (CVPIA) of 1992, which mandates changes in the management of the Central Valley Project, particularly for the protection, restoration, and enhancement of fish and wildlife. One component of the CVPIA is the Anadromous Fish Restoration Program (AFRP). The AFRP has a goal of at least doubling the natural production of anadromous fish in Central Valley streams. AFRP has helped implement nearly 200 projects to restore natural anadromous fish production.

A third example is the Central Valley Joint Venture (CVJV), which protects, restores, and enhances wetlands and associated habitats for waterfowl, shorebirds, and songbirds in the Central Valley through partnerships among conservation organizations, government agencies, and private landowners. The CVJV Implementation Plan focuses on wetlands and the values they provide to birds. It contains Central Valley-wide objectives, expressed as acres of habitat of seasonal and semi-permanent wetlands, riparian areas, rice cropland, and other waterfowl-friendly agricultural crops.

Fourth, the Southern California Wetlands Recovery Project, chaired by the California Natural Resources Agency and supported by the Coastal Conservancy, works to acquire and restore wetlands, watersheds, and streams in coastal Southern California. The aim is to reestablish a mosaic of fully functioning wetlands with a diversity of habitat types and connections to uplands to preserve self-sustaining populations of species. About 120 projects are in-process or are completed, with more than 2,700 acres acquired and protected and more than 800 acres enhanced or restored. These include Tijuana Estuary, South San Diego Bay National Wildlife Refuge, the Bolsa Chica and Ballona wetlands, and the Santa Clara River Parkway.

The final example is the Santa Ana River Watershed Program that successfully integrates habitat restoration and endangered species recovery with flood control, groundwater recharge, and water quality improvement. Prado Dam is a key component, serving both flood protection and water storage. There is a habitat area upstream of the dam that has expanded over the last 20 years to support both the largest patch of riparian forest and the largest number of the endangered Bell’s vireo (a songbird) in Southern California. The invasive giant reed (arundo) displaces native vegetation along the river, impedes flow during floods, and is a heavy water user. An aggressive program of giant reed removal serves to improve habitat for the vireo, reduce flood risk, and recover more water. The river is the main source of recharge for the Orange County Groundwater basin and consists mainly of treated wastewater from upstream cities. Constructed wetlands remove nitrogen from river water.

Potential Benefits

Provision of Ecosystem Services

California rivers and their associated floodplain ecosystems provide numerous public and private benefits that can be thought of as goods and services. These include water purification, groundwater recharge, erosion control, storage of floodwaters, hydropower generation, soil-building, pollination, wood products, carbon sequestration (greenhouse gas mitigation), fisheries, wildlife, and recreation.

Market opportunities for nature's services, often called "payments for ecosystem services", are contracts negotiated with landowners to manage land and water so as to maintain or enhance the specified services. A new direction in efforts to protect and restore ecosystems is to develop those markets. Numerous pilot projects are under way in California and elsewhere. These typically involve collaboration among diverse interests, agreement on a geographic boundary, identification of management practices, and – often the hardest step – economic valuation of the benefits derived from the practices. The projects also must identify beneficiaries and establish mechanisms for them to pay for the goods and services they receive.

Estimation of the monetary value of nature's services can be important information for resource managers who normally see only the costs of ecosystem protection, but not the benefits, in their budgets. Examples of current and emerging projects appear in Volume 2, *Regional Reports*, and include the following: farming for carbon capture and land subsidence reversal on islands in the Delta; forest, water, and fire management in the Mokelumne River watershed; mountain meadow improvement in the Sierra and Cascades; and natural resource management in the Santa Ana River watershed.

A recent initiative by the California Department of Conservation and the Environmental Defense Fund (the "Conservation Pivot") assesses the policy framework that supports conservation on farms and ranches. It concludes that broader use of economic incentives to measure and produce ecosystem services on privately owned lands is the key, both to protecting farms and ranches and to preserving and enhancing nature's services, in the face of population growth, infrastructure demands, and climate change.

Reliability of Water Supply

As ecosystem restoration actions help increase the abundance of endangered species and fewer Endangered Species Act conflicts should occur, particularly in the Delta. These conflicts repeatedly disrupt water supplies. Thus, one result of ecosystem restoration should be a more reliable water supply.

An example of a more direct water supply benefit is the restoration of meadows that occur in the headwaters of rivers and streams. Meadows have wide, shallow vegetated channels that spread flood peaks across the meadow floodplain and recharge the underlying aquifer. In contrast, gully erosion drains groundwater stored in meadows and eliminates meadow wetlands. Meadow restoration reverses gully erosion and returns the vegetation to wetland and riparian forms. The U.S. Forest Service estimates that meadow restoration in national forests in the Sierra Nevada could add 50,000 to 500,000 acre-feet of groundwater storage per year. See Chapter 23, "Forest Management," in this volume for further discussion.

Water Quality

The numerous ways that natural ecosystems contribute to water quality improvement are described in other resource management strategies in this volume. For the role of wetlands and riparian forests in filtering contaminants from runoff, see Chapter 18, "Pollution Prevention," and Chapter 23, "Forest Management." Chapter 23 describes the role of forests in preventing erosion and subsequent sedimentation of streams. Finally, Chapter 27, "Watershed Management," explains that drinking water drawn from forested land requires less treatment than water derived from agricultural or developed land because it is less contaminated.

Sustainability

Water and flood management projects that incorporate ecosystem restoration are likely to be more sustainable than those that do not. Projects are more sustainable (that is, they operate as desired with less maintenance effort) when they work with, rather than against, natural processes that distribute water and sediment. Including ecosystem restoration in a project usually requires a return to more natural patterns of erosion, sedimentation, flooding, and instream flow, among others. This, in turn, makes such projects more resistant to disruption by the natural processes, which makes these projects easier to maintain. As expected, cost savings over the life cycle of the projects accrues as a benefit, because repair and maintenance will cost much less.

Climate Change Mitigation and Adaptation

Ecosystem restoration can play a large role in climate change mitigation. Because plant growth depends on the capture and incorporation of atmospheric carbon into plant tissue, trees and other plants sequester carbon. Growth rates of trees in low-elevation riparian forests in California are among the highest in the world, except the tropics. Thus, significant expansion of riparian forest acreage in inland and coastal valleys could serve as a large carbon sink that offsets carbon emissions. Although construction activities during restoration could produce some greenhouse gases, those emissions should be far less than the total of greenhouse gases sequestered through forest growth.

Ecosystem restoration can also play a role in climate change adaptation. The Central Valley Flood Protection Plan outlines the State's proposed response to a predicted climate regime of more frequent and larger floods. Part of that response is to increase the use of floodwater bypasses by creating new ones and widening the existing set. Beyond their role in flood protection, bypasses return floodplains to a more natural function and allow restoration of native floodplain vegetation. In turn, this helps to stabilize soils, increase groundwater infiltration and storage, and reduce floodwater velocities, bank erosion, and sedimentation of streams. Furthermore, because a return to a more natural floodplain function makes more room for flood peaks in valley areas, it allows more reservoir capacity to be dedicated to water supply, rather than be set aside for floodwater storage.

The expected shift to more severe flooding may diminish the ability to continue to farm many areas because the increased cost of recovery from floods could make farming uneconomical. However, making a clear dedication of land to expand flood-carrying capacity will reduce the flood risk on the remaining farmland and thus make that land more secure for agriculture.

Flood Management

The principal opportunities for improvement in both flood and habitat management occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. As suggested above, many actions taken for ecosystem restoration can also support more sustainable flood management.

Four major structural elements of flood management in California affect ecosystems: dams, on-channel levees, floodwater bypasses, and setback levees. Their flood management roles are clear. Dams impound floodwater and reduce peak flows. Levees keep rivers in their channels and off their floodplains. Bypasses allow controlled conveyance of floodwater across floodplains. Setback levees reduce water velocities and flood elevations, when compared to on-channel levees, and therefore sustain less erosion damage.

The combined use of dams and levees reduces the frequency and extent of floodplain inundation. In contrast, setback levees and bypass channels allow more frequent inundation of potential habitat space on floodplains. Native riparian and aquatic animal and plant communities of California are adapted to seasonal flooding conditions. Thus, setback levees and bypasses are better tools to integrate habitat and flood protection than dams and on-channel levees. Flood bypasses, in particular, can serve as important fish rearing habitat, which is a use of the Yolo Bypass. The Yolo Bypass provides juvenile salmon with far better growth and survival opportunities than the nearby channelized rivers that are now the main habitat for juvenile salmon.

Ecosystem restoration can improve flood protection by reducing levee erosion, increasing floodwater conveyance, deflecting dangerous flows away from levees, and strengthening levee surfaces. For example, levee erosion is a maintenance concern that often can be alleviated by slowing water velocity along the levee face. This can be done by setting the levee back and by growing plants on the lower levee slope and between the levee and the main channel. The vegetation reduces the force of water against the levee. Also, a new setback levee can be built with sound materials on a more stable foundation than many existing levees. The selection of appropriate vegetation is a key to reducing levee erosion while retaining the flood-carrying capacity of the stream channel.

A recent example of the use of suitable plants occurred at O'Connor Lakes on the Feather River, downstream of Yuba City, where a right-angle bend in the levee had been subject to severe and repeated erosion. A technical analysis of the paths taken by floodwater identified areas of the river channel where forest could remain (instead of being cleared periodically), areas where restoration of native trees and shrubs would not interfere with flood flows, and areas where the vegetation needed to be low and flexible enough to smooth the way for floods. The latter area was planted with native grasses and herbs. Overall, the new design increased the area of native vegetation by 230 acres, protected existing habitat from removal, reduced the risk of levee erosion and the need for expensive levee repair, and reduced the cost of keeping the channel clear for floodwater conveyance. Thus, a cheaper and more effective way to maintain the flood channel was also better for fish and wildlife habitat.

As with floodwater bypasses, habitat for juvenile fishes can be developed with setback levees. One such project on the lower Bear River in Sutter County was contoured to drain water and fish back to the river when floodwaters recede, thus preventing fish stranding. The project also created several hundred acres of forest and grassland habitat. The new, larger more durable levee, set back from the erosive forces of the river, improved flood protection for the urban area behind it.

Potential Costs

A comprehensive statewide summary of the costs of ecosystem projects does not exist. However, as of 2011, the Ecosystem Restoration Program, now managed by California Department of Fish and Wildlife, had funded 579 projects, worth about $718 million. About half of that amount was spent for riparian habitat, fish screens, and improvements to water and sediment quality.

Under the authority of the Central Valley Project Improvement Act, State and federal government spent about $630 million for fish and wildlife restoration since 1992 (U.S. Department of the Interior 2005).

The Central Valley Joint Venture has used a mix of public and private funds to accomplish its goals. Table 22-1 (updated March 2011) illustrates the budgets and the acres of habitat conserved (Central Valley Joint Venture 2011).

As of 2010, the Southern California Wetlands Recovery Project has spent more than $450 million completing projects from Santa Barbara County to San Diego County (Southern California Wetlands Recovery Project 2010).

Major Implementation Issues

Climate Change

Climate change will likely make preservation and restoration of key habitats more difficult. Perhaps the most important reason for this is an expected decline in the availability of moisture. A combination of rising temperatures, more intense floods, a smaller snowpack, more frequent drought, and more frequent and intense wildfires will reduce both surface and groundwater storage as more water runs off or evaporates and less water infiltrates into the ground. These changes in temperature and moisture will force species and natural communities to move with their preferred temperature and moisture regimes — uphill, northward, and into cool canyons — until blocked by topographic or other barriers. The result is that many species and ecosystems will occupy ever smaller and more isolated patches of physical habitat. As their abundance declines, more species will risk extinction.

Table 22-1 Acres Conserved by Central Valley Joint Venture

NAWCA Regions	Acres Conserved[a]	NAWCA Grant Funding	Federal Funding[b]	Non-federal Partners[c]
All of California	714,000	$72,000,000	$109,000,000	$230,000,000
North Central Valley/Delta	341,400	$32,300,000	$82,000,000	$85,200,000
Southern Central Valley	258,600	$21,000,000	$21,700,000	$56,600,000

Notes:

NAWCA = North American Wetlands Conservation Act of 1989

[a] This column reflects habitat protected, restored, and enhanced acres.

[b] This column reflects additional federal partner contributions.

[c] This column reflects non-federal partner contributions.

Two examples are especially relevant to water and flood management. First, in many low- and middle-elevation streams today, summer temperatures often approach the upper tolerance limits for salmon and trout; higher air and water temperatures will exacerbate this problem. As the timing of peak tributary runoff shifts toward winter, less of the winter flow is likely to be captured in reservoirs. This will leave less cold water for fish in spring and summer. Thus, climate change might require dedication of more water simply to maintain existing fish habitat, and plans to expand habitat will face stiffer competition from other demands on water.

The second example results from the continued rise in sea level and upstream encroachment of salt water. As this happens, the brackish and fresh aquatic habitats of the Sacramento-San Joaquin Estuary, which are critical to many at-risk species, will shift upstream and inland. Continuing urbanization on the edges of the Delta will limit opportunities to acquire or restore lands that could provide suitable habitat. Thus, threatened and endangered species could be increasingly squeezed between the inland sea and the encroaching cities.

Conflicting Objectives with Traditional Flood Management

Ecosystem restoration and traditional flood management often have conflicting objectives. Traditional flood planning assigns all the physical space in a river channel to floodwater conveyance and leaves little room for habitat values. Many of the greatest opportunities for ecosystem restoration, especially in the Central Valley and other valleys, require incorporation of habitat into the flood protection system. At this early stage in statewide flood planning, there is a lack of consensus on how to design such an integrated system and on the desirability thereof. For example, many would balk at using newly-created flood capacity in a river channel to make room for forests.

Californians need to be satisfied that the promise of an integrated approach to flood and ecosystem management can provide habitat without greater risk of flood damage. A habitat project that fails to achieve its objectives is costly, but not dangerous. In contrast, a flood protection project that fails can mean catastrophe for life and property.

Opposition to Conversion of Farmland to Habitat

Many of the opportunities for ecosystem restoration are on land that is now farmed, especially in the Central Valley and the Delta. Although some habitat types, such as seasonal wetlands, can be farmed at other times of year, others, such as riparian forest and most permanent wetlands, cannot. Thus, significant amounts of habitat restoration on arable land, coupled with continued urban growth, could hasten the decline of some forms of agriculture in California. The loss of farmland, especially for habitat uses, is controversial.

Instream Flows

Restoration of adequate instream flows and channel and floodplain form and function is a priority for the California Department of Fish and Wildlife (DWF). DFW has legal mandates to determine flows that will ensure the viability of fish and wildlife, identify the watercourses to evaluate, initiate flow studies, and develop and submit recommendations to the SWRCB for use in allocating water. Much work remains to complete studies and develop recommendations. Until then, incomplete knowledge will hamper restoration of adequate stream flows.

Mercury Contamination

Wetland restoration carries the potential for methylmercury contamination. Some seasonally and permanently flooded wetlands can convert elemental mercury to methylmercury. Methylmercury is highly toxic and can accumulate in natural food chains and in fish that people eat. Many areas targeted for habitat restoration, particularly in and near the Delta, are contaminated with mercury. Hence, wetland restoration in those areas could exacerbate methylmercury production. The SWRCB approved a basin plan amendment for the control of methylmercury and total mercury in the Delta in 2011. The regulation requires wetland project proponents to take part in evaluations of practices to reduce methylmercury discharges and apply controls.

Recommendations

1. Devise climate change adaptations that benefit both ecosystems and water and flood management. The principal predicted effect of climate change on California ecosystems is that it will further fragment and shrink them. Thus, appropriate corrective actions should serve to reconnect and expand them. The overarching recommendation is to establish large biological reserve areas that connect or reconnect habitat patches. These proposed "landscape reserves" are discussed further in the biodiversity and habitat section of the California Natural Resources Agency's Climate Adaptation Strategy (2009). More specific measures that can help ecosystems adapt to climate change are those that integrate ecosystem restoration into flood and water projects. The following measures were discussed above:

   A. Reconnect rivers to their historic floodplains as part of new flood management approaches.

   B. Increase the use of setback levees and floodwater bypasses.

   C. Expand lowland riparian forest acreage in the form of continuous corridors along watercourses.

   D. Set aside habitat in the Delta to compensate for habitat lost to sea level rise.

   E. Restore mountain meadows.

2. Promote multidisciplinary approaches to water and flood management. Conflicting objectives are commonplace in water and flood planning which makes it essential to foster broad participation and collaboration among the affected parties to generate a shared vision of water and flood management that incorporates multiple interests.

3. Expand financial incentives for farmers to grow and manage habitat. One promising approach is to devise a system of payments for ecosystem services in which beneficiaries pay natural resource managers for practices that support and enhance the desired goods and services. Stakeholders must identify and agree on what the relevant goods and services, the beneficiaries, and the monetary value of the benefits are. Programs such as the Environmental Quality Incentives Program administered by the USDA, Natural Resources Conservation Service (NRCS) and DWR's Flood Corridor grant program are examples of other incentives that could be expanded could take. See Chapter 21, "Agricultural Land Stewardship," in this volume for further discussion.

4. Provide for instream flow needs. Provide a comprehensive and appropriately funded program to identify instream flow needs, perform the necessary studies, and make scientifically defensible recommendations for instream flows to protect fish and wildlife.

5. Continue collaboration between wetland stakeholders and regional water quality control boards (RWQCBs) to reduce mercury contamination. Wetland stakeholders are working with the RWQCBs to identify and conduct research to reduce human and ecosystem exposure to mercury without preventing other efforts to improve ecosystem health through wetland restoration.

References

References Cited

California Resources Agency. 2009. 2009 *California Climate Change Adaptation Strategy Public Review Draft*. Sacramento (CA): California Natural Resources Agency. 161 pp. Viewed online at: www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-D.PDF. Accessed: Nov., 2009.

Additional References

California Department of Conservation and Environmental Defense Fund. 2013. Status report on the "Conservation Pivot." Draft.

Central Valley Joint Venture. 2006. *Central Valley Joint Venture 2006 Implementation Plan — Conserving Bird Habitats*. Sacramento (CA): Central Valley Joint Venture. U.S. Fish and Wildlife Service. 286 pp. Viewed online at: http://www.centralvalleyjointventure.org/assets/pdf/CVJV_fnl.pdf. Accessed: Nov. 3, 2009.

———. 2011. *Conserving Birds and Their Habitats in California's Central Valley Fact Sheet*. Sacramento (CA): Central Valley Joint Venture. U.S. Fish and Wildlife Service. Viewed online at: http://www.centralvalleyjointventure.org/assets/pdf/2011_CVJV_Fact_Sheet.pdf.

Central Valley Regional Water Quality Control Board. 2010. *Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin River Delta Estuary*. Resolution No. R5-2010-0043. Sacramento (CA): Viewed online at: http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/delta_hg/2011oct20/bpa_20oct2011_final.pdf. Accessed: March 2, 2012.

California Department of Fish and Wildlife. 2010. *Ecosystem Restoration Program End of Stage 1 Executive Summary.* Sacramento (CA): California Department of Fish and Wildlife.12 pp. Viewed online at: http://www.dfg.ca.gov/erp/stage1.asp. Accessed: May 18, 2012.

Null SE. 2008. *Improving managed environmental water use: Shasta River flow and temperature modeling*. Davis (CA): [Ph.D. dissertation.] Department of Geography. University of California, Davis. 265 pp.

Orange County Water District. 2008. Prado wetlands. Fountain Valley (CA): Orange County Water District. [Web site.] Viewed online at: http://www.ocwd.com/Environment/PradoWetlands.aspx. Accessed: Nov.4, 2009.

Viani LO, editor. 2008. *Riparian Habitat Conservation and Flood Management in California*. Riparian Habitat Joint Venture Conference. Dec. 4-6, 2007. Sacramento, CA. Petaluma (CA): PRBO Conservation Science. 116 pp. Viewed online at: www.prbo.org/calpif/rhjvconference/proceedings.

Siegel SW. 2007. F*oundation Concepts and Some Initial Activities to Restore Ecosystem Functions to the California Delta*. First Draft. Sacramento (CA): Prepared for the Delta Vision Blue Ribbon Task Force. Delta Protection Commission. 33 pp. Viewed online at: http://www.delta.ca.gov/res/docs/meetings/2008/012408_item_29.pdf.

State Water Resources Control Board. 2010. Draft *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*. Prepared Pursuant to the Sacrament-San Joaquin Delta Reform Act of 2009. Sacramento (CA): 191 pp. Viewed online at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/draft_report072010.pdf. Accessed: March 2, 2012.

Southern California Wetlands Recovery Project. 2010. Southern California Wetlands Recovery Project Completed Projects. Oakland (CA): Southern California Wetlands Recovery Project. Viewed online at: http://www.scwrp.org/pdfs/WRP-Completed-Projects_June-2010.pdf. Accessed: May 18, 2012.

Sweeney K. 2007. *A Symposium on Climate Change and Public Lands*. White paper in advance of symposium on climate change and public lands. Petaluma (CA): PRBO Conservation Science. 19 pp. Viewed online at: www.prbo.org/cms/docs/climatechange/kevinsweeney.pdf.

U.S. Bureau of Reclamation, U.S. Fish & Wildlife Service. 2005. *10 Years of Progress. A Summary of Activities and Accomplishments in the Implementation of the Central Valley Project Improvement Act*. Title 34. Public Law 102-575. 1993-2002. Sacramento (CA): U.S. Bureau of Reclamation. Viewed online at: http://www.usbr.gov/mp/cvpia/docs_reports/docs/cvpia_10yr_progress_final_summ_rpt.pdf. Accessed: May 18, 2012.

U.S. Bureau of Reclamation. 2009. Central Valley Project Improvement Act (CVPIA). Sacramento (CA): U.S. Bureau of Reclamation, Mid-Pacific Region. Viewed online at: www.usbr.gov/mp/cvpia. Accessed: Nov., 2009.

U.S. Fish and Wildlife Service. 2009. Anadromous fish restoration program (AFRP) program. Stockton (CA): U.S. Fish and Wildlife Service, Stockton Office. [Web site.] Viewed online at: http://www.fws.gov/stockton/afrp/. Accessed: Nov.3, 2009.

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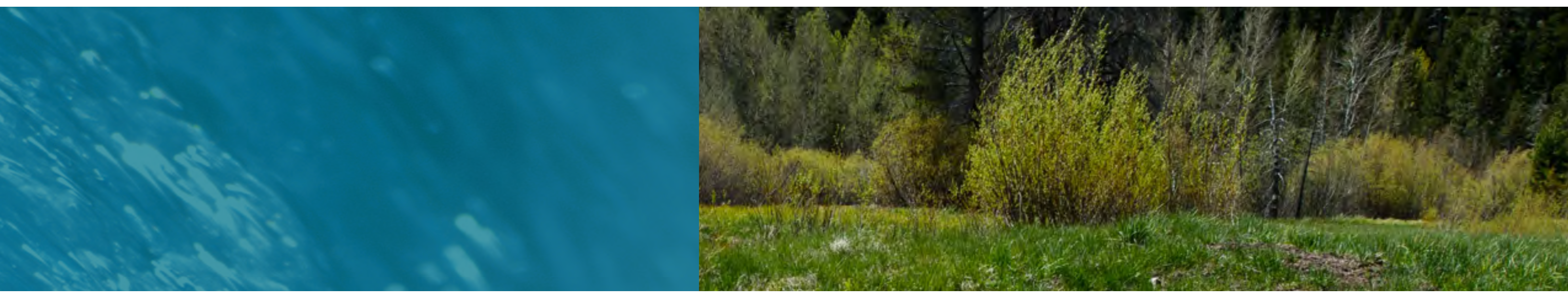
CHAPTER 23

Forest Management



Cookhouse Meadow, Sierra Nevada Mountains. To restore Cookhouse Meadow, a technique called "Pond and Plug" was employed, in which ponds and/or widened areas of waterways are excavated to produce fill material that then is used to plug or otherwise redirect the flow of water. The ponds become excellent wildlife habitat, particularly for migratory birds.

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Chapter 23. Forest Management

Forest lands in California, the majority of which are in the middle to high elevation foothills and mountains, produce a diverse array of resources such as water, timber, native vegetation, fish, wildlife, and livestock, and outdoor recreation. However, the water produced by these forests has economic value that equals or exceeds that of any other forest resource (Krieger 2001; California Department of Forestry and Fire Protection 2003). Most of California's major rivers and a substantial portion of its runoff originate in these forests; therefore, most of California's major water development projects are tied strongly to forested watersheds.

Forest management activities can affect water quantity and quality. This strategy focuses on forest management activities, on both public and privately-owned forest lands, whose goals specifically include improvement of the availability and quality of water for downstream users.

Water rights for groundwater in most areas of California are assigned to overlying landowners and reasonable use is unregulated. In contrast, surface water rights, which are managed and enforced by the State Water Resources Control Board (SWRCB), are a complicated mixture of riparian, appropriative, and adjudicated rights. The U.S. Department of Agriculture Forest Service (USDA Forest Service) uses federal reserved, appropriative, riparian, and overlying adjudicated water rights to manage forest lands. A large percentage of water flowing from forests is appropriated by state and federal water projects, municipal water agencies, irrigation districts and hydropower companies, many of which are fully appropriated. A list of fully appropriated stream systems for California is available on the SWRCB Web site: http://www.waterboards.ca.gov/waterrights/water_issues/programs/fully_appropriated_streams/.

Water quality in California is protected by the SWRCB and nine regional water quality control boards (RWQCBs). The RWQCBs regulate compliance with the federal Clean Water Act through designation of beneficial uses, development of numeric and narrative water quality objectives, water quality control policies, basin plans, basin plan prohibitions, issuance of various types of permits, and enforcement actions. The SWRCB prepares lists of impaired water bodies every two years, as required by Section 303(d) of the Clean Water Act. In addition to listings of threatened or endangered fish and wildlife species by the California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service, these impaired water body listings have greatly influenced forestry practices on non-federal lands during the past decade (Cafferata et al. 2007a).

Forest Ownership and Management in California

California has more than 30 million acres of forested lands (California Department of Forestry and Fire Protection 2003; Christensen 2008), which are located primarily in the major mountains of the Coast Ranges, Klamath Mountains, Cascade Range, and the Sierra Nevada. Forest lands in California are owned and managed by a wide array of federal, state, tribal, and local agencies, non-governmental organizations, and private companies, families, and individuals (Table 23-1), each of whom has a different forest management strategy with different goals and constraints.

The largest public forest landowner in the state is the USDA Forest Service, which owns and manages 18 National Forests in California. California's National Forests were established under the Organic Act of 1897, which specifically states that a primary purpose of these lands is to "secure favorable conditions of water flow." U.S. Secretary of Agriculture Tom Vilsach emphasized the role of the USDA Forest Service in protecting water sources in his remarks made on August 14, 2009:

> We must work and must be committed to a shared vision, a vision that conserves our forests and the vital resources important to our survival while wisely respecting the need for a forest economy that creates jobs and vibrant rural communities. Our shared vision must begin with a complete commitment to restoration. Restoration, for me, means managing forest lands first and foremost to protect our water sources while making our forests far more resilient to climate change.

The USDA Forest Service Pacific Southwest Region manages roughly 20 million acres in California for multiple uses including, among other things, timber and livestock production, mineral production, and outdoor recreation (USDA Forest Service 2007). Despite their name, these National Forests include a wide variety of ecological communities, including subalpine and montane forests, alpine shrublands, chaparral, desert, and wetlands. Timber on National Forests is produced through commercial timber sales to private contractors and livestock are grazed under a permit system. Environmental issues related to resource management on National Forests are addressed under the National Environmental Policy Act (NEPA). Resource management on each National Forest is guided by a Land and Resource Management Plan (LRMP), which is revised and updated roughly every fifteen years. The content and format of LRMPs is governed by national planning rules, which are also revised periodically, with the most recent planning rule completed in 2011. All future LRMPs will emphasize sustainability, restoration, and forest health.

The U.S. Bureau of Land Management (BLM) manages 1,650,000 acres of forest in the state (USDA Forest Service 2008), primarily in the North Coast region and the Modoc Plateau. The BLM is a multiple-use land management agency that produces timber through commercial sales and manages livestock grazing through a permit system. Environmental issues related to resource management on public lands administered by the BLM are addressed under NEPA.

The National Park Service (NPS) manages 1,287,000 acres of forest in 23 units in California (USDA Forest Service 2008). Unlike the USDA Forest Service and BLM, the NPS is not a multiple-use management agency, but instead has a mission to preserve natural and cultural resources specifically for public enjoyment and scientific purposes. Commercial timber harvests and livestock grazing are not allowed in national parks, although vegetation may be managed for forest health and fire protection purposes. Pack stock grazing is allowed when permitted.

Commercial timberlands (forests used or suitable for producing timber) comprise 16.6 million acres of forest land across the state (California Department of Forestry and Fire Protection 2003), nearly half of which is in non-federal ownership. More than five million acres are zoned for timber production and are primarily managed by large, industrial landowners (California Department of Forestry and Fire Protection 2003), with the remaining non-federal timberlands owned primarily by small non-industrial landowners with a wide range of management objectives. State Demonstration Forests include about 71,000 acres statewide (California Department of Forestry and Fire Protection 2013). Timber harvesting on non-federal forest lands is regulated by the California State Board of Forestry and Fire Protection (BOF) and the California Department of Forestry and Fire Protection (CAL FIRE). The BOF adopts regulations that CAL FIRE has enforced on the ground since 1975. Timber production is the primary use

Table 23-1 Acres of Forest Land by Ownership in California

Landowner	Acres[a]	Percentage
Private non-corporate	8,448,000	22.5
Private corporate	4,719,000	12.6
County	330,000	0.9
State	726,000	1.9
USFS[b]	20,166,000	53.7
BLM	1,650,000	4.4
NPS	1,287,000	3.4
Other federal	231,000	0.6
Total	37,557,000	100.0

Source: California Department of Water Resources 2011; Christensen et al. 2008.

Notes:
[a]Acres reported are "real" forest rather than total ownership.

[b]USDA Forest Service 2008.

of privately-held forests, but some company-owned forest lands are used for livestock grazing and permitted outdoor recreation, including fishing and hunting. In addition, with the passage of recent climate change legislation (AB 32), some forests are likely to be managed to enhance carbon sequestration and provide offsets to greenhouse gas (GHG) emissions.

Urban forestry, although geographically distinct from wildland forests, offers important benefits for water resources and mitigation of climate change. Urban forests are managed by municipal parks and public works departments, as well as by many private organizations and individuals. Trees in urban environments provide more than just aesthetic benefits, including interception of rainfall, reduction of urban runoff, and energy-efficient shade during hot weather.

Forest management agencies also have responsibilities for protection of water quality and beneficial uses, such as aquatic habitat. The USDA Forest Service, CAL FIRE, and BOF have been designated by the SWRCB as water quality management agencies for lands that they administer or regulate, and have all implemented water quality management plans that have been certified by the SWRCB. These water quality management programs incorporate best management practices (BMPs) or Forest Practice Rules (FPRs) that are designed to prevent adverse impacts to water quality from forest management activities, and include monitoring programs to evaluate BMP/FPR implementation and effectiveness. The USDA Forest Service water quality program also includes restoration of "legacy" sources of pollution.

Extensive monitoring of California's FPRs for protecting water quality on non-federal timberlands was conducted from 1996 through 2004 by two State programs — one using independent contractors acting as third party auditors to collect field data, and one using CAL FIRE forest practice inspectors (Cafferata and Munn 2002; Ice et al. 2004; Brandow et al. 2006). Together, these projects inspected more than 600 randomly selected timber harvesting plans (THPs) that had gone through one or more over-wintering periods after the completion of logging. Both projects found that hillslope surface erosion features were almost always associated with improperly implemented forest practice rules on forest roads and at watercourse crossings, and that watercourse and lake protection zones (buffer strips) retained high levels of post-harvest canopy and surface cover, which prevented harvest-related erosion. Approximately 20 percent of stream crossings were found to have significant problems with both forest practice rule implementation and effectiveness. Overall, California forest practice rule implementation rates have been found to be among the highest of any of the Western states, and when properly implemented, these practices have been found to be highly effective in preventing hillslope erosion features (Ice et al. 2004; Council of Western State Foresters 2007; Ice et al. 2010).

The USDA Forest Service reported on monitoring data collected from 2003 through 2007 at roughly 2,900 randomly located sites to evaluate the implementation and effectiveness of its water quality BMPs on National Forests (USDA Forest Service 2009). The BMP Evaluation Program uses 29 different onsite monitoring protocols to evaluate BMP implementation and effectiveness, with the majority related to timber and engineering practices. Overall, 86 percent of the BMPs evaluated were rated as correctly and fully implemented, and 93 percent of these were rated as effective in protecting water quality, comparable to results documented on private timber lands. Among all evaluations, 98 percent were found to have no significant adverse effects on water quality. The BMPs most likely to be associated with measurable adverse water quality were road stream crossings, developed recreation sites, and water source development. These BMPs also were found to have relatively low effectiveness when implemented.

Effects of Forest Management on Water Supply

The scientific evidence for relations between forests and water supply, however, has been inconclusive (Dudley and Stolton 2003; Troendle et al. 2007). Research has shown that forests have had a limited role in flood protection and variable effects on total water yields and base flows (Ziemer and Lisle 1998; USDA Forest Service 2000; Calder et al. 2007; Moore and Wondzell 2005; National Academy of Sciences 2008). In contrast, several studies have convincingly demonstrated that forests protect water quality by reducing erosion and removing runoff pollutants (e.g., USDA Forest Service 2000; Dudley and Stolton 2003; Calder et al. 2007). Forested watersheds in interior California are the location of California's winter snowpack. In contrast to rainfall that runs off rapidly, these snowpacks store enormous quantities of water through the winter wet season and release this stored water as spring and early summer snowmelt runoff, when it is most needed by humans and the environment, reducing the need for additional downstream dams and reservoirs. (For information on the benefits of increasing snowpack and extending snowmelt via snow fences, refer to Volume 3, Chapter 32, "Other Resource Management Strategies.")

Predicted climate changes for California are likely to have large impacts on forest ecosystems and on water supply in the near future. Climate model predictions suggest that there will be a shift in precipitation that results in more rainfall and less snowfall at mid-elevations in the Sierra Nevada (see http://www.water.ca.gov/climatechange for more detail), and in fact, more rapid spring snowmelt in the Sierra Nevada is already occurring (Peterson et al. 2008). This predicted shift toward less snow is critically important for water management because the existing water development infrastructure is designed to exploit streamflows that are driven by gradual releases of water during snowmelt. If snow is replaced by rain at mid-elevations, then winter flood peaks are likely to become larger and more frequent, and reservoir storage is likely to be exceeded in wet months when demand is low. Correspondingly, summer stream base flows will be lower in dry months, when demand is high. These climate-driven impacts could lead to proposals for new dams and reservoirs on forest streams with their resulting environmental impacts, as well as for additional off-site reservoirs.

Climate change also directly affects forests through increased drought stress, which makes trees more vulnerable to insect attack, with the resulting increased rates of tree mortality influencing wildfire frequency, size, and severity. These stresses on forests will affect their capacity to naturally regulate streamflow and buffer water quality. Many streams that are now perennial are likely to become intermittent with the resulting loss of riparian zones, aquatic habitats, and other beneficial uses of water that depend on perennial flows.

The importance of forest management for protection and improvement of water resources has increased due to concerns about increased demand for water, extended drought, economic and environmental costs of new water-supply infrastructure, effects of water transfers on endangered species, and effects of climate change on water supply and hydropower generation. Although current scientific consensus supports the role of forests as protectors of water quality, the potential for improvements in the availability of water through active forest management should not be overlooked (Bales et al. 2011). The following sections discuss forest management actions that have potential for improving water resources in California. (Discussion of an additional management action, snow fences, is in Chapter 27, “Watershed Management,” in this volume.) Forest management activities that alter streamflow regimen to benefit downstream water users (primarily by altering the timing of streamflow peaks) may be more successful than attempts to increase total water yield.

Vegetation Management for Water Supply

Management of forest vegetation to improve water supplies has a long history in the western United States. Early efforts attempted to reduce transpiration or increase snowpack by removal of trees, most ending with limited success (Ziemer 1987). Changes in water yields resulting from vegetation management are highly variable and difficult to measure, with indications that treatments must remove at least 20 percent of the vegetation to have a measurable effect on streamflow (Troendle et al. 2007). Computer simulations by Troendle et al. (2007) indicate that every twelve acres of forest thinning (fuels reduction) could theoretically produce an increase of 1 af of runoff. They suggested that the water yield response to large-scale forest thinning in the northern Sierra Nevada forests would be short-lived with a single treatment, perhaps only 15 years, but that an active management program could result in subtle increases in water yield. Some studies have provided limited evidence that measurable water-yield increases have occurred in larger watersheds in the past in response to vegetation removal. Blanchard (1962, as cited in Zinke 1987) investigated the cumulative effect of 30 years of logging on the South and Middle Forks of the Mokelumne River in the central Sierra Nevada. He reported that between 1930 and 1961, approximately 40,000 acres of forest were logged and that water yields from these watersheds gradually increased during that time period.

Innovative approaches that utilize selective thinning of younger, smaller trees, according to E. Holst of the Environmental Defense Fund, show some promise for limited improvement in streamflow regimen, as well as reducing fuel loading and increasing carbon sequestration (also, Troendle et al. 2007). However, research to date in California indicates a limited potential for increases in water yield following forest vegetation management treatments (e.g., Rector and MacDonald 1987). Most of this research was conducted under conditions of lower stand densities than now exist in California forests. Vegetation treatments in forests with higher stand densities could produce more benefits to water resources than indicated by research over the past several decades. Research is currently underway to evaluate such benefits (Bales et al. 2011). The effects of vegetation treatments on water availability will likely depend on the extent and intensity of treatments, as well as the length of intervals between treatments. Decisions as to whether to implement specific vegetation management projects will need to consider effects on other forest resources and potential adverse effects to water quality from vegetation treatments. Bales et al. (2011) report that their preliminary estimates based on average climate information suggest that treatments in the Sierra Nevada that would reduce forest cover by 40 percent of maximum levels across a watershed could increase water yields by about 9 percent. These treatments, however, also have potential to increase surface runoff and erosion from disturbed soils (Cram et al. 2007).

Fuels/Fire Management

Wildfire Impacts on Watershed Resources

Wildfires affect water resources by removing vegetation and altering soils and ground cover, with the magnitude of post-wildfire impacts being dependent on burn severity (Ice et al. 2004; Neary et al. 2005; Moody et al. 2008). These changes have large implications to water resources through their effects on transpiration rates, water infiltration rates, rates and magnitudes of erosion, peak and base streamflows, and total water yield.

In the absence of human intervention, wildfires were regular occurrences in California forests, where relatively frequent fires prevented large accumulations of fuel materials and fires were generally fast-moving, low-intensity, and did not kill established trees. Active fire suppression since the 1920s has led to a situation in much of California where forests have developed high fuel loads that greatly increase the risk of catastrophic high-intensity, stand-replacing fires that kill all vegetation, generate large volumes of eroded soil and ash (Robichaud 2000; Reneau et al. 2007; Rulli and Rosso 2007; Carroll et al. 2007), and cause large quantities of mobilized nutrients such as nitrate nitrogen, ammonium nitrogen, and phosphate phosphorus to move into stream runoff (Miller et al. 2006).

The removal of forest canopies that is associated with high burn severity temporarily reduces transpiration and interception losses. Consequently, streamflows increase until vegetative re-growth increases transpiration to or above pre-fire rates (Driscoll et al. 2004), and yields of water from a burned watershed are increased.

In areas with heavy fuels (typically forests and chaparral that have not burned or been treated to reduce fuels for many years) intense wildfire can lead to development of hydrophobic soil layers, particularly in dry coarse-textured soils, that dramatically reduce surface water infiltration rates. The impermeability of hydrophobic soil layers, in conjunction with the lack of ground cover remaining after fires, can lead to increased erosion and early-season surface runoff (Neary et al. 2005; Onda et al. 2007; Moody et al. 2008), causing greater transport of sediment to downstream reservoirs and adverse impacts to water treatment and conveyance facilities (Neary et al. 2005; Moser 2007).

Post-wildfire erosion is highly variable, difficult to predict, and highly dependent on the size, number, and intensity of storm events during the first one-to-two winters following the fire.

Increases in erosion are typically two or more orders of magnitude for intense wildfires the first winter after burning (Robichaud et al. 2010).

Peak streamflows are increased after intense wildfires, but the magnitude of this increase varies greatly by size of the watershed and its location in California. Changes in post-wildfire peak flows are greatest in small watersheds (e.g., < 250 acres) since stormflow response of small basins is controlled primarily by hillslope processes, including infiltration rate, which, in turn, are affected by wildfire (Neary et al. 2005). While data are limited, peak flow increases are likely to be higher in Southern California chaparral-covered basins than in Northern California coastal and snow-dominated watersheds (Robichaud et al. 2000; Neary et al. 2005). Peak flow increases in Southern California are commonly predicted to increase two to three times following intense wildfire for flows that occur with a recurrence interval of two years or greater (Rowe et al. 1949; Moody and Martin 2001).

Although increased water yield is a potential impact of large, intense wildfires, it is generally not significant. Where 75 to 100 percent of the vegetative cover is removed, runoff may increase from 0.1 af per acre burned in watersheds receiving 15 inches of mean annual precipitation, to 0.8 af per acre burned for watersheds receiving 40 inches of mean annual precipitation (based on Turner 1991). In forested areas, water-yield increases are minimal until basal area loss to fire exceeds 50 percent (Potts et al. 1989).

The additional water yields that result from catastrophic wildfires are generally considered to have little value for water supply and hydroelectric energy generation. Almost all of the additional runoff occurs during the wet season and must be regulated for dry season use by surface reservoir storage (Ziemer 1987). Typically, flows increase during large storm events when water is intentionally allowed to pass through reservoirs owing to flood management concerns. The occasional short-term positive gains from increased water yield are more than offset by the frequent short- and long-term negative impacts of increased peak flows, increased sedimentation, and decreased water quality (California State Board of Forestry 1996).

Increases in suspended sediment and turbidity are usually the greatest impact to water quality following intense wildfire, besides the direct and indirect effects fires can have on water delivery infrastructure. While data are scarce, post-wildfire turbidity values are often expected to exceed drinking water standards for water supplies, and make water treatment more difficult and expensive. Post-fire sediment concentrations are generally highest the first year after the fire, but the extent of sediment mobilization depends on the size of the storms following the fire (Fiori 2005). Increased sedimentation can severely impact aquatic habitat, including that for state and federally listed anadromous salmonids in Northern California. Intense wildfires also remove streamside vegetation, causing water temperatures to rise (Amaranthus et al. 1989; Mahlum et al. 2011). Increased water temperatures can adversely fish species by increasing pathogens and algae, and by decreasing amount of dissolved oxygen and aquatic organisms available to fish (Amaranthus et al. 1989).

Nitrogen is the most important nutrient affected by fire, with the amount of change in nitrogen in a burned area being directly related to the magnitude of soil heating and fire severity, and proportional to the amount of organic matter destroyed (Neary et al. 2005). Intense wildfire can lead to significantly increased nitrogen loads in stream water, particularly in Southern California where post-wildfire concentrations of nitrogen in streams as soluble nitrate have been found to exceed drinking water standards (Meixner and Wohlgemuth 2004), but not in Northern California (Cohen 1982).

Fuel Treatments to Reduce Wildfire Impacts on Watershed Resources

Fuel hazard reduction projects have been shown to reduce the risk of catastrophic crown wildfire (Martinson and Omi 2003; Omi and Martinson 2004), reducing both the severity and frequency of wildfire (Elliot 2010). Fuel reduction projects can have adverse effects on water quality (McClurkin et al. 1987; Wondzell 2001; Grace et al. 2006), but these effects are generally minor and temporary, and are far exceeded by the adverse effects of catastrophic wildfires (Benavides-Solorio and McDonald 2001; USDA Forest Service 2005; Madrid et al. 2006; Hatchett et al. 2006; Cram et al. 2007; Robichaud et al. 2007; Gokbulak et al. 2008). The adverse impacts of wildfire are generally much greater per unit of affected area than the impacts of fuel reduction projects, and also affect much larger areas than are included in fuel reduction treatments. Prescribed fire, thinning, and mastication are the main types of fuel reduction methods used to decrease the intensity, extent, and negative consequences of wildland fire in California. Prescribed herbivory (e.g., cattle and goat grazing used to maintain fuel breaks) is an additional option that is sometimes used. The most effective fuel reduction treatments for decreasing the spread and intensity of wildfires have been combinations of mechanical treatments and prescribed burning (Stephens and Moghaddas 2005; Dailey et al. 2008). Fuel management treatments are generally required every 10 to 20 years to maintain their effectiveness in reducing the risk of catastrophic wildfire (Robichaud et al. 2010).

In general, hydrologic impacts from prescribed burning are small, since these fires are usually low intensity (Beschta 1990; Heard 2005; Robichaud et al. 2010). Prescribed burns in chaparral typically generate more soil heating than prescribed burns in either grasslands or forests and produce more sediment than with other vegetation types (10-30 percent of the sediment yields after high severity wildfires) (Wohlgemuth 2001). Prescribed fires in chaparral that kill a significant proportion of the mature canopy or expose more than 35 to 50 percent of the soil can have a significant, detectable effect on annual water yields lasting 8-10 years, but with little detectable impact on downstream water storage reservoirs (Troendle et al. 2010). Nutrient impacts to water quality associated with prescribed burns is minimal in both forested and chaparral watersheds (Stephens et al. 2004; Meixner and Wohlgemuth 2004).

Commercial thinning operations that remove a significant portion of the overstory canopy have the potential to elevate stream sediment loads when the proportion of bare soil is high (Robichaud et al. 2010). Roads associated with commercial thinning operations usually are the largest sediment source associated with commercial timber operations (MacDonald et al. 2006). Only relatively heavy thinning operations can be expected to increase annual water yields in wetter environments, with no measurable increase in runoff expected from thinning operations that remove less than 15 percent of the forest cover or in areas with less than 18 inches of annual precipitation (Reid 2012; Robichaud et al. 2010). Burning of slash piles often produced with thinning produces intense soil heating at the pile locations and alters soil properties, but very limited movement of nutrients downslope from the piles has been detected (Hubbert et al. 2010).

Hydrologic impacts associated with non-commercial fuel reduction thinning operations that are done to reduce the risk of catastrophic wildfire are small, producing only short-lived impacts to runoff and sediment production. Non-commercial thinning to reduce fuel loads is increasingly being accomplished using masticating machines that mechanically grind, crush, shred, chip, and chop fuel. Woody material that remains following mastication increases the amount of ground cover and substantially reduces erosion potential. While research is limited, mastication appears to be an effective thinning treatment for overstocked timber stands with few negative impacts on soil compaction or soil erosion (Hatchett et al. 2006).

Management Strategies to Reduce Adverse Impacts Associated with Wildfire

Forest management activities to reduce fire severity on California's 18 National Forests are currently administered under the National Fire Plan (NFP) and the Healthy Forest Initiative (HFI). Approximately 70 percent of the 20 million acres of National Forest system lands in California, or 14 million acres, are in need of treatments to reduce fuel loads to natural levels. In all of California, approximately 21 million acres have been designated as high-priority landscape for treatment (California Department of Forestry and Fire Protection 2010a). The USDA Forest Service and other federal and state agencies are currently treating about 220,000 acres per year in California (approximately half with prescribed burning), while an average of 320,000 acres are burned annually by wildfires (California Department of Forestry and Fire Protection 2010a). Prior to European settlement (pre-1800), it has been estimated that 4.5 million acres are burned per year on average in California (Stephens et al. 2007).

Firefighting tactics are increasingly being modified to protect water quality and aquatic organisms (National Wildfire Coordinating Group Training Working Team 2004). Guidelines in effect since 2000 specify that aerial fire retardant drops are to be avoided within 300 feet of waterways (National Interagency Fire Center 2010). Rapid restoration of areas disturbed by fire suppression actions to reduce erosion potential and protect water quality is routinely included in suppression efforts on both National Forest and non-federal lands in California. Fire control lines, particularly those created by heavy equipment, disturb the soil, increase soil compaction, reduce infiltration, can become sources of sediment if not properly rehabilitated, and can alter runoff patterns (Neary et al. 2005; Backer et al. 2004). Practices used to reduce these impacts include installation of proper drainage structures on firelines and roads, and removal of soil from emergency stream crossings built when constructing firelines with crawler tractors.

Following fire containment, burned areas associated with wildfires greater than 500 acres on National Forest lands are assessed, and high-risk areas with downstream values-at-risk are treated to prevent adverse effects on water quality and other resources (Robichaud et al. 2000). Values-at-risk refers to natural resources such as salmonid habitat and human communities that may be adversely affected by the movement of water and sediment from burned areas.

The USDA Forest Service uses its Burned Area Emergency Response (BAER) program to prescribe practices to reduce erosion potential, as well as to reduce threats to life and property. Similarly, at the direction of the governor, California's Emergency Management Agency (Cal EMA), Natural Resources Agency, and Environmental Protection Agency (Cal EPA) assemble multi-disciplinary teams when necessary to assess post-wildfire potential impacts to life and property on state and private lands. Commonly specified measures include notification of residents in areas at risk for debris slides and channel-derived debris flows, use of automated precipitation and stream gauges linked to local government response and flood control agencies for early warning for evacuation, road and stream crossing improvements, installation of structure protection devices (e.g., K-rails), and on USDA Forest Service lands where there are high values-at-risk, such as aerially applied straw mulch, and hydro-mulch (Robichaud et al. 2000; Wohlgemuth et al. 2009). Aerial grass seeding has rarely been used in California after 2000, since it has not been shown to be effective in reducing hillslope erosion and often inhibits native species regeneration (Conard et al. 1995; Wohlgemuth et al. 1998; Beyers 2004). Post-wildfire assessment programs will likely become increasingly important in the future due to projections of higher frequency and intensity of wildfires related to climate change.

Recommendations

It is recommended that watershed protection be enhanced through the strategic placement of fuel reduction projects in high-priority water supply watersheds, (high-priority water supply watersheds are displayed in Chapter 3 of the *2010 Assessment of California's Forest and Rangelands* [California Department of Forestry and Fire Protection 2010a]) utilizing existing state and federal cost-share programs on non-federal wildlands (California Department of Forestry and Fire Protection 2010b). Fuel reduction projects should use: (1) mechanical thinning treatments that limit ground disturbance, particularly on steeper slopes and more erodible soil types (Cram et al. 2007), and include appropriate road design, construction, and maintenance practices, (2) mastication where slope gradient is appropriate, and (3) low-severity prescribed fire preserving the litter/duff layer and existing nitrogen levels. Fuel reduction treatments, such as thinning, can reduce the threat of high-intensity wildfire, and make California forests more resilient in warmer climates (Bales et al. 2011), as well as providing other ancillary benefits, such as biogeneration of power.

Road Management

Thousands of miles of roads have been constructed through forests in California, primarily to provide access for timber harvest. The 18 National Forests in California alone contain approximately 50,000 miles of forest roads, of which roughly 20,000 miles may no longer be needed for their original purposes (Dombeck 2007). Private forest lands contain many additional thousands of miles of roads. These are mostly unpaved roads and they can have significant effects on hydrology and water quality through their roles in sediment transport and hydrology when they are improperly designed, constructed, or maintained.

Unpaved roads, particularly those adjacent to streams and road stream crossings, are usually the dominant source of management-related sedimentation in forested environments in California due to surface erosion, gullying, and mass wasting (Cafferata and Munn 2002; USDA Forest Service 2004; MacDonald et al. 2004; Coe 2006; Cafferata et al. 2007b). Excessive sedimentation associated with roads is a concern because of potential negative impacts on stream habitat and water quality from sediment that is discharged either episodically when roads or road-stream crossings catastrophically fail, or chronically from incremental surface erosion. However, a relatively small proportion of the total road length produces most of the road-related sediment delivered to streams (McCashion and Rice 1983; Coe 2006).

Forest roads can have significant effects on hydrology by generating overland flow and intercepting subsurface flow, which increases flood peaks (Jones and Grant 1996) and decreases recession flows. Stream crossings are vulnerable to damage by high flows (Furniss et al. 1998) and can divert streams from their natural channels, resulting in serious erosion and water quality problems (Best et al. 2004).

Roads built to modern standards have reduced impacts to forest streams, but many of the forest roads in California were built decades ago to very low design standards, often in environmentally sensitive locations such as unstable hillslopes and riparian areas. A significant number of older roads are part of the current road network, while others have been neglected and abandoned with no consideration or mitigation of ongoing erosional impacts (Cafferata et al. 2007b). These "legacy" roads are particularly susceptible to catastrophic failure during high magnitude, low frequency storm events, such as the one in 1997 that caused extensive flooding throughout a large part of Northern and Central California (Furniss et al. 1998; Madej 2001).

Many of these adverse hydrologic and water quality impacts of roads can be reduced by upgrading and replacing culverts, outsloping road treads, and installing road drainage structures such as waterbars and rolling dips at appropriate spacing, particularly near stream crossings (Furniss et al. 1991; Weaver and Hagans 1994; Keller and Sherar 2003). Roads no longer necessary for resource management or recreation can be effectively decommissioned by removal of fills at stream crossings and partial or total outsloping of road treads, including cuts and fills (Madej 2001; Cook and Dresser 2007). Road decommissioning can potentially reduce water quality impacts. However, it can be difficult to find roads producing significant impacts that people agree should be decommissioned.

Detailed field surveys are the main tool available to identify the road segments of greatest concern (Weaver et al. 2006; Korte and MacDonald 2007). Public and private landowners in California are actively inventorying their road networks, prioritizing road segments requiring road improvement or decommissioning work, and completing projects. A considerable amount of road upgrade work has been completed to date with both public and private financing. While there are short-term impacts associated with road improvement and decommissioning, particularly at stream crossings, improved operator practices has lessened these effects (Pacific Watershed Associates 2005; Cafferata et al. 2007b), and treatments will reduce the long-term sediment production overall from older roads (Madej 2001).

Riparian Forests

Riparian forests are forested lands, usually in narrow linear strips, that are located immediately adjacent to streams, lakes, or other water bodies. These communities occupy a transition zone between aquatic and terrestrial habitats, and are distributed in complex patterns that are responses to geomorphology, annual flood timing and extent, soil moisture, and plant competition. The boundaries between riparian and upland forests are not always distinct, and the width of a riparian forest strip varies laterally throughout the channel network and is strongly influenced by geomorphology (Naiman et al. 1998).

In recognition of the central role played by riparian forests in the landscape, the California Forest Practice Rules require that the beneficial functions of riparian zones and populations of native aquatic and riparian-associated species must be maintained where they are in good condition, protected where they are threatened, and restored where they are impaired insofar as is feasible. Unfortunately, riparian forests are prone to invasion by noxious non-native plant species that reduce the value of the riparian community to humans and wildlife.

Forested floodplains are zones of very high biological diversity, generally harboring the highest biodiversity of both terrestrial and aquatic organisms within the watershed landscape (Naiman et al. 1998) and providing important habitat for wildlife (Kattelmann and Embury 1996; Ligon et al. 1999). Riparian floodplains play large roles in forested watersheds that are disproportional to their small area in the landscape. The high surface roughness of forested floodplains has large effects on stream hydrology by reducing floodwater velocities and spreading flood flows across a larger area of the floodplain. The retention and slowing of floodwaters across a wider area allows floodwaters to recharge alluvial groundwater aquifers and attenuates downstream flood flows (Cafferata et al. 2005).

Studies have shown that riparian forests can improve water quality. Riparian forests contribute to reductions in sediment, nutrient, and pesticide loads of surface runoff through physical and biological processes, reducing these inputs to watercourses. Canopy shading by riparian trees reduces stream water temperatures, which is important for many fish species that are adversely affected by elevated water temperatures. In cooler coastal areas, canopy shading may restrict primary productivity (Wilzbach et al. 2005).

Riparian forests are protected on federal, state, and private timberlands by regulating areas near streams as riparian buffers, within which management actions such as timber harvesting and road building are regulated. The width of riparian buffers, and restrictions on management activities within them, are based largely on land ownership. Within the National Forests, riparian buffer widths vary based on planning province standards and guidelines, with riparian protection being most extensive for the six National Forests that operate under the Northwest Forest Plan. Provincial refers to the three major planning provinces used in the National Forest System in California — the Northwest Forest Plan province, the Sierra Nevada Framework province, and the Southern California province.

Even with these protections, the extent of riparian forest is greatly diminished from its historical extent, particularly in lowland valleys where riparian forests have been converted to orchards and other agricultural uses. In the Central Valley, riparian forests historically covered more than 900,000 acres but presently account for less than 100,000 acres (Barbour et al. 1993).

Unmanaged riparian stands can be sources of rapid fire migration in fire-prone landscapes (Murphy et al. 2007). Fuels reduction within riparian buffers may be needed in some cases to reduce threats of catastrophic wildfires, particularly in the interior parts of California (USDA Forest Service 2007; Van de Water and North 2011). Goals for this type of work include creating fire resilient forests, promoting reduced fire intensities, and retaining functional aquatic and riparian habitat following a wildfire. Removal of trees from riparian buffers remains highly controversial (Welsh 2011), and forest management and regulatory agencies are carefully evaluating monitoring data, particularly with regard to the use of mechanical equipment in streamside zones (Norman et al. 2008).

Some riparian forests are used for livestock grazing, usually within allotments that consist mostly of upland pasture. The availability of water and forage make riparian areas attractive to livestock, which can damage riparian forests through trampling, browsing, and contamination of streams with fecal material (Campbell and Allen-Diaz 1997). BMPs for range management and National Forest standards and guidelines for riparian management are designed to protect riparian forests from damage by livestock. Although exclusion of cattle may be needed during and immediately after restoration of riparian forests, grazing strategies that minimize impacts on riparian forests through restrictions on livestock numbers, distribution, and season of use can be used to eliminate the need for permanent fencing.

Riparian forests are primarily a result of the interplay of hydrologic processes occurring in the stream, floodplain, and groundwater, and alteration of these processes can have dramatic effects on riparian plant communities. Many of the tree and shrub species that dominate California riparian forests (e.g., cottonwood, willow) are dependent for regeneration on the annual flooding and exposure of a floodplain because their seeds can only germinate in moist, emergent areas that have been scoured of vegetation – conditions that occur only after high water events. Dominant riparian tree species often have little or no tolerance for dry conditions and require the reliable source of moisture supplied by the streamflow. Some riparian plant species have shallow root systems and can only utilize water in shallow areas of the soil profile or in the stream channel directly, while other species have roots that penetrate deeper into the soil profile and utilize available groundwater, which is typically replenished by streamflow infiltration. Species distributions are further affected by patterns of sediment deposition caused by stream hydrologic processes. Riparian plants, particularly trees, also affect stream hydrology, in turn, by contributing large woody debris that creates pools, and affect channel morphology through the actions of roots.

Riparian forests, therefore, may affect and be effected by channel incision and groundwater storage in much the same ways as meadows. The water quantity and quality benefits provided by riparian forests can be preserved and enhanced through actions that maintain natural channel geomorphology. Thus, protection of riparian forests depends heavily on effective management of upland watersheds to prevent excessive runoff and sedimentation, as well as control of non-native invasive species.

Meadow Restoration and Groundwater

Meadow wetlands are level or gently sloping alluvial landforms with seasonally high water tables that support flood-tolerant herbaceous plants (Ratliff, 1985; Weixelman et al. 2011). Geologic and climatic factors have resulted in the formation of numerous meadows in the mountains of California, with most meadows located in the Sierra Nevada. These meadows, in aggregate, comprise a small part of the landscape, but they provide disproportionally important ecological services owing to their role in retaining water at or near the land surface during California's long dry summers.

In their natural condition, meadows have shallow meandering channels that allow high flows to spread across the meadow surfaces, depositing suspended sediments and recharging meadow aquifers (Wood 1975). These meadows act as natural reservoirs, storing and releasing snowmelt and rainfall runoff that passes over and through fine-grained, sod-covered meadow deposits (Loheide and Gorelick 2007; Cornwell and Brown 2008; Hammersmark et al. 2008; Tague et al. 2008; Ohara et al. 2013).

By 1940, many meadows throughout the Sierra Nevada had been eroded by incised channels, or gullies, as a result of unrestricted livestock grazing, road building, railroad construction, elimination of beavers, and other causes (Hughes 1934; Kraebel and Pillsbury 1934; Wood 1975; Ratliff 1985; Kattelmann and Embury 1996; Martin 2006). A recent survey found that more than half of Sierra Nevada meadows are eroded by incised channels (Fryoff-Hung and Viers 2013). Current activities are designed to avoid damage to meadows, but the effects of earlier practices remain on the landscape and are unlikely to heal without active restoration (Ratliff 1985). Future disturbances from wildfires, intense storms, encroachment by conifers, and illegal activities could cause further damage that will require restoration.

Eroded meadows lose their capacity to store groundwater (Loheide and Gorelick 2007; Cornwell and Brown 2008; Hammersmark et al. 2008; Tague et al. 2008) because deeply incised channels can convey flood peaks without overbank flooding and recharge, and because groundwater is drained more rapidly from meadow aquifers. In addition, channel erosion in meadows adds to stream sediment loads through bank erosion and headcut retreat, adversely affecting downstream water quality and reservoir capacity (Micheli and Kirchner 2002). Loss of groundwater to evapotranspiration, however, is often reduced by meadow erosion and increased by restoration (Loheide and Gorelick 2005).

In the 2009 SWP update, potential groundwater storage benefits of meadow restoration were estimated at 50,000 to 500,000 acre-feet annually. The large uncertainty in these estimates resulted from the limited information available at that time regarding meadow areas, erosion depths, and hydraulic properties.

Based on preliminary results of an ongoing regional assessment (Fryoff-Hung and Viers 2013), the potential groundwater storage benefits of meadow restoration throughout the Sierra Nevada are likely to range from 25,000 to 50,000 acre-feet annually. These estimates are lower than the estimated range in the 2009 SWP update because recently acquired measurements indicate that meadow areas and erosion depths are lower than initially estimated for the 2009 SWP update.

The reduced soil moisture and elimination of surface flooding that is associated with meadow incision leads to changes in the associated plant community to types that have less value and provide fewer ecological services. Drying of meadow soils allows invasion by drought-tolerant brush and conifer species that contribute to heavy fuel loading and add to the risk of catastrophic wildfires (Allen-Diaz 1991; Dwire et al. 2006; Berlow et al. 2002; Loheide and Gorelick 2007). Loss of high quality forage provided by wet-meadow sedges, rushes, and grasses decreases forage value for meadows that are grazed by livestock (Ratliff 1985; Stohlgren et al. 1989). Loss of wetland vegetation reduces habitat area for several rare, threatened or endangered species such as the Mountain Yellow-legged Frog, Willow Flycatcher, and Bell’s Vireo.

When groundwater is available, but not so persistent as to induce anoxia or root rot, woody species such as lodgepole pine and sagebrush may transpire groundwater at rates similar to or possibly higher than wet meadow herbaceous vegetation (e.g., Lautz 2007; Tague 2009). Woody plants at some elevations continue to transpire throughout the year (although at lower rates during the winter; Bales et al. 2011), adding to transpiration losses, whereas herbaceous meadow plants senesce in the fall and do not transpire for about half of each year (e.g., Wood 1975). Removing encroaching conifers or sagebrush may in some cases result in reduced groundwater transpiration losses (Cafferata 2005). This might extend the period that meadow areas are wet longer into the summer season, but it would not be expected to produce a major shift in groundwater trends. The effect on summer groundwater elevation would decrease over time if coniferous or shrub vegetation were allowed to regenerate.

The USDA Forest Service and other agencies and organizations have been restoring meadows for many decades (Kraebel and Pillsbury 1934; Hughes 1934). In the past 20 years, the pace and scale of meadow restoration have accelerated owing to increased external support and the advent of the “plug and pond” restoration methodology. This acceleration of meadow restoration has raised concerns among some downstream water users that restoration may decrease summer streamflows, and has highlighted the need to better understand meadow hydrology and the manner in which restoration affects downstream flows.

The effects of meadow restoration on streamflow are not well documented except in a few cases. Streamflow records in the Feather River watershed do not show clear evidence for increased flows downstream of restoration projects, and in fact show at least temporary decreases in some restored meadows (Hoffman et al. 2013). However, recent scientific publications have generally indicated that meadow restoration will benefit downstream flows during dry periods (Tague et al. 2008; Hammersmark et al. 2008; Ohara et al. 2013). Long-term effects of restoration on downstream flows are likely to vary depending on climate, geology, vegetation, and land use.

Urban Forestry

Trees planted along streets and in city parks, lots, and private residences collectively form urban forests, and urban forestry practices address the maintenance of existing urban trees as well as the planting of new trees in and around cities. Although urban forests are not managed specifically for natural resource production or conservation, they have environmental benefits that extend well beyond aesthetics.

Urban areas in California cover roughly 5 percent (7,944 square miles) of the land base, but support 94 percent of the population (California Department of Forestry and Fire Protection 2010a). An estimated 15.1 percent of California's urban area (800,000 acres), which is home to almost one-third of the state's population (9.5 million people), is associated with high threats from air pollution and urban heat islands (California Department of Forestry and Fire Protection 2010a). Urban trees are an important means of mitigating heat and air pollution. As a result, communities throughout California are recognizing the importance of urban trees and have plans to expand urban forests. The need for expanding or enhancing urban forests is substantial, with 372 communities identified as high priority for tree planting in urban areas by the *2010 CAL FIRE Forest and Range Assessment* (California Department of Forestry and Fire Protection 2010a).

Urban Watershed Forestry

While not part of the wild environment, urban trees contribute to the overall health of a watershed, and their contribution is addressed by the discipline of urban watershed forestry, which is an integration of urban and community forestry and watershed planning. Urban and community forestry focuses on how to manage urban forests for environmental, community, and economic benefits while watershed planning focuses on strategic land use and resource management within a watershed. The integration of these two methods into urban watershed planning recognizes the role trees play in protecting water resources, and is becoming a valuable resource management tool for urban planners.

Tree Cover and Watershed Benefits

Trees in an urban setting provide multiple watershed benefits (Table 23-2), including reduction of stormwater runoff and stream channel erosion, improved soil and water quality, and reduction of air and water temperatures. For example, it is possible for a single tree to contain 100 gallons of water or more within its leaves and bark, which when multiplied by the many trees in an urban setting, produces an impressive retention capacity that can reduce stormwater runoff by 2-7 percent (Tree City USA 2010). In conjunction with other landscaping, an estimated 65 percent

Table 23-2 Watershed Benefits of Urban Forest Cover

Benefit	Description
Reduce storm water runoff and flooding	Trees intercept rainfall in their canopy, reducing the amount of rain that reaches the ground. A portion of this captured rainwater evaporates from tree surfaces. Trees take up water from the soil through their roots, which increases soil water storage potential and lengthens the amount of time before rainfall becomes runoff. Trees promote infiltration by slowing down runoff and by increasing soil drainage in the root zone. The addition of organic matter (e.g., leaves) also increases storage of water in the soil, further reducing runoff. Forested land produces very little runoff, which can reduce downstream flood flows that erode stream channels, damage property, and destroy habitat.
Improve regional air quality	Trees absorb pollutants such as nitrogen dioxide, carbon monoxide, ozone, and particulate matter from the atmosphere. Trees reduce air temperature, which reduces formation of pollutants that are temperature dependent, such as ozone. Trees indirectly improve air quality by cooling the air, storing carbon, and reducing energy use, which reduces power plant emissions.
Reduce stream channel erosion	Trees growing along a streambank prevent erosion by stabilizing the soil with root systems and the addition of organic matter.
Improve soil and water quality	Trees prevent erosion of sediment by stabilizing the soil, and by substantially dispersing raindrop energy. Trees take up stormwater pollutants, such as nitrogen, from soil and groundwater. Forested areas can filter sediment and associated pollutants from runoff. Certain tree species break down pollutants commonly found in urban soils, groundwater, and runoff, such as metals, pesticides, and solvents.
Provide habitat for terrestrial and aquatic wildlife	Forests (and even single trees) provide habitat for wildlife in the form of food supply, interior breeding areas, and migratory corridors. Streamside forests provide habitat in the form of leaf litter and large woody debris for fish and other aquatic species. Forest litter such as branches, leaves, fruits, and flowers form the basis of the food web for stream organisms.
Reduce summer air and water temperatures	Riparian forests shade the stream and regulate summer air and water temperatures, which is critical for many aquatic species. Trees and forests shade impervious surfaces, reducing temperature of stormwater runoff, which can minimize the thermal shocks normally transmitted to receiving waters during storms.

Source: Watershed Forestry Resource Guide - Urban Watershed Forestry 2008 (http://www.forestsforwatersheds.org/urban-watershed-forestry).

runoff reduction can be achieved (Tree City USA 2010), and water retention systems such as vegetation swales, stormwater basins, structural soils, tree pits, and riparian buffers improve runoff reduction even more.

Stormwater Runoff

Trees reduce stormwater runoff by using soil water through transpiration and intercepting rainwater on leaves, branches, and tree trunks, which changes runoff quantity and pollutant loads in several ways. Evapotranspiration increases soil water storage potential, tree root systems can increase soil infiltration rates, and interception of rainfall by the canopy reduces the volume and timing of runoff and reduces soil erosion caused by impacts from raindrops.

Structural Soils

Urban areas are challenged by extensive impervious surfaces, damaged soils, and little room for greenspace or for stormwater management facilities. In 2004, a collaboration of researchers from Virginia Polytechnic Institute, Cornell University, and University of California, Davis formed a work group to study the use of trees and structural soils to improve water quality. The system developed and evaluated by the group utilized stormwater BMPs to reduce peak flow, reduce runoff volume, and remove pollutants. The system works by guiding the water into a structural soil retention area beneath the pavement where it is absorbed by soil infiltration and root uptake for tree transpiration. Trees have the potential to develop full canopies that result in increased water interception because the reservoir offers a large root area. Tree roots take up excess nutrients and water in the soil reservoir and can enhance infiltration into the subsoil. Together, trees and structural soils can create a zero runoff site. The group found that with such a system it was possible to distribute stormwater management by taking advantage of the mitigation services provided by urban trees (Xiao and McPherson 2009). It also created an alternative to detention ponds in urbanized areas.

Quantifying Benefits

Urban trees have multiple co-benefits. A large deciduous canopy tree can intercept 760 gallons of rainfall in its crown annually and aid in reducing runoff of polluted stormwater and flooding, a benefit valued at $6 annually on the basis of local expenditures for water quality management and flood control (USDA Forest Service 1999). Larger potential for canopy interception increases the beneficial effects of tree interception of rainfall, with these effects being greater in larger trees and evergreen trees. An evergreen camphor tree, for instance, is estimated to intercept 4,000 gallons annually, providing even greater benefits than a deciduous tree of similar size (USDA Forest Service 1999). In addition, shade from urban forests reduces energy use of city residents by reducing temperatures inside buildings and lowering energy usage rates for interior cooling.

Urban trees also offset greenhouse gas emissions and provide larger-scale climate benefits through their persistent sequestration of carbon in woody material. A study in San Francisco found that urban trees within the city annually sequester an estimated 2,271 tons of CO_2 and indirectly reduce energy plant emissions by 257 tons of CO_2, representing an estimated value of $2.3 million annually (Maco et al. 2003). The combined value of this benefit (e.g., carbon sequestration and offset from reduction in energy use) was estimated at $37,907 annually (Maco et al. 2003). Considering that San Francisco has a mild climate with cool summers, the benefit can be substantially higher in warmer inland cities. There are an estimated 188.5 million urban trees statewide that sequester approximately 414,000 metric tons of carbon annually (or approximately 1.52 million metric tons CO_2) (Novak et al. 2009), so the contribution of urban trees to atmospheric carbon dynamics is substantial.

Recommendations

- Fund urban tree planting in high-priority communities, which should yield multiple water use benefits, such as reductions in stormwater runoff and improved water quality, among other benefits such as air pollution mitigation and reduced energy use. The 2010 Forest and Range Assessment (California Department of Forestry and Fire Protection 2010a) identified 372 communities as high-priority areas for urban tree planting in order to conserve energy or improve air quality.
- Preserve space for large-statured trees in new developments and create such space in developed areas that currently do not have adequate planting sites. Preserving and planting large-statured trees will have a large beneficial impact and improve the extent of urban tree canopy in priority areas. Additionally, improved management of existing urban forest resources will assist in maximizing the benefits of current tree canopy while minimizing long-term costs.
- Encourage and implement BMPs that promote urban forestry for urban stormwater management, which take advantage of benefits offered from tree canopy interception for reduced peak stormwater flows, reduced runoff volume, and removal of pollutants. Use of a variety of stormwater management techniques should be encouraged to maximize urban tree benefits to water resources.

Forest Loss and Fragmentation

The subdivision of large forest parcels and their subsequent development for rural residential uses can cause impacts on water quantity and quality. During the construction phase, there can be increased erosion and sediment delivery to streams. Over the long term, roads and increased impervious surface may change the timing and magnitude of peak streamflow events in small watersheds. Roads and stream crossings also are the main sources for long term increases in sediment delivery. Although studies comparing the impacts of forest management versus rural residential land uses are rare, there is evidence that rural residential roads produce more sediment than logging roads. Rural residential uses also may affect water quantity at the small watershed scale. These uses will often rely on springs and diversions for water supply. The result may be reduced summertime base flows in streams with attendant biological consequences. The regulatory framework controlling forest management uses is much more demanding than the controls on rural residential uses. In particular, the California Forest Practice Rules require practices to control erosion and sediment delivery. In contrast, most rural counties do not have grading ordinances or similar regulations, especially in relation to private roads (Harris and Cafferata 2005).

Recommendation

Encourage the use of conservation easements to permanently conserve California's private forestlands. Conservation easements are a cost-effective and permanent method of conserving vital water infrastructure, and they could be used more extensively to promote long-term forest stewardship in private forestlands, particularly where land conversion projects are common. The goal is to secure proper watershed functions through conservation easements that permanently conserve forest landscapes, avoiding conversion to housing subdivisions and agricultural lands.

Illegal Marijuana Cultivation

In the past five years, increased impacts from commercial-scale illegal cannabis growing operations have been documented in forested counties throughout California and particularly in the California coast ranges, both on public and private lands. While largely anecdotal, without specific data on numbers of watercourses affected, the impacts have been well documented with digital photographs taken during law enforcement operations (Giusti 2012).

Illegal growing activities adversely impact watershed resources in three main ways: (1) illegal diversions of water from tributary streams utilize low summer flows required for sustaining state and federally listed anadromous salmonids and other species; (2) illegal grading and road building operations cause surface erosion and slope instability, which produces accelerated sedimentation; and (3) large-scale use of pesticides, fertilizers, and rodenticides adversely impacts water quality.

Typical commercial-scale illegal marijuana gardens found on public land include approximately 7,000 plants, with each large plant using approximately one gallon of water per day (Mallery 2011). This equates to approximately 7,000 gallons of water per day over a period of 3 to 4 months or about 2 to 2.5 acre-feet per year per commercial-scale operation. The 2010 Mendocino County Grand Jury Report estimates that only 10 percent of illegally grown marijuana is confiscated annually. More than 500,000 plants are confiscated in many years. Assuming those years are representative, an estimated 5,000,000 plants are produced annually, according to G. Giusti of the University of California Cooperative Extension, Ukiah.

The greatest impact to water resources by illegal marijuana plantations is often not the absolute size of the diversion, but the size of the diversion in relation to the stream being diverted in that it is not unusual for all of the streamflow from a watercourse to be illegally diverted for irrigation using dams, pumps, and elaborate water distribution systems (Thorsen 2011; Mallery 2011). Use of large off-site water storage devices, such as 50,000 gallon water "bladders", has also been documented. Water diversion causes early de-watering of intermittent streams during a critical time of year for juvenile fish.

Illegal and unregulated grading operations, including grading that enables marijuana cultivation, have been documented in several North Coast counties and they have been found to have adverse watershed impacts. Illegal grading operations increases suspended sediment concentrations and turbidity in intermittent and perennial fish-bearing watercourses, adversely impacting both macroinvertebrates and anadromous salmonids. The extent of illegal grading and its significance to anadromous fish species is currently unknown, however, since counties lack adequate staff to monitor for illegal and/or improper grading (Harris 2011).

Unregulated pesticide, fertilizer, and rodenticide use is extensive in commercial-scale operations and potentially presents a major problem for water quality (Giusti 2012). Mallery (2011) states that an estimated 1.5 pounds of fertilizer are used for every 10 marijuana plants. A three week-long, multi-agency law enforcement operation on public and private lands in Colusa, Glenn, Lake, Mendocino, Tehama, and Trinity Counties in 2011 removed 5,459 pounds of fertilizer and 149 pounds of pesticides from cultivation sites (USDA Forest Service 2011c). An average 5 acre site can contain 20 pounds of rodenticides, 30 bags of fertilizer, plant growth hormones, insecticides, herbicides, and fungicides as well as other chemicals (Mallery 2011). Unused or abandoned chemicals are typically left on-site and leach into waterways and groundwater aquifers, and gasoline and other petroleum products also produce water quality impacts (Giusti 2012).

While the total number and area covered by illegal commercial-scale marijuana operations is unknown, the fact that they operate outside of laws and regulations governing water diversion and water quality protection indicates that they are producing significant impacts wherever they occur. The North Coast Regional Water Quality Control Board is proceeding with an effort to regulate marijuana cultivation on private lands in conformance with the state's non-point source policy by addressing potential water quality impacts resulting from grading activities, road construction, road maintenance, and hazardous materials handling.

Climate Change

Forests will play an increasingly important role in protecting California's watersheds and associated water supply as the climate warms and precipitation patterns become increasingly variable. Climate change impacts on California's forests that have been measured in the past 100 years include a 10 percent decrease in snowpack, changes in streamflow timing, increased wildfires, and more severe pest outbreaks (California Department of Water Resources 2008).

While susceptible to anticipated changes, proper management of forest habitat provides both climate change adaptation and mitigation benefits. The USDA Forest Service has prepared a resource titled *Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options* (USDA Forest Service 2011a). The guidebook is based on the "science-based principles, processes, and tools necessary to assist with developing adaptation options for national forest lands," which can be useful for all forest managers seeking guidance on climate change. One of the key components of successful adaption in forests will be long-term monitoring and research on the various recommendations and policies that are currently promoted and an adaptive management approach that allows incorporation of new information into the existing management paradigm.

Adaptation

Many existing forest management practices can promote resilience to climate change, and in fact, the best way to ensure successful implementation of high-priority actions is to integrate climate adaptation into existing planning and operational processes. Strategic forest road management will be important in areas prone to flooding and erosion, which can significantly affect water quality due to sediment transport. Incorporating anticipated climate change impacts and vulnerabilities into road management plans and policies will ensure that priorities are based on the changed conditions under which forest roads will need to be managed in the future. Fuel reduction plans should also incorporate climate change considerations so that the threat of high-intensity wildfire situations can be reduced.

Restoration, protection, and proper management of meadows can provide increased water storage and flood protection benefits, which will be very important since increasingly extreme storm events are an anticipated impact of climate change, and precipitation is expected to fall more frequently as rain rather than as snow at lower elevations (California Department of Water Resources 2008). Protection and restoration of headwater streams, including conifer growth in the riparian corridor, could buffer against increasing stream temperature as well as provide habitat connectivity. Healthy forests protect biodiversity, which will be an important buffer against climate change impacts (USDA Forest Service 2011b).

Mitigation

California's forests are carbon sinks, and thus are an important part of climate change mitigation. Sustainable forestry management practices that protect ecosystem services provide greenhouse gas reduction through carbon sequestration as well as other benefits such as water quality protection and energy savings.

Fuel reduction projects, such as mechanical thinning and low severity prescribed fires, initially entail GHG emissions, but could reduce the threat of high-intensity wildfire and thus prevent even greater emissions at a future date as well protect carbon sequestration capacity of remaining trees in thinned stands. Likewise, managing forest roads uses energy in the short-term, but could result in overall energy savings through reduced sediment transport during heavy rainfall events, thus reducing the energy needed to treat the water downstream.

Urban forestry provides multiple benefits related to climate change mitigation such as decreasing and filtering stormwater runoff, reducing ambient summer air and water temperatures, and carbon sequestration. Careful maintenance of existing urban trees may help offset the "urban heat island" effect and reduce the amount of energy used for cooling in the summer months.

Potential Costs

Vegetation Management

Unit costs for vegetation management on private forest lands in California vary between $20 and $1,200 per acre, depending on the methods used. Manual removal of undesirable species ranges from $70 to $1,200 per acre. Herbicide applications range from $20 to $250 per acre. Herbivory costs range from $500 to $1,200 per acre. Mechanical treatments cost between $800 and $1,200 per acre. M. Land, of the USDA Forest Service, reported in 2008 that unit costs for vegetation management on National Forest System lands in California are generally higher, ranging from approximately $1,000 to $2,000 per acre. On federal land, some or all of the costs of vegetation management can be offset by revenues from commercial timber sales.

Fuels/Fire Management

Unit costs for prescribed fire on private forest lands in California are up to $500 per acre for grass and shrub fuels and higher for heavier fuels. R. Griffith, of the USDA Forest Service, has stated that unit costs for fuel reduction projects on National Forest System lands in California ranged from $144 to $2,476 per acre between 2004 and 2006, with an average unit cost of $593 per acre.

Road Management

Road upgrading or “storm-proofing” is used to reduce the potential for sediment delivery to stream channels for roads that will remain in service. Recent unit cost estimates for storm-proofing roads on National Forest System lands in the Coast Ranges ranged from $6,520 to $13,580 per mile. Road decommissioning is generally much more expensive due to greater planning, heavy equipment use, and hauling costs.

Riparian Forests

No unit cost information is available for riparian forest protection, improvement, or restoration. Actions to benefit riparian forests include appropriate management in both the riparian zone (Van de Water and North 2011; Liquori et al. 2012) and upland watershed improvement projects. Unit costs for upland projects should reasonably represent unit costs for riparian forests.

Meadow Groundwater Storage

Costs of recent meadow restoration projects, including planning and environmental compliance, range from approximately $1,000 to $2,500 per acre, according to hydrologist Craig Oehrli of the USDA Forest Service and soil scientist Randy Westmoreland of the Tahoe National Forest, with the higher costs being associated with projects that require construction of new channels using heavy equipment and end-hauled materials. Maintenance costs for meadow restoration projects are generally very low.

Urban Forestry

The costs of urban tree planting and maintenance can vary greatly with location, site conditions, and the type of tree planted. Total planting cost in California can vary between $45 and $160 per tree. After trees are established, maintenance costs are initially minimal, but begin to accrue after about 10 years when trees start to require pruning and hardscape damage from roots needs to be repaired. These maintenance costs can be reduced by careful selection of trees and planting sites. Additional maintenance costs include inspection, administration, legal claims, disease control, removals, and storm litter cleanup. Maintenance costs are typically higher for trees planted in public spaces, since they require more frequent pruning to avoid interference with power and telecommunications lines, and are also generally adjacent to streets and sidewalks. Average annual tree maintenance costs in California, including planting and maintenance, vary from $13 to $65 annually per tree, with costs higher on public versus private lands (McPherson et al. 2005).

Illegal Marijuana Cultivation

Mallery (2011) states that the average cost of cleanup for a 10-acre site on public lands involving the use of a helicopter is $5,000. When environmental remediation is included, the cost of site processing doubles, bringing the average to approximately $10,000 per 10 acres. These expenses include helicopter fees, fuel consumption, wages, food, gear (tents, hard hats, gloves, shovels, etc.), trash disposal fees, and other variable costs not including the cost of raids, eradication, or investigations (Mallery 2011). Removal of water storage detention basins requires care to restore original flow patterns, while minimizing sedimentation and changes to perennial and intermittent streamflows. Additionally, the removal of miles of irrigation tubing is one of the most intensive parts of remediation efforts, in terms of time, effort, and cost (Mallery 2011). Agencies such as the USDA Forest Service have to divert funding from their primary land management functions to finance cleanup efforts because of the high cost cleaning up illegal sites. Law enforcement incurs added costs when needed to address illegal operators before environmental cleanup efforts can take place.

Major Implementation Issues

The issues described in this section are challenges for implementing one or more of the activities described in the "Quantifying Benefits" section.

Information Needs

Forest management agencies and private timber companies are conducting a number of long-term studies in forested watersheds, including Redwood Creek, Caspar Creek, and South Fork Wages Creek in the northern part of the Coast Ranges; Little Creek in the central part of the Coast Ranges; Judd Creek and Battle Creek in the northern Sierra Nevada; Frasier Peak Creek and Bear Trap Creek in the central Sierra Nevada; and Speckerman Creek, Big Sandy Creek, and the Kings River Experimental Watershed in the southern Sierra Nevada. These studies are providing valuable information about the effects of forest management activities on water quality and quantity, particularly related to timber harvesting, road building, and fuel treatments.

Continued monitoring and additional studies are needed to better understand the effects of forest management activities on water quantity and quality over the wide range of climatic and physiographic conditions found in California. The processes and pathways by which water arrives at the land surface as rain or snow and then reaches stream channels, profoundly affects streamflow regimen, erosion, and contaminant transfer, but these processes are generally poorly understood. Methods for estimating evapotranspiration from different vegetation types need refinement and field verification. Knowledge of groundwater recharge, flowpaths, and storage is limited for mountainous forested watersheds, especially those underlain by fractured rocks. Sources of sediment, transport mechanisms, and the relative importance of erosional processes are not well documented.

Monitoring of streamflow to detect effects of land use is most useful on headwater streams that are not affected by artificial regulation or diversion (MacDonald and Coe 2007). A statewide network of 886 streamflow monitoring stations is operated in California by the U.S. Geological Survey (USGS), but only 214 of these gauges are on streams with more than 50 percent forest cover. Only 31 of these are long-term stations (20 or more years of record) on unregulated and undiverted streams, according to C. Parrat of the U.S. Geological Survey, and very few of these stations include water quality monitoring. That density is an average of one long-term stream gauge on an unregulated and undiverted stream for every 1,893 square miles of forest in the state, and some of these stations are in danger of closure due to inadequate long-term funding. A higher density of stream gauges and water quality monitoring stations would be helpful for understanding the distribution, timing, and quality of streamflow from forested watersheds across the state.

Coordination Needs

Forest owners and management agencies have disparate management objectives and constraints, and forest ownership boundaries rarely coincide with natural watershed boundaries, which lead to fragmented, uncoordinated activities that are potentially not effective over the entire watershed. For example, USDA Forest Service funds and staff can generally be used only for work on National Forest System lands, state agencies are frequently prohibited from working on federal lands, and many watershed improvement grant programs are limited to non-federal agencies and organizations. Increased coordination among state, federal, and tribal, private, and non-profit forestry and watershed agencies would provide better opportunities to increase protection of water quality.

A prime example of successful coordination was announced on August 28, 2012 when the Karuk Tribe and the USDA Forest Service signed a Memorandum of Understanding that will protect the Katimiin Cultural Management Area, near present-day Somes Bar, California. This agreement will restore a sacred landscape by using both Karuk traditional knowledge and management practices and the Klamath National Forest Land and Resource Management Plan, which is administered by the Six Rivers National Forest. The agreement will help prevent wildfires as well as build an understanding and cooperation between cultures, the people, and the environment.

Limited Funding for Forest Watershed Restoration

The rate of progress of meadow restoration, road storm-proofing and decommissioning, and vegetation treatment work is largely limited by available funds. In recent years, appropriated federal funding for watershed programs on National Forests has decreased, and revenue-generating timber sales have declined since the mid-1980s. A large proportion of funding for watershed restoration and fuel treatments is now supplied through state bond measures and grant programs. Some grant programs, however, require non-federal matching funds, which limits the eligibility of projects on federal forest lands.

New sources of funding are needed to continue making progress in watershed restoration. Management of forest resources often results in benefits in water supply, flood control, and flow regulation to downstream communities, whose residents, in most cases, are unaware of these benefits of upstream forest management. With an appropriate outreach effort, these communities, which do not usually contribute to the funding of upstream forest management, might be willing to contribute if the costs and benefits could be demonstrated to them.

Regulatory Requirements

Forest management actions that affect the amounts or timing of streamflow, such as attenuating flood peaks and increasing infiltration to groundwater, may be viewed as threats to existing appropriated rights, and could potentially result in water rights litigation. Surface waters may be appropriated by landowners and other users and these appropriators have legal rights to the water they are permitted to divert. In most cases, reduced flood peaks will not result in less available water for downstream users, but water rights may need to be resolved for any additional water made available by meadow restoration, vegetation management, and fuels treatment.

Harvesting of timber on non-federal lands must comply with the California Forest Practices Act and Rules, the California Environmental Quality Act (CEQA), and other state regulations. Timber harvests and other vegetation and fuel management projects on federal lands are analyzed following NEPA guidelines, and appropriate BMPs are determined for protection of water quality. Federal and non-federal timber harvests, vegetation management, and fuels projects are also regulated by the RWQCBs through Waste Discharge Requirements (WDR) or Waivers of Waste Discharge Requirements.

Duplicative environmental reviews and inconsistencies in regulatory requirements among agencies make permitting of vegetation management projects difficult, increase costs, and slow the rate of progress of watershed restoration efforts. For example, Waste Discharge Requirement stipulations and conditions for Waivers of Waste Discharge Requirements vary among the nine RWQCBs. In some situations, projects require more than one permit related to water quality, sometimes from as many as three different agencies. A streamlined "one-stop shopping" approach would expedite projects and lower implementation costs.

Prescribed fires, which are being more widely used for vegetation management, are regulated by the California Air Resources Board (ARB) and local air pollution control agencies and can only be conducted on days approved for burning on the basis of air quality conditions. The USDA Forest Service is currently working cooperatively with the RWQCBs to increase opportunities for prescribed burning. Additionally, the ARB, along with the U.S. Environmental Protection Agency (EPA) and local air quality management districts, regulate biomass power plants that often utilize woody material generated by vegetation management projects.

Overarching Recommendations

The following recommendations are intended to address the issues identified in the previous section.

Monitoring and Research

Long-term monitoring is needed to understand hydrologic changes resulting from climate change and management actions, and more data collection stations are needed to accurately determine how changes in hydrology and water quality are related to climate change and forest management activities:

1. Additional stream gauges are needed throughout the forested regions of California to adequately represent the existing range of hydroclimatic and geologic conditions. In particular, gauges would be helpful on small (first to third order) reaches on unregulated and undiverted streams, in both managed and pristine watersheds.

2. Additional precipitation stations and snow courses are needed to increase the accuracy of determinations of climatic trends and evaluations of effects of management activities.

3. Additional water quality and sediment monitoring stations are needed to quantify the effects of climate change and forest management activities on surface water quality.

4. Additional long-term monitoring wells would be useful for understanding groundwater resources in forested watersheds.

Forest management for water resources could benefit from additional research on:

5. Effectiveness of BMPs in protecting beneficial uses of water.
6. Effects of vegetation and fuels management on soil moisture, groundwater recharge, and streamflow. More quantification of both the short- and long-term effects of prescribed fire on soil and water nutrient status is needed to determine the most beneficial and most ecosystem friendly return interval as a management strategy. Determination of the impacts of burn frequency on soil and vegetative properties that influence infiltration, percolation, surface runoff, and groundwater discharge would also be advantageous (Tahoe Science Consortium 2007).
7. Effects of wildfires and wildfire control measures on water quantity, water quality, and aquatic organisms.
8. Role and magnitude of groundwater storage in mountain meadows and its effects on streamflow regulation, and of the potential benefits of meadow restoration for water quantity and quality.
9. Sediment sources and erosion processes in managed and unmanaged forested watersheds.
10. Effects of riparian forests in maintaining stream temperatures and cycling nutrients.
11. Effects of urban trees in reducing non-point source pollution.

Coordination

Actions that would provide for better multi-party coordination of forest management, including communication between downstream water users and upstream forest managers, residents and workers, include:

12. Involvement of forest managers in integrated resource water management plan development.
13. Determination of mutually agreeable objectives for forest and meadow protection and restoration in terms of land area and timelines, and commitments from forest managers to meet these objectives.
14. Expanded authority and interagency agreements to allow federal, state, and non-governmental agencies to share expertise, staff time, and funding across jurisdictional boundaries for the purposes of watershed and water quality protection and improvement.
15. Develop a public education campaign directed at water users and communities in the Central Valley, Bay Area, and Southern California to increase support of forest management funding for improvement of water resources, particularly related to vegetation management.
16. Resolve water rights issues related to restoration of forested watersheds, and develop mechanisms for marketing of additional water made available by restoration projects.

17. Expand the scope of state water resource development and conservation measures to include headwaters areas of the state and urban forestry in metropolitan areas.

18. Increase eligibility of federal agencies for grant programs, and allow federal funds and in-kind services to be used as grant matches.

Regulatory Requirements

The water quality management plans developed by the SWRCB and forest management agencies can be revised to address concerns with impaired water bodies, while at the same time providing consistency and cost-effectiveness. Regulatory workloads can be reduced by combining environmental compliance into fewer streamlined procedures that would apply to all projects that meet criteria for low risk of adverse watershed effects or net beneficial water quality effects.

The following recommendations are directed at regulatory oversight of forest water resources:

19. Revise forest management agency water quality programs as necessary to identify, prioritize, and repair existing pollution sources, improve BMPs, and modify monitoring programs.

20. Incorporate existing Management Agency Agreements between the SWRCB and forest management agencies into cost-effective and consistent regulatory mechanisms compliant with current state law.

21. Deregulate low-risk noncommercial vegetation and fuels management projects that reduce the risks of catastrophic wildfires and therefore have net beneficial effects on water quality.

22. Complete a water quality management plan for the U.S. Bureau of Land Management.

23. Change the SWRCB's Water Quality Control Policy for Addressing Impaired Waters to incorporate Category 4B of EPA's Integrated Reporting Guidance, thereby allowing water quality management programs of other entities to be used to attain water quality standards in 303(d)-listed impaired waters in lieu of adopting total maximum daily loads (TMDLs) and duplicative TMDL implementation plans.

Beneficial Forest Management in Areas with Commercial-Scale Marijuana Cultivation

24. A combination of innovative prevention and enforcement approaches are needed to gain control over commercial-scale marijuana operations in California. Google Earth imagery and other remote sensing tools, such as infrared heat imaging, are now available to allow for increased site detection and information gathering. Even with these tools, however, new law enforcement strategies, a commitment to long-term investment of adequate resources, and large-scale changes in public policy are needed to change the current situation (Mallery 2011).

25. Education is also an important component of preserving public lands for public benefit, such as the production of abundant, clean water. Major knowledge gaps exist between the public, politicians, and law enforcement agency personnel (Mallery 2011), although several recent newspaper stories, blog postings, and PowerPoint presentations to regulatory agencies

and others have heightened general awareness of this threat to water quality in California (Dawson 2011). The effects of marijuana cultivation on water quality and fisheries resources were part of a state legislative hearing in Sacramento in February 2012, with discussion of possible legislative action. Water quality and fisheries protection are two essential components of a successful California Water Plan.

26. Commercial-scale marijuana cultivation on public and private lands is producing significant environmental problems. There are possible solutions, but without essential changes in law enforcement strategies and public policy, it is a problem that can be expected to continue into the foreseeable future (Mallery 2011).

Special Author's Note

This chapter is dedicated to Melvin Carmen of the North Fork Mono Tribe in 2009, in recognition of his vision of incorporating Forest Management into the California Water Plan.

References

References Cited

Allen-Diaz BH. 1991. "Water table and plant species relationships in Sierra Nevada meadows." [Journal.] American Midland Naturalist. 126:30-43.

Amaranthus M, Jubas H, Arthur D. 1989. "Stream shading, summer streamflow and maximum water temperature following intense wildfire in headwater streams." In: N. Berg N, editor. *Proceedings of the Symposium on Fire and Watershed Management, 26–28 October 1988*. Berkeley (CA): USDA Forest Service. Pacific Southwest Forest and Range Experiment Station. General Technical Report PSW-109. pp. 75-78.

Backer DM, Jensen SE, McPherson GR. 2004. "Impacts of fire-suppression activities on natural communities." [Journal.] Conservation Biology 18(4): 937-946.

Bales RC, Battles JJ, Chen Y, Conklin MH, Holst E, O'Hara K, Saksa P, Stewart W. 2011. *Forests and Water in the Sierra Nevada: Sierra Nevada Watershed Ecosystem Enhancement Project*. Report number 11.1. Merced (CA): Sierra Nevada Research Institute University of California, Merced. 39 pp.

Barbour M, Pavlik BS, Lindstrom S. 1993. *California's Changing Landscapes: Diversity and Conservation of California Vegetation*. Sacramento (CA): The California Native Plant Society. 244 pp.

Benavides-Solorio J, MacDonald LH. 2001. "Post-fire runoff and erosion from simulated rainfall on small plots, Colorado Front Range." [Journal.] Hydrological Processes. 15(15):2931-2952.

Berlow EL, D'Antonio CM, Reynolds SA. 2002. "Shrub expansion in montane meadows: the interaction of local-scale disturbance and site aridity." [Journal.] Ecological Applications. 12(4):1103-1118.

Beschta, RL 1990. "Effects of fire on water quantity and quality." In: Walstad JD, Radosevich SR, Sandberg DV editors. *Natural and Prescribed Fire in Pacific Northwest Forests*. Corvallis (OR): Oregon State University Press. pp. 219–232.

Best DW, Kelsey HM, Hagans DK, Alpert M. 2004. "Role of fluvial hillslope erosion and road construction in the sediment budget of Garret Creek, Humboldt County, California." In: Nolan KM, Kelsey HM, Marron DC, editors. *Geomorphic Processes and Aquatic Habitat in the Redwood Creek Basin, Northwestern California*. Washington (DC): U.S. Geological Survey. Professional Paper 1454. pp. M1-M11

Beyers JL 2004. "Postfire seeding for erosion control: Effectiveness and impacts on native plant communities." [Journal.] Conservation-Biology 18: 947-956.

Blanchard FB. 1962. *Logging and Water Supply in the Mokelumne River Basin—A Preliminary Appraisal*. File Report. Oakland (CA): East Bay Municipal Utilities District, Water Resources and Planning Division. 3 pp.

Brandow CA, Cafferata PH, Munn JR. 2006. *Modified Completion Report Monitoring Program: Monitoring Results from 2001 through 2004. Monitoring Study Group Final Report*. Sacramento (CA): California State Board of Forestry and Fire Protection. 80 pp.

Cafferata PH, Munn JR. 2002. *Hillslope Monitoring Program: Monitoring Results from 1996 through 2001. Monitoring Study Group Final Report*. Sacramento (CA): California State Board of Forestry and Fire Protection. 114 pp.

Cafferata PH 2005. *Herbert Avenue Meadow Restoration Project Hydrologic Review*. Memorandum dated May 25, 2005, sent to Mary Huggins, South Lake Tahoe, CA. California Department of Forestry and Fire Protection, Sacramento, CA. 12 p.

Cafferata PH, Berbach M, Burke J, Hendrix J, Klamt R, Macedo R, Spittler T, Vyverberg K, Wright-Shacklett C. 2005. *Flood Prone Area Considerations in the Coast Redwood Zone. Final Report of the Riparian Protection Committee*. Sacramento (CA): California Department of Forestry and Fire Protection. 67 pp.

Cafferata PH, Hall DO, Gentry GD. 2007a. "Applying scientific findings to forest practice regulations in California." In: *Proceedings of the 1997 NCASI West Coast Regional Meeting*. Special Report No. 97-13. 1997 NCASI West Coast Regional Meeting. 2007. Sept. 26-27, 1997. Portland (OR): National Council for Air and Stream Improvement. Research Triangle Park (NC): p. H-39 to H-46.

Cafferata PH, Coe DBR, Harris RR. 2007b. "Water resource issues and solutions for forest roads in California." [Journal.] Hydrological Science and Technology. 23(1-4):39-56.

Calder I, Hofer T, Vermont S, Warren P. 2007. "Towards a new understanding of forests and water." [Journal.] Unasylva. 229. 58:3-43.

California Department of Forestry and Fire Protection. 2003a. *The Changing California: Forest and Range 2003 Assessment Technical Report, Forest Land Base*. Sacramento (CA): California Department of Forestry and Fire Protection, Fire and Resource Assessment Program. Chapter 2. Productive Capacity. Viewed online at: http://www.frap.cdf.ca.gov/assessment2003/Chapter2_Area/forestlandbase.html. Accessed: Nov. 10, 2009.

———. 2003b. *The Changing California: Forest and Range Assessment: Assessment Summary, Fire and Resource Assessment Program*. Sacramento (CA): California Department of Forestry Fire Protection. Variously paged. Viewed online at: http://www.frap.cdf.ca.gov/assessment2003/index.html.

———. 2010a. *California's Forests and Rangelands: 2010 Assessment*. Sacramento (CA): California Department of Forestry Fire Protection. Fire and Resource Assessment Program. 343 pp. Viewed online at: http://frap.fire.ca.gov/assessment2010.html.

———2010b. *California's Forests and Rangelands: 2010 Strategy Report*. Sacramento (CA): California Department of Forestry Fire Protection. Fire and Resource Assessment Program. 208 pp. Viewed online at: http://www.sierrainstitute.us/burneycreek-hatcreek/California_Forest_Strategy_Report_2010.pdf.

———. 2013. "Demonstration State Forests." Sacramento (CA): California Department of Forestry Fire Protection. [Web site.] Viewed online at: http://calfire.ca.gov/resource_mgt/resource_mgt_stateforests.php.

California Department of Water Resources. 2008. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water*. Sacramento (CA): California Department of Water Resources.

Campbell CG, Allen-Diaz B. 1997. "Livestock grazing and riparian habitat water quality: an examination of oak woodland springs in the Sierra foothills of California." In: Pillsbury NH, Verner, J. Tietje WD, editors. *Proceedings of a Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues*. General Technical Report PSW-GTR-160. Mar. 19-22, 1996. San Luis Obispo (CA): USDA Forest Service. Pacific Southwest Research Station. Albany (CA): pp. 339-346. Viewed online at: http://www.treesearch.fs.fed.us/pubs/28193.

Carroll EM, Miller WW, Johnson DW, Saito LS, Qualls RG, Walker RF. 2007. "Spatial analysis of a high magnitude erosion event following a Sierran wildfire." [Journal.] Journal of Environmental Quality. 36:1105-1111.

Christensen GA, Campbell SJ, Fried JS, technical editors. 2008. *California's Forest Resources 2001–2005: Five-year Forest Inventory and Analysis Report*. General Technical Report PNW-GTR-763. Portland (OR): USDA Forest Service. Pacific Northwest Research Station. 183 pp.

Coe DBR. 2006. *Sediment Production and Delivery from Forest Roads in the Sierra Nevada*. [Master's thesis.] Fort Collins (CO): Colorado State University. 110 pp.

Cohen WL. 1982. *Effects of the Atlas Peak Fire on Surface Water Quality in Upper Milliken Creek Watershed, Napa County, California*. Master of Science Thesis. Davis (CA): University of California, Davis. Davis, CA. 132 pp.

Conard SG, Beyers JL, Wohlgemuth PM. 1995. "Impacts of post-fire grass seeding on chaparral ecosystems: what do we know and where do we go from here?" Fairfield (WA): In: Keeley JE, Scott T editors. *Brushfires in California Wildlands: Ecology and Resource Management*. International Association of Wildland Fire. pp. 149-161.

Cook C, Dresser A. 2007. "Erosion and channel adjustments following forest road decommissioning Six Rivers National Forest." In: Furniss M, Clifton C, Ronnenberg K, editors. *Advancing the Fundamental Sciences: Proceedings of the Forest Service National Earth Sciences Conference*. Forest Service National Earth Sciences Conference. Oct. 18-2, 2004. San Diego (CA): USDA Forest Service. Pacific Northwest Research Station. Portland (OR): pp. 297-309.

Cornwell K, Brown K. 2008. *Physical and Hydrological Characterization of Clark's Meadow in the Last Chance Watershed of Plumas County*. Sacramento (CA): Report to the Natural Heritage Institute Mountain Meadows IRWMP. California State University Sacramento. Department of Geology. 38. pp.

Cram DS, Baker TT, Fernald AG, Madrid A, Rummer B. 2007. "Mechanical thinning impacts on runoff infiltration and sediment yield following fuel reduction treatments in a southwestern dry mixed conifer forest." [Journal.] Journal of Soil and Water Conservation. 62(5):359-366.

California State Board of Forestry and Fire Protection. 1996. "Assets at risk and their role in the fire plan: water and watersheds." In: *California Fire Plan: A Framework for Minimizing Costs and Losses from Wildland Fires*. Sacramento (CA): California State Board of Forestry and Fire Protection. pp. 73-82.

Council of Western State Foresters. 2007. *Forestry Best Management Practices for Western States: A Summary of Approaches to Water Quality Implementation and Effectiveness Monitoring. Final Report*. Lakewood (CO): Council of Western State Foresters. 20 pp. Viewed online at: http://www.wflccenter.org/news_pdf/240_pdf.pdf.

Dailey S, Fites JA, Reiner A, Mori S. 2008. *Fire Behavior and Effects in Fuel Treatments and Protected Habitat on the Moonlight Fire*. Vallejo (CA): USDA Forest Service, Pacific Southwest Region. Adaptive Management Service Enterprise Team. 60 pp. Viewed online at: http://www.fs.fed.us/r5/hfqlg/monitoring/resource_reports/fire_and_smoke/dfpz_effectiveness/moonlight_fire_effects_assessment.pdf. Accessed Nov. 10, 2009.

Dawson B. 2011. "Pollute, poach, dewater: legacies of illicit cannabis grows." Green Blog - UC work in natural resources, pest management, climate change and sustainable agriculture. Oakland (CA): University of California Agriculture and Natural Resources. [Blog.] Nov., 16. Viewed online at: http://ucanr.org/sites/UCCNP/Green_Blog/?blogpost=6188&blogasset=18704.

Dombeck M. 2007. "Deterioration of forest roads threatens our drinking water." San Jose Mercury News. San Jose (CA): San Jose Mercury News. [Web site.] Viewed online at: http://www.mercurynews.com/opinion/ci_7211103. Accessed Jan. 2012.

Driscoll DG, Carter JM, Ohlen DO. 2004. *Hydrologic Effects of the 1988 Galena Fire, Black Hills Area, South Dakota*. Denver (CO): Water-Resources Investigations Report 03-4323. U.S. Geological Survey. 67 pp. Viewed online at: http://pubs.water.usgs.gov/wri034323.

Dudley N, Stolton S. 2003. *Running Pure: The Importance of Forest Protected Areas to Drinking Water*. Washington (DC): World Bank/WWF Alliance for Forest Conservation and Sustainable Use. 114 pp. Viewed online at: http://www.panda.org/what_we_do/how_we_work/conservation/forests/publications/?uNewsID=8443.

Dwire KA, Kauffman JB, Baham JE. 2006. "Plant species distribution in relation to water-table depth and soil redox potential in montane riparian meadows." [Journal.] Wetlands. 26(1):131-146.

Elliot WJ. 2010. "Effects of forest biomass use on watershed processes in the western United States." [Journal.] Western Journal of Applied Forestry. 25(1):12-17.

Fiori RA. 2005. *Instream and Riparian Dynamics Following Wildfire in an Alluvial Old-growth Redwood Forest--Canoe Creek, Humboldt Redwoods State Park*. California State Parks. North Coast Redwoods District. Eureka (CA): 22 pp.

Fryoff-Hung A. Viers JH. 2013. *Sierra Nevada Meadow Hydrology Assessment, Final Project Report*. University of California, Davis, 1114 pp. Viewed online at http://meadows.ucdavis.edu/data/9.

Furniss MJ, Roelofs TD, Yee CS. 1991. "Road construction and maintenance." In: Meehan WR, editor. I*nfluences of Forest and Rangeland Management*. Bethesda (MD): Special Publication 19. American Fisheries Society. pp. 297-324.

Furniss MJ, Ledwith TS, Love MA, McFadin BC, Flanagan SA. 1998. *Response of Road-Stream Crossings to Large Flood Events in Washington, Oregon and Northern California*. Washington (DC): USDA Forest Service. Technology and Development Program. 14 pp.

Giusti GA. 2012. Illicit cannabis production impacts on forest and wildland resources. Sacramento (CA): Presentation to the California State Board of Forestry and Fire Protection. Apr. 4, 2012. [PowerPoint presentation.] Viewed online (2010 version of the presentation) at: http://ucanr.org/blogs/Green/blogfiles/9273.pdf.

Gokbulak F. Serengil Y, Ozhan S, Ozyuvaci N, Balc, N. 2008. "Effect of timber harvest on physical water quality characteristics." [Journal.] Water Resources Management. 22(5):635-649.

Grace JM, Skaggs RW, Chescheir GM. 2006. "Hydrologic and water quality effects of thinning loblolly pine." [Journal.] Transactions of the American Society of Agricultural Engineers. 49(3):645-654.

Hammersmark CT, Rains MC, Mount JF. 2008. "Quantifying the hydrological effects of stream restoration in a montane meadow, Northern California USA." River Research and Applications Vol. 24 (6): 735-753. [Journal]. Viewed online at: http://onlinelibrary.wiley.com/doi/10.1002/rra.1077/abstract.

Hammersmark CT, Dobrowski SZ, Rains MC, Mount JF. 2010. "Simulated Effects of Stream Restoration on the Distribution of Wet-Meadow Vegetation." [Journal.] Restoration Ecology. 18:882–893.

Harris RR. 2011. *Policies and Procedures for Protecting Anadromous Salmonid Habitat in Del Norte, Humboldt, Mendocino, Trinity and Siskiyou Counties*. Final Report prepared for the Five Counties Salmonid Conservation Program. Weaverville (CA): 52 pp. Viewed online at: http://www.5counties.org/docs/2011_reassessment.pdf.

Harris RR, Cafferata PH. 2005. *Forest Loss and Fragmentation; Session 2: Impacts and Implications—Impacts on water quantity and quality [Abstract]*. California Forest Futures 2005 Conference, May 24-25, 2005, Sacramento, CA.

Hatchett B, Hogan MP, Grismer ME. 2006. "Mechanical mastication thins Lake Tahoe forest with few adverse impacts." [Journal.] California Agriculture. 60(2):77-82.

Heard AM. 2005. *Effects of Landscape Scale Prescribed Fire on Hydrology and Stream Chemistry*. Master of Science Thesis. Fort Collins (CO): Colorado State University. 119 pp.

Hill BR. 1990. "Groundwater discharge to a headwater valley northwestern Nevada USA." [Journal.] Journal of Hydrology. 113:265-283.

Hill BR, Mitchell-Bruker S. 2010, Comment on "A framework for understanding the hydroecology of impacted wet meadows in the Sierra Nevada and Cascade Ranges, California, USA." [Comment on paper published in Hydrogeology Journal 17:229–246. 2009, by Loheide II SP, Deitchman RS, Cooper DJ, Wolf EC, T. Hammersmark CT, Lundquist JD.] Hydrogeology Journal 18(7):1741-1743.

Hoffman J, Roby K, Bohm B. 2013, *Effects of Meadow Restoration on Stream Flow in the Feather River Watershed: A Review Based on Monitoring Data and Pertinent Research, Version 5.5 (final)*, June 12, 2013, report to Feather River Coordinated Resource Management Council Executive Committee, 33 pp.

Hubbert K, Busse M, Overby S, Shestak C. 2010. Soil heating beneath burn piles: effects on soil physical properties and water chemistry in the Lake Tahoe Basin. [Poster presentation.] ASA, CSSA, SSSA 2010 International Annual Meeting, Oct. 21-Nov 4, 2010. Long Beach (CA): USDA Forest Service. Pacific Southwest Research Station.

Hughes JE. 1934. *Erosion Control Progress Report*. Plumas National Forest. Milford Ranger District. 26 pp.

Ice G, Dent L, Robben J, Cafferata P, Light J, Sugden B, Cundy T. 2004. "Programs Assessing Implementation and Effectiveness of State Forest Practice Rules and BMPs in the West." Water, Air, and Soil Pollution: Focus 4(1): 143-169.

Ice G, Shilling EG, Vowell JG. 2010. "Trends for Forestry Best Management Practices Implementation." Journal of Forestry. 108. 267-273.

Jewett DG, Lord ML, Miller JR, Chambers JC. 2004. "Geomorphic and hydrologic controls on surface and subsurface flow regimes in riparian meadow ecosystems." In: Chambers JC, Miller JR, editors. *Great Basin Riparian Ecosystems*. Covelo (CA): Society for Ecological Restoration International. Island Press. Chapter 5, pp. 124-161.

Jones JA, Grant GE. 1996. "Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon." [Journal.] Water Resources Research. 32(4):959-974.

Kattelmann R, Embury M. 1996. "Riparian areas and wetlands." In: *Sierra Nevada Ecosystem Project. Final Report to Congress, Volume III: Assessments, Commissioned Reports and Background Information*. Davis (CA): University of California, Centers for Water and Wildland Resources. Chapter 5, pp. 201-274. Viewed online at: http://pubs.usgs.gov/dds/dds-43/VOL_III/VIII_TOC.PDF.

Kellar G, Sherar J. 2003. *Low Volume Roads Engineering: Best Management Practices Field Guide.* Washington (DC): Prepared for U.S. Agency for International Development by the Conservation Management Institute, Virginia Polytechnic Institute and State University and USDA Forest Service. Viewed online at: http://pdf.usaid.gov/pdf_docs/PNADB595.pdf.

Korte A, MacDonald LH. 2007. *Preliminary Summary: Sediment Production and Delivery in the Southern Sierra Nevada*. Watershed Science Program, Colorado State University, Fort Collins (CO). 5 pp. [Unpublished paper.]

Kraebel CJ, PillsburyAF. 1934, Handbook of Erosion Control in Mountain Meadows. USDA Forest Service. California Forest and Range Experiment Station. Berkeley(CA): 69 pp.

Krieger DJ. 2001. *The Economic Value of Forest Ecosystem Services: A Review*. Washington (DC): The Wilderness Society. 40 pp. Viewed online at: http://www.cfr.washington.edu/classes.esrm.465/2007/readings/WS_valuation.pdf.

Lautz LK. 2008. "Estimating groundwater evapotranspiration rates using diurnal water-table fluctuations in a semi-arid riparian zone." [Journal.] Hydrogeology Journal. 16: 483-497.

Liang L, Kavvas ML, Chen ZQ, Anderson M, Ohara N, Wilcox J, Mink L. 2007. "Modeling river restoration impact on flow and sediment in a California watershed." In: Kabbes KC, editor. *Proceedings of the 2007 World Environmental and Water Resources Congress*. 2007 World Environmental and Water Resources Congress. May 15-19, 2007. Tampa (FL): American Society of Civil Engineers. Reston (VA): pp. 1-10. Viewed online at: http://ascelibrary.org/doi/abs/10.1061/40927(243)353.

Ligon F, Rich A, Rynearson G, Thornburgh D, Trush, W. 1999. *Report of the Scientific Review Panel on California Forest Practice Rules and Salmonid Habitat*. Sacramento (CA): California Natural Resources Agency and the National Marine Fisheries Service. 181 pp.

Loheide SPII, Gorelick SM. 2005. "A local-scale, high-resolution evapotranpiration mapping algorithm (ETMA) with hydroecological applications at riparian meadow restoration sites." [Journal.] Remote Sensing of Environment. 98: 182-200.

Loheide SP II, Gorelick SM. 2007. "Riparian hydroecology: a coupled model of the observed interactions between groundwater flow and meadow vegetation patterning." [Journal.] Water Resources Research. 43:W07414. Viewed online at: http://onlinelibrary.wiley.com/doi/10.1029/2006WR005233/abstract.

Liquori M, Cafferata P, Boston K, Gienger R, Hope D. 2012. "The VTAC Committee: developing guidance for an alternative regulatory pathway to the anadromous salmonid protection rules." In: Standiford RB, Weller TJ, Piirto DD, Stuart, JD technical coordinators. Proceedings of Coast Redwood Forests in a Changing California: A Symposium for Scientists and Managers. Albany (CA): USDA U.S. Forest Service. Pacific Southwest Research Station General Technical Report PSW-GTR-238. pp 79-89.

McCashion JD, Rice RM. 1983. "Erosion on logging roads in northwestern California: How much is avoidable?" [Journal.] Journal of Forestry. 81(1):23-26.

McClurkin DC, Duffy PD, Nelson NS. 1987. “Changes in forest floor and water quality following thinning and clearcutting of 20-year-old pine.”[Journal.] Journal of Environmental Quality. 16:237-241.

MacDonald LH, Coe D, Litschert S. 2004. “Assessing cumulative watershed effects in the central Sierra Nevada: hillslope measurements and catchment-scale modeling.” In: Murphy DD, Stine PA, editors. *Proceedings of the Sierra Nevada Science Symposium*. Sierra Nevada Science Symposium. Oct. 7-10, 2002, Kings Beach (CA): USDA Forest Service. Pacific Southwest Research Station. Albany (CA): pp. 149-157. Viewed online at: http://www.treesearch.fs.fed.us/pubs/26449.

MacDonald LH, Brown E, Pietraszek JH, Welsh M, Eccleston D, Larsen IJ. 2006. “Long-term Sediment Production and Recovery Rates from Forest Thinning, Roads, and Wildfires.” American Geophysical Union, Fall Meeting 2006, Abstract #B22E-08.

MacDonald LH, Coe, D. 2007. “Influence of headwater streams on downstream reaches in forested areas.” [Journal.] Forest Science. 53(2):148-168.

Maco S, McPherson G, Simpson J, Peper P, Xiao Q. 2003. *City of San Francisco, California Street Tree Resource Analysis*. Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service. CUFR-3.

McPherson G, Simpson J, Peper P, Maco S, Xiao Q. 2005. “Municipal forest benefits and costs in five U.S. cities.” [Journal.] Journal of Forestry. (Dec):411-416.

Madej MA. 2001. “Erosion and sediment delivery following removal of forest roads.” [Journal.] Earth Surface Processes and Landforms. 26:1-16.

Madrid A, Fernald AG, Baker TT, Vanleeuwen DM. 2006. “Evaluation of silvicultural treatment effects on infiltration, runoff, sediment yield, and soil moisture in a mixed conifer New Mexico forest.” [Journal.] Journal of Soil and Water Conservation. 61(3):159-168.

Mahlum SK, Eby LA, Young MK, Clancy CG, Jakober M. 2011. “Effects of wildfire on stream temperatures in the Bitterroot River Basin, Montana.” [Journal.] International Journal of Wildland Fire. 20:240–247.

Mallery M. 2011. “Marijuana national forest: encroachment on California public lands for cannabis cultivation.” Office of Undergraduate Research, University of California, Berkeley. Berkeley Undergraduate Journal. 23(2). 50 pp. Viewed online at: http://escholarship.org/uc/item/7r10t66s.

Martin S. 2006. Topics in mountain meadows. Merced (CA): [PowerPoint class presentation.] University of California, Merced. 45 pp.

Martinson EJ, Omi PN. 2003. “Performance of fuel treatments subjected to wildfires.” In: Omi PN, Joyce LA. editors. *Fire, Fuel Treatments, and Ecological Restoration: Conference Proceedings, April 16-18, 2002*. Fort Collins (CO): Proceedings RMRS-P-29. USDA Forest Service. Rocky Mountain Research Station. pp. 7-13

Meixner T, Wohlgemuth P. 2004. “Wildfire impacts on water quality.” [Journal.] Southwest Hydrology 3(5):24-25.

Micheli ER, Kirchner JW. 2002. “Effects of wet meadow riparian vegetation on streambank erosion. 2. Measurements of vegetated bank strength and consequences for failure mechanics.” [Journal.] Earth Surface Processes and Landforms. 27:687-697.

Miller WW, Johnson DW, Loupe TM, Sedinger JS, Carroll EM, Murphy JD, Walker RF, Glass D. 2006. “Nutrients flow from runoff at burned forest site in Lake Tahoe Basin.”[Magazine article] California Agriculture. University of California Agriculture and Natural Resources. Apr-Jun:65-71.

Moody JA, Martin DA. 2001. “Post-fire, rainfall intensity-peak discharge relations for three mountainous watersheds in the western USA. [Journal.] Hydrological Processes 15: 2981-2993.

Moody JA, Martin DA, Cannon SH. 2008. “Post-wildfire erosion response in two geologic terrains in the western USA.” [Journal.] Geomorphology. 95:103-118.

Moore RD, Wondzell SM. 2005. “Physical hydrology and the effects of forest harvesting in the Pacific Northwest: a review.” [Journal.] Journal of the American Water Resources Association. Aug.:763-784.

Moser E. 2007. *Aerial Application of Fire Retardant Environmental Assessment: Hydrology Specialist Report*. USDA Forest Service. T.E.A.M.S. Enterprise Unit. 10 pp. Viewed online at: http://www.fs.fed.us/fire/retardant/references/01Hydro.pdf.

Murphy K, Rich T, Sexton T. 2007. *An Assessment of Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition on the Angora Fire*. Vallejo (CA): USDA Forest Service. R5-TP-025. 32 pp.

Naiman RJ, Fetherston KL, McKay SJ, Chen J. 1998. "Riparian forests." In: Naiman RJ, Bilby RE, editors. *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*. New York: Springer-Verlag. pp. 289-323. [Book.]

National Academy of Sciences. 2008. *Hydrologic Effects of a Changing Forest Landscape*. Washington (DC): Report in Brief. Report brief was prepared by the National Research Council. Viewed online at: http://dels.nas.edu/resources/static-assets/materials-based-on-reports/reports-in-brief/forest_hydrology_final.pdf.

National Interagency Fire Center (. 2010. "Suppression chemicals and delivery systems." In: Interagency Standards for Fire and Fire Aviation Operations ("Red Book"). Boise (ID): Viewed online at: http://www.nifc.gov/PUBLICATIONS/redbook/2011/Ch12.pdf. Chapter 12. pp 12-1—12-6.

National Wildfire Coordinating Group Training Working Team. 2004. *Resource Advisor's Guide for Wildland Fire*. PMS 313. NFES 1831. Boise (ID): National Interagency Fire Center. 14 pp. Viewed online at: http://www.nwcg.gov/pms/pubs/RAguide_2004.pdf.

Neary DG, Ryan KC, DeBano LF, editors. 2005. *Wildland Fire in Ecosystems: Effects of Fire on Soils and Water*. General Technical Report RMRS-GTR-42, Vol. 4. Ogden (UT): USDA Forest Service, Rocky Mountain Research Station. 250 pp.

Norman S, Loupe T, Keely J. 2008. *Heavenly Creek SEZ Demonstration Project 2007 Soil Monitoring Report*. South Lake Tahoe (CA): USDA Forest Service. Lake Tahoe Basin Management Unit. 58 pp. Viewed online at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm9_045987.pdf.

Novak DJ, Greenfield EJ. 2009. *Urban and Community Forests of the Pacific Region: California, Oregon, Washington*. GTR NRS-65. St. Paul (MN): USDA Forest Service, Northern Research Station. 43 pp.

Ohara N, Kavvas, ML, Chen ZQ, Liang L, Anderson M. Wilcox J, Mink L. 2013. *Modelling Atmospheric and Hydrologic Processes for Assessment of Meadow Restoration Impact on Flow and Sediment in a Sparsely Gauged California Watershed*. Hydrological Processes. DOI: 10.1002/hyp.9821.,14 pp.

Omi PN, Martinson, EJ. 2004. "Effectiveness of thinning and prescribed fire in reducing wildfire severity." In: Murphy DD, Stine PA editors. *Proceedings of the Sierra Nevada Science Symposium: Science for Management and Conservation*. Albany (CA): General Technical Report PSW-193. USDA Forest Service. pp. 87-92

Onda Y, Dietrich WE, Booker F. 2007. "Evolution of overland flow after a severe forest fire Point Reyes California." [Journal.] Catena. 72:13-20.

Pacific Watershed Associates. 2005. *Evaluation of Road Decommissioning CDFG Fisheries Restoration Grant Program 1998 to 2003*. Arcata (CA): Pacific Watershed Associates. Final Report submitted to the California Department of Fish and Game under Contract #P0210559. 91 pp. Viewed online at: http://www.pacificwatershed.com/sites/default/files/CDFG_PWA_decom_report.pdf.

Peterson DH, Stewart I, Murphy F. 2008. "Principle hydrologic responses to climatic and geologic variability in the Sierra Nevada, California." [Journal.] San Francisco Estuary and Watershed Science. California Bay-Delta Authority Science Program and John Muir Institute of the Environment. 6(1): Article 3.

Potts DF, Peterson DL, Zuuring HR. 1989. *Estimating Postfire Water Production in the Pacific Northwest*. Berkeley (CA): USDA Forest Service. Research Paper PSW-197. USDA Forest Service. Pacific Southwest Forest and Range Experiment Station. 9 pp.

Ratliff RD. 1985. *Meadows in the Sierra Nevada of California: State of Knowledge*. Berkeley (CA): General Technical Report PSW-84. USDA Forest Service. Pacific Southwest Forest and Range Experiment Station. 52 pp. Viewed online at: http://www.treesearch.fs.fed.us/pubs/27313.

Rector JR, MacDonald LH 1987. "Water yield opportunities on National Forest lands in the Pacific Southwest Region." In: *Proceedings, California Watershed Management Conference*. Report No. 11. Wildland Resources Center. University of California, Berkeley. pp. 68-73.

Reid LM. 2012. "Comparing hydrologic responses to tractor-yarded selection and cable-yarded clearcut logging in a coast redwood forest." In: Standiford RB, Weller TJ, Piirto DD, Stuart JD technical coordinators. *Proceedings of the Coast Redwood Forests in a Changing California: A Symposium for Scientists and Managers*. Albany (CA): General Technical Report PSW-GTR-238. USDA Forest Service. Pacific Southwest Research Station. pp. 141-151.

Reneau SL, Katzman D, Kuyumjian GA, Lavine A, Malmon DV. 2007. "Sediment delivery after a wildfire." [Journal.] Geology. 35(2):151-154.

Robichaud PR. 2000. "Forest fire effects on hillslope erosion: what we know." Portland (OR): Watershed Management Council (WMC) Archives 9(1). Winter 2000. at Watershed.org. Viewed online at: http://www.watershed.org/?q=node/329. Accessed: Nov. 12, 2009.

Robichaud PR, Beyers JL, Neary DG. 2000. *Evaluating the Effectiveness of Postfire Rehabilitation Treatments*. Fort Collins (CO): General Technical Report RMRS-GTR-63. USDA Forest Service. Rocky Mountain Research Station. 89 pp. Viewed online at: http://www.fs.fed.us/rm/pubs/rmrs_gtr063.pdf.

Robichaud PR, Pierson FB, Brown, RE. 2007. "Runoff and erosion effects after prescribed fire and wildfire on volcanic ash-cap soils." In: Page-Dumroese D. Miller R. Mital J. McDaniel P. Miller D, editors. *Volcanic-Ash-Derived Forest Soils of the Inland Northwest*. Fort Collins (CO): USDA Forest Service Proceedings RMRS-P-44. Properties and Implications for Management and Restoration. Nov. 9-10, 2005. Coeur d'Alene (ID): USDA Forest Service. Rocky Mountain Research Station. pp. 83-94. Viewed online at: http://www.treesearch.fs.fed.us/pubs/26215.

Robichaud PR, MacDonald LH, Foltz, RB. 2010. "Fuel management and erosion." In: Elliot WJ, Miller IS, Audin L., editors. *Cumulative Watershed Effects of Fuel Management in the Western United States*. Fort Collins: (CO): USDA, Forest Service, Rocky Mountain Research Station. Chapter 5 pp. 79-100. General Technical Report RMRS-GTR-231.

Rowe PB, Countryman CM, Storey HC. 1949. *Probable Peak Discharges and Erosion Rates from Southern California Watersheds as Influenced by fire*. Berkeley (CA): USDA Forest Service. California Forest and Range Experiment Station 342 pp.

———. 1954. *Hydrologic Analysis Used to Determine Effects of Fire on Peak Discharge and Erosion Rates in Southern California Watersheds*. Berkeley (CA): USDA. California Forest and Range Experiment Station.

Rulli MC, Rosso R. 2007. "Hydrologic response of upland catchments to wildfires." [Journal.] Advances in Water Resources. 30(10):2072-2086.

Stephens SL, Meixner T, Poth M, McGurk B, Payne D. 2004. "Prescribed fire, soils, and stream water chemistry in a watershed in the Lake Tahoe Basin." [Journal.] International Journal of Wildland Fire 13:27-35.

Stephens SL, Moghaddas JJ. 2005. "Experimental fuel treatment impacts on forest structure potential fire behavior and predicted tree mortality in a California mixed conifer forest." [Journal.] Forest Ecology and Management. 215:21-36.

Stephens SL, Martin RE, Clinton NE. 2007. "Prehistoric fire area and emissions from California's forests, woodlands, shrublands and grasslands." [Journal.] Forest Ecology and Management. 251:205-216.

Stohlgren TJ, DeBenedetti SH, Parsons DJ. 1989. "Effects of herbage removal on productivity of selected high-Sierra meadow community types." [Journal.] Environmental Management. 13(4):485-491.

Tague C, Heyn K, Christiansen L. 2009. "Topographic controls on spatial patterns of conifer transpiration and net primary productivity under climate warming in mountain ecosystems." [Journal.] Ecohydrology 2: 541-554.

Tague C, Valentine S, Kotchen M. 2008. "Effect of geomorphic channel restoration on streamflow and groundwater in a snowmelt-dominated watershed." [Journal.] Water Resources Research 44(W10415): 10 pp.

Tahoe Science Consortium. 2007. *Comprehensive Science Plan for the Lake Tahoe Basin: Conceptual Framework and Research Strategies*. Final draft prepared as a deliverable under U.S. Environmental Protection Agency Cooperative Agreement X7-96963901-0. 290 pp.

Thorsen K. 2011. “Exploring the problem of domestic marijuana cultivation.” U.S. Senate Caucus on International Narcotics Control. Statement for the Record by Kim Thorsen, Deputy Assistant Secretary, Law Enforcement, Security and Emergency Management. Department of the Interior. Dec. 7. [Statement for the Record.] Viewed online at: http://drugcaucus.senate.gov/hearing-12-7-11/DOI%20Statment%20for%20the%20Record%20on%20Marijuana%20Cultivation.pdf.

Tree City USA. 2010. “How trees can retain stormwater runoff.” Tree City USA Bulletin. No. 55. pp. 1-8. Nebraska City (NE): Published for the Friends of Tree City USA by Arbor Day Foundation. [E-news.] Viewed online at: http://www.fs.fed.us/psw/programs/uesd/uep/products/11/800TreeCityUSABulletin_55.pdf.

Troendle CA, Nankervis JM, Peavy A. 2007. *Impacts of Vegetation Management on Water Yield. Final Report*. Fort Collins (CO): The Herger-Feinstein Quincy Library Group Project. USDA Forest Service. Pacific Southwest Region. Resource Reports - Hydrology and Fisheries. Contract AG 3187 D 05 0043. 23 pp. Viewed online at: http://www.fs.fed.us/r5/hfqlg/monitoring/resource_reports/hydrology_and_fisheries/Water_Yield_Full_Report_Feb242007.pdf.

Troendle CA, MacDonald LH, Luce CH, Larsen IJ. 2010. “Fuel management and water yield.” In: Elliot WJ Miller IS, Audin L. editors. *Cumulative Watershed Effects of Fuel Management in the Western United States*. Fort Collins (CO): USDA. U.S. Forest Service Rocky Mountain Research Station. General Technical Report RMRS-GTR-231. Chapter 7. pp. 126-148.

Turner KM. 1991. “Water salvage from Mediterranean-type ecosystems.” In: Bailey HE, Forrest C, Snow L, editors. *Water Supply and Water Reuse: 1991 and Beyond. Proceedings of the American Water Resources Association Annual Symposium*. American Water Resources Association Annual Symposium. Jun. 2-6, 1991. San Diego (CA): American Water Resources Association. [Book.] pp. 83-90.

USDA U.S. Forest Service. 1999. *Benefits of the Urban Forest*. Davis (CA): Fact Sheet #1. USDA Forest Service. Pacific Southwest Research Station. Center for Urban Forest Research. 2 pp.

———. 2000. *Water and the Forest Service*. Washington (DC): FS-660. USDA U.S. Forest Service. 40 pp. Viewed online at: http://www.fs.fed.us/publications/policy-analysis/water.pdf.

———. 2001. Sierra Nevada Framework Planning Amendment FEIS. USDA U.S. Forest Service. Vallejo (CA): [Web site.] Viewed online at: http://www.fs.usda.gov/detail/r5/landmanagement/planning/?cid=stelprdb5415847.

———. 2004. *Best Management Practices Evaluation Program: 1992-2002 Monitoring Results*. Vallejo (CA): USDA Forest Service. Pacific Southwest Region. Final Report. 76 pp.

——— .2005. *A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western states*. Fort Collins (CO): 17 p. General Technical Report RMRS-GTR-149. USDA Forest Service. Rocky Mountain Research Station. Viewed online at: http://www.fs.fed.us/rm/pubs/rmrs_gtr149.pdf.

——— .2006. *Urban Watershed Forestry Manual*. Viewed online at: www.na.fs.fed.us/watershed. Accessed: Aug., 2011.

———. 2007a. *An Assessment of Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition on the Angora Fire*. Vallejo (CA): R5-TP-025. USDA Forest Service. Pacific Southwest Research Station. Viewed online at: http://www.cnpssd.org/fire/angorafireusfsfullreport.pdf. Accessed: Nov.10, 2009.

———. 2007b. *Land Areas of the National Forest System*. Washington (DC): FS-383. USDA Forest Service.131 pp.

——— . 2008. *Land Areas of the National Forest System as of September 30, 2007*. Washington (DC): FS-383. USDA Forest Service. 131 pp.

——— . 2009. *Best Management Practices Evaluation Program: 2003-2007 Monitoring Results. Final Report*. Vallejo (CA): USDA Forest Service. Pacific Southwest Region. 28 pp.

——— . 2011a. *Responding to Climate Change in National Forests: A Guidebook for Developing Adaptation Options*. Portland (OR): General Technical Report PNW-GTR-855. USDA Forest Service. Pacific Northwest Research Station. Viewed online at: http://www.fs.fed.us/psw/publications/millar/Peterson%20et%20al.%20%28Adaptation%20Guidebook%29%20%28Feb.%202011%29.pdf.

——— . 2011b. *National Report on Sustainable Forests – 2010*. Washington (DC): FS-979. USDA Forest Service. Viewed online at: http://www.fs.fed.us/research/sustain/national-report.php.

——— . 2011c. "Operation Full Court Press concludes three week operation targeting illegal marijuana plants on public lands." USDA Forest Service Pacific Southwest Region press release dated August 8, 2011. Viewed online at: http://www.fs.fed.us/r5/news/2011/OperationFullCourtPress.shtml.

Van de Water K, North M. 2011. "Stand structure, fuel loads, and fire behavior in riparian and upland forests, Sierra Nevada Mountains, USA; a comparison of current and reconstructed conditions." [Journal.] Forest Ecology and Management 262: 215-228.

Weaver WE, Hagans DK. 1994. *Handbook for Forest and Ranch Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Maintaining, and Closing Wildland Roads*. Ukiah (CA): Mendocino County Resource Conservation District. 161 pp.

Weaver W, Hagans D, Weppner E. 2006. "Upslope erosion inventory and sediment control guidance." Part X. In: *California Salmonid Stream Habitat Restoration Manual*. 1998 revised 3rd edition. Sacramento (CA): California Department of Fish and Game. 108 pp.

Welsch HH. 2011. "Frogs, fish and forestry: an integrated watershed network paradigm conserves biodiversity and ecological services." [Journal.] Diversity 3: 503-530.

Wilzbach MA, Harvey BC, White JL, Nakamoto RJ. 2005. "Effects of riparian canopy opening and salmon carcass addition on the abundance and growth of resident salmonids." [Journal.] Canadian Journal of Fisheries and Aquatic Sciences. 62: 58-67.

Weixelman DA, Hill B, Cooper DJ, Berlow EL, Viers JH, Purdy SE, Merrill AG, Gross SE. 2001, *Meadow Hydrogeomorphic Types for the Sierra Nevada and Southern Cascade Ranges in California*. USDA Forest Service. R5-TP-034. 33 pp.

Wohlgemuth PM, Beyers JL, Wakeman CD, Conard SG. 1998. "Effects of fire and grass seeding on soil erosion in southern California chaparral." In: Gray S Chairman. *Proceedings of the 19th Annual Forest Vegetation Management Conference: Wildfire Rehabilitation*. Redding (CA) University of California Cooperative Extension Forestry. pp. 41-51

Wohlgemuth PM. 2001. "Prescribed fire as a sediment management tool in southern California chaparral watersheds." In: *Proceedings of the 7th Federal Interagency Sedimentation Conference*. March 25–29. Reno (NV): Federal Energy Regulatory Commission. 2:X-49-X-56.

Wohlgemuth PM, Beyers JL, Hubbert KR. 2009. "Rehabilitation Strategies after Fire: The California, USA experience. pp. 511-536 In: Cerdá A, Robichaud PR editors. *Fire Effects on Soils and Restoration Strategies*. Enfield (NH): Science Publishers.

Wondzell SM. 2001. "The influence of forest health and protection treatments on erosion and stream sedimentation in forested watersheds of eastern Oregon and Washington. [Journal.] Northwest Science 75:128-140.

Wood SH. 1975. "Holocene stratigraphy and chronology of mountain meadows Sierra Nevada California." In: *Earth Surface Monograph*. Vallejo (CA): Volume 4. USDA Forest Service. Pacific Southwest Region. 180 pp.

Xiao Q, McPherson G, Simpson J, Ustin S. 1998. "Rainfall interception by Sacramento's urban forest." [Journal.] Journal of Arboriculture. 24(4):235-244.

Xiao Q, G. McPherson. 2009. *Testing a Bioswale to Treat and Reduce Parking Lot Runoff*. Center for Urban Forest Research. USDA Forest Service. Viewed online at: http://www.fs.fed.us/psw/programs/uesd/uep/products/psw_cufr761_P47ReportLRes_AC.pdf.

Ziemer, RR. 1987. "Water yield from forests: an agnostic view: In: Callaham RZ, DeVries JJ, editors. *Proceedings of the California Watershed Management Conference*. California Watershed Management Conference. Nov. 18-20, 1986. West Sacramento (CA): University of California Wildland Resources Center. pp. 74-78.Viewed online at: http://www.treesearch.fs.fed.us/pubs/8672.

Ziemer RR, Lisle TE. 1998. "Hydrology." In: Naiman, RJ; Bilby, RE, editors. *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*. New York (NY): Springer-Verlag. Chapter 3. pp. 43-68. Viewed online at: http://www.fs.fed.us/rm/boise/publications/misc/naiman_riparianecology.pdf.

Zinke PJ. 1987. "The recovery factor in watershed land use for timber harvest and growth." Impact '87. California Licensed Foresters Association (CLFA) Annual Conference. Mar. 6-7, 1987 Sacramento (CA): California Licensed Foresters Association. 7 pp.

Additional References

Battany MC, Grismer ME. 2000. "Rainfall runoff and erosion in Napa Valley vineyards: effects of slope cover and surface roughness." [Journal.] Hydrological Processes. 14:1289-1304.

Bayley PB, Li HW. 2008. "Stream fish response to grazing exclosures." [Journal.] North American Journal of Fisheries Management. 28:135-147.

Day SD, Dickinson SB, editors. 2008. *Managing Stormwater for Urban Sustainability using Trees and Structural Soils*. Blacksburg (VA):Virginia Polytechnic Institute and State University. Viewed online at: http://www.vtfpr.org/urban/documents/TreesAndStructuralSoilsManual.pdf. Accessed: Aug., 2011.

Diamond JM. 2005. *Collapse: How Societies Choose to Fail or Succeed*. New York (NY): Viking Press. 575 pp.

Erman DC, Newbold JD, Roby KB. 1977. *Evaluation of Streamside Buffer Strips for Protecting Aquatic Organisms*. Davis (CA): Contribution No. l65. California Water Resources Center. University of California, Davis. 48 pp.

Giono J. 2005. *The Man Who Planted Trees*. 20th anniversary edition. White River Junction (VT): Chelsea Green. 61 pp.

Harris RR, Cafferata PH. 2005. Forest Loss and Fragmentation. Session 2: Impacts and Implications—Impacts on Water Quantity and Quality [Abstract]. PowerPoint presentation. California Forest Futures 2005 Conference. May 24-25. Sacramento (CA):

Herbst DB, Kane JM. 2004. *Responses of Stream Channels Riparian Habitat and Aquatic Invertebrate Community Structure to Varied Livestock Grazing Exposure and Management in the West Walker River Watershed (Mono County California)*. South Lake Tahoe (CA): Lahontan Regional Water Quality Control Board. Final report submitted in partial fulfillment of Lahontan Regional Water Quality Control Board contract numbers 9-046-256-0 9-118-160-0 and 0-091-160-0. 41 pp. Viewed online at: http://www.swrcb.ca.gov/rwqcb6/water_issues/programs/swamp/docs/herbst_kane_wwgs_2004.pdf.

Hymanson ZP, Collopy MW, editors. 2010. *An Integrated Science Plan for the Lake Tahoe Basin: Conceptual Framework and Research Strategies*. Albany (CA): USDA Forest Service. Pacific Southwest Research Station. Chapter 4.11. p. 117-123. General Technical Report PSW-GTR-226. Viewed online at: http://www.fs.fed.us/psw/publications/documents/psw_gtr226/psw_gtr226.pdf.

Knapp RA, Matthews KR. 1996. "Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: Impacts and management implications." [Journal.] North American Journal of Fisheries Management. 16:805-820.

Madej MA, Ozaki V. 1996. "Channel response to sediment wave propagation and movement, Redwood Creek, California, USA." [Journal.] USA Earth Surface Processes and Landforms. 21(10):911-927.

McGurk BJ, Berg NH, Davis ML. 1996. "Camp and Clear Creeks El Dorado County: predicted sediment production from forest management and residential development." In: *Sierra Nevada Ecosystem Project. Final Report to Congress, Volume II: Assessments and Scientific Basis for Management Options*. Davis (CA): University of California, Centers for Water and Wildland Resources. Chapter 53. pp. 1407-1420. Viewed online at: http://pubs.usgs.gov/dds/dds-43/VOL_II/VII_C53.PDF.

McPherson EG, Simpson JR, Peper PJ, Xiao QF. 1999. *Tree Guidelines for San Joaquin Valley Communities*. Davis (CA): USDA Forest Service. Pacific Southwest Research Station. Western Center for Urban Forest Research and Education. 59 pp.

McPherson E, Gregory S, James R, Peper P, Crowell J, Aaron MN, Xiao Q. 2010. *Northern California Coast Community Tree Guide: Benefits, Costs, and Strategic Planting*. Albany (CA): General Technical Report PSW-GTR-228. USDA Forest Service. Pacific Southwest Research Station.

Miller WW, Johnson DW, Denton C, Verburg PSJ, Dana GL, Walker RF. 2005. "Inconspicuous nutrient laden surface runoff from mature forest Sierran watersheds." [Journal.] Water, Air and Soil Pollution. 163:3-17.

Murphy DD, Stine PA, editors. 2004. *Proceedings of the Sierra Science Symposium*. General Technical Report PSW GTR-193. Oct. 7-10, 2002. Kings Beach (CA): USDA Forest Service. Pacific Southwest Research Station. Albany (CA): 287 pp.

Newbold JD, Erman DC, Roby KB. 1980. "Effects of logging on macroinvertebrates in streams with and without buffer strips." [Journal.] Canadian Journal of Fisheries and Aquatic Science. 37:1076-1085.

Ponce VM, Lindquist, DS. 1990. "Management of baseflow augmentation: a review." [Journal.] Water Resources Bulletin. 26(2):259-268.

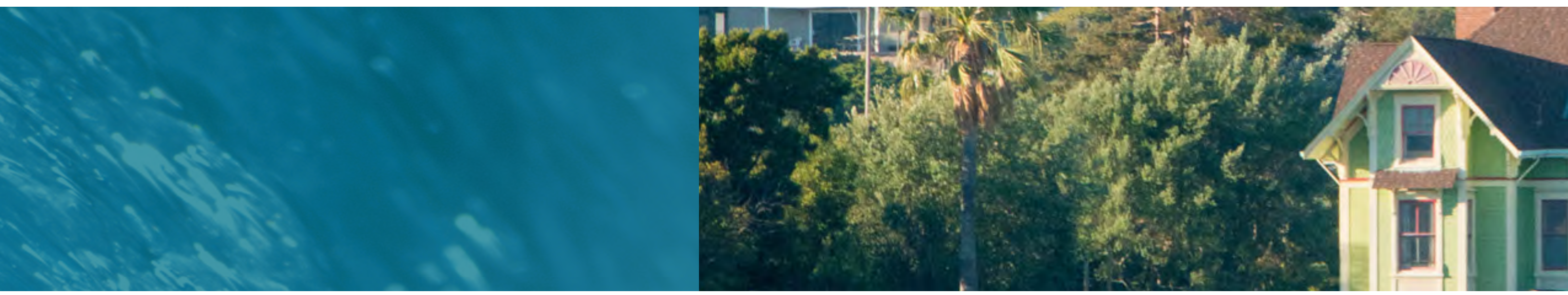
University of California, Centers for Water and Wildland Resources.1996. *Sierra Nevada Ecosystem Project. Final Report to Congress. Volume I. Assessment Summaries and Management Strategies*. Davis (CA): Chapter 8. Watersheds and Aquatic Biodiversity. pp. 123-133. Viewed online at: *http://pubs.usgs.gov/dds/dds-43/VOL_I/VI_C08.PDF*.

USDA Forest Service. 2002. *Control Stormwater Runoff with Trees*. Davis (CA): Fact Sheet #4. USDA Forest Service. Pacific Southwest Research Station. Center for Urban Forest Research. 2 pp.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 24

Land Use Planning and Management



Benicia, CA. This residential hillside depicts the benefits of compact development, accommodating a range of architectural styles as well as open space and mature vegetation toward the top of the hill, though the minimal difference in elevation between the homes and the waterline, common in such developed areas, could increase impacts of sea level rise over the next 50-100 years.

Contents

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Boxes

Chapter 24. Land Use Planning and Management

Land Use Planning and Management in California

Land use planning and management cut across many resource management strategies of the *California Water Plan Update 2013* (Update 2013) (see Box 24-1). More efficient and effective land use is linked to several resource management strategies including watershed, water use efficiency, groundwater quality, flood management, parks and recreation, climate change adaptive management, and agricultural lands stewardship. Directing development away from agricultural lands permits multi-objective management of these lands for agricultural preservation, floodplain management, water quality, habitat conservation, and sustainable development. In addition, planning for more compact and sustainable communities, both urban and rural, will assist in reducing reliance on the state's water supply, and result in more efficient use of California's water resources. Important considerations of water issues and land use planning include not only the effects of the physical environment, but also the economic and social impacts of land use planning and development.

Stronger collaboration between land use planners and water managers can promote more efficient and effective land-use patterns and integrated regional water management (IRWM) practices, which can produce safer and more resilient communities. Integrating land use and water management consists of planning for the housing and economic development needs of a growing population, while providing for the efficient use of water, water quality, energy, and other resources. The way in which Californians use land — the type of land use, transportation, and level of use — has a direct relationship to water supply and quality, flood management, hazard mitigation, and other water issues. Likewise, the better integrated water resources are, the more efficient local communities can be at producing land use planning benefits and opportunities. For example, compact development patterns in existing urban areas can limit the amount of development in floodplains, leading to improved flood management and safety and more efficient infrastructure.

Land use planners consider water throughout the local land use planning process, and water is a critical element in adopting efficient land use planning policies. The availability of water supplies, water resource features such as streams, wetlands, and groundwater recharge areas, and policies and regulations about water quality, drainage, and flooding are all considered for a community's land use vision. Planners should also consider the benefits of integrating water-related features for flood management, water supply and quality, recreation, and climate change adaptive management.

California's projected growth and urban development increases the pressure on natural resource conservation, and amplifies the need for a comprehensive land use decision-making process integrated with water management. This advisory resource management strategy describes the co-benefits of a working relationship between land use planning and water management by demonstrating how sustainable land use decisions, in both urban and rural areas, can improve water supply affordability and quality, increase flood protection, conserve vital natural habitats, lead to more efficient energy and public resource use, and produce land use benefits from

Box 24-1 Key Resource Management Strategy Cross-Cutting Links

Land use planning and management share strategies and benefits with watershed planning and management, agricultural lands stewardship, water use efficiency, water quality, and climate change, to name a few. The themes of flood risk and surface water management can meet sustainability issues in land use planning — place making. These strategies benefit from participation by all levels of government relying on local knowledge and management capacity. In common with many other cross-cutting themes in local government, the quality of outcomes depends on joining services and various stakeholders effectively. These listed management strategies and others tie in with the following sustainability issues:

- Climate change adaptation includes preparing for flooding.
- Biodiversity — sustaining existing biodiversity and its potential enhancement — comes by managing waterways well.
- Community engagement increases public awareness of the issue.
- Development and provision of green infrastructure increases sustainability.

The following are key, but not the only, cross-cutting resource management strategies: Chapter 3, “Flood Management”; Chapter 9, “Conjunctive Management and Groundwater Storage”; Chapter 18, “Pollution Prevention”; Chapter 20, “Urban Stormwater Runoff Management”; Chapter 21, “Agricultural Land Stewardship”; Chapter 22, “Forest Management”; Chapter 27, “Watershed Management”; Chapter 28, “Economic Incentives”; Chapter 29, “Outreach and Engagement.”

improved water management. Although many of these issues are discussed in greater detail in other resource management strategies, this section focuses on the impact that land use can have on them.

This resource management strategy is consistent with the State’s planning goals and policies for more compact sustainable development established in Assembly Bill (AB) 857 (2002), Senate Bill (SB) 732 (2008), and SB 375 (2008); strategies developed by the California Air Resources Board (ARB) to achieve AB 32 (2006) greenhouse gas (GHG) reduction target; and regional blueprint planning funded by the California Department of Transportation (Caltrans). California has enacted policies and programs designed to meet the water management benefit potential of land use with the understanding that these policies are implemented regionally and locally. These policies, and this resource management strategy, reflect the diversity of California’s communities and land use types.

State, Regional, and Local Land Use Planning Framework

Key State Agencies

State government has typically played a limited or indirect role in land use planning, leaving the lion’s share of land use authority to local governments. State government generally prepares strategic and functional plans for issues such as air pollution, water quality, transportation, housing, solid waste management, and climate change adaptation to provide assistance on local department programs, decisions, and projects. Unlike most other resources subject to State oversight, and in some cases management, there is no State oversight agency for land use.

State law requires that State policies, to the extent they support land use, be expressed through local general plans and land use regulations. The State Planning and Zoning Laws establish a detailed process for local planning, but with limited exceptions, do not require local plans to achieve substantive State policies. The exceptions are the housing element requirements and flood management legislation (see the section on Coordinating Land Use and Flood Management).

Also, State regulatory authority for air and water pollution is increasingly affecting land use decisions. The issue of stormwater runoff has led to the creation of many watershed planning efforts that operate on a regional or sub-regional level and may be part of an IRWM planning effort (see Chapter 20, "Urban Stormwater Runoff Management," in this volume). Efforts to control stormwater runoff and non-point source pollution are likely to affect the design, character, and even the location of local urban development by encouraging green stormwater solutions (wetlands restoration, use of pervious surfaces) rather than more traditional engineering approaches such as channelization (see Box 24-2 for descriptions of other planning efforts).

The Governor's Office of Planning and Research (OPR) and the Strategic Growth Council (SGC) provide critical support to local and regional governments related to land use planning for rural and urban communities.

Governor's Office of Planning and Research

The Governor's Office of Planning and Research (OPR) is responsible for coordinating State functional plans and ensuring consistency with State policies. OPR, created by statute in 1970, is part of the Office of the Governor. OPR serves as staff to the governor and his cabinet for long-range planning and research, and constitutes the comprehensive State planning agency (Government Code Section 65040). In addition, the Government and Public Resources Codes set forth multiple functions for OPR, including:

- Formulation of long-range land use goals and policies.
- Conflict resolution among State agencies.
- Coordination of federal grants for environmental goals.
- Coordination of statewide environmental monitoring.
- Coordination of research on growth and development.
- Management of State planning grants and encouragement of local and regional planning.
- Creation and adoption of general plan guidelines.
- Drafting of CEQA guidelines for adoption by the Secretary of Natural Resources.
- Creation of a State Environmental Goals and Policy Report (EGPR), every four years.
- Operation of the State Clearinghouse for distribution and review of CEQA documents.
- Coordination of environmental justice activities.
- Coordination with U.S. military for land use and other issues in the state.

One of OPR's primary responsibilities is working with State agencies and departments, regional planning organizations, and local jurisdictions on topics relating to land use planning. OPR has developed numerous resources to assist local governments in managing land use-related issues, including information related to infill, renewable energy, general plan guidelines, transportation, and more.

Box 24-2 Other Planning Efforts

There are multiple statewide planning efforts that utilize land use planning and management strategies. The following are described in more detail; this is not intended to be an exhaustive list.

- Integrated Regional Water Management (IRWM) Planning. The California State government is guiding integrated regional water management (IRWM) to diversify and strengthen water management. The IRWM program provides guidance to regions for developing and implementing plans that integrate water management for water supply and quality, flood management, drought preparedness, land use, natural habitat and conservation, and reduced dependence on imported water among other objectives.
- The IRWM Planning Act provides a general definition of an IRWM plan as well as a requirement for state guidelines that must include standards for identifying a region for the purposes of developing or modifying an IRWM plan. This regional definition objective is to effectively integrate water management (IWM) programs and projects within a hydrologic region. SB X2 1 (2008) authorized grant funding for IRWM as approved by voters for Proposition 84 and Proposition 1E.
- FloodSAFE is a long-term strategic initiative developed to reduce flood risk in California. It is designed with the recognition that addressing risks of flood damage statewide will take decades. FloodSAFE is also an important component of the California Department of Water Resources' (DWR's) IWM Initiative, which is designed to achieve a sustainable, robust, and resilient flood and water management system for the benefit of all Californians.
- California's Flood Future: Recommendations for Managing the State's Flood Risk (2013). IWM is the strategic approach that combines flood management, water supply, land use, and ecosystem actions for multiple benefits. An IWM approach promotes management flexibility and resiliency to accommodate changing conditions, such as climate change and flood or drought events. Long-term commitments through land use and alignment among responsible public agencies are necessary to create sustainable, affordable water resources systems.
- Urban Water Management Plan (UWMP). DWR provides urban water management planning services to local and regional urban water suppliers. In 1983, the California Legislature enacted the UWMP Act. The act states that every urban water supplier that provides water to 3,000 or more customers, or that provides over 3,000 acre-feet of water annually, should make every effort to ensure the appropriate level of reliability in its water service sufficient to meet the needs of its various categories of customers during normal, dry, and multiple dry years. The act describes the contents of the UWMP, as well as how urban water suppliers should adopt and implement the plans. It is the intention of the Legislature, in enacting this part, to permit levels of water management planning commensurate with the numbers of customers served and the volume of water supplied.
- Best management practices (BMPs) are techniques used to control stormwater runoff, sediment control, and soil stabilization, as well as management decisions to prevent or reduce non-point source pollution. The U.S. Environmental Protection Agency defines a BMP as a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of storm water runoff in the most cost-effective manner."
- Stormwater management BMPs are control measures taken to mitigate changes to both quantity and quality of urban runoff caused through changes to land use. Generally, BMPs focus on water quality problems caused by increased impervious surfaces from land development. BMPs are designed to reduce stormwater volume, peak flows, and/or non-point source pollution through evapotranspiration, infiltration, detention, and filtration or biological and chemical actions. Stormwater BMPs can be classified as "structural" or "non-structural."
- Low-impact development (LID) is a term to describe a land planning and engineering design approach to managing stormwater runoff. LID emphasizes conservation and use of on-site natural features to protect water quality. This approach implements engineered small-scale hydrologic controls to replicate the pre-development hydrologic regime of watersheds through infiltrating, filtering, storing, evaporating, and detaining runoff close to its source. Planners select structural LID practices for an individual site in consideration of the site's land use, hydrology, soil type, climate, and rainfall patterns. There are many variations of LID practices, and some practices may not be suitable for a given site. Many are practical for retrofit or site renovation projects, as well as for new construction. Frequently used practices include:
  - Bioretention cells, also known as rain gardens.
  - Cisterns and rain barrels.
  - Green roofs.
  - Pervious concrete, also called "porous pavement," similar to permeable paving.
  - Grassed swales, also known as bioswales.

(See also Box 24-6, "Low-Impact Development (LID) Runoff Control Objectives.")

OPR is preparing an environmental goals and policy report (EGPR) for California. The 2013 EGPR will provide an overview of the State's environmental goals and key steps to achieving these goals, as well as develop a framework of metrics and indicators to help inform decision-making, at all levels, to help the state reach these goals.

California has established a series of ambitious environmental goals (e.g., the Renewable Portfolio Standard and the GHG emission reduction goals), including efforts to reduce GHG emissions, develop a clean economy, and provide clean air and water for all residents. By 2035, California is projected to have a population of 50 million residents. The decisions that are made to accommodate this growth need to be made with the achievement of these environmental goals in mind. OPR is seeking to prepare an EGPR that is inspirational and forward-looking, broad and inclusive, and engaging and interactive.

Strategic Growth Council

The Strategic Growth Council (SGC), established through SB 732 in 2008, is a committee of the agency secretaries from Business, Transportation, and Housing; California Health and Human Services; California Environmental Protection Agency; and California Natural Resources Agency; as well as the director of the Governor's Office of Planning and Research and one public member appointed by the governor. The SGC is charged with four main tasks to encourage the development of sustainable communities, summarized as follows:

- Coordinate State programs to achieve sustainability objectives.
- Provide local assistance.
- Fund and distribute data and information.
- Recommend policies advancing sustainable communities.

Based on these four strategies, the SGC works toward a broad range of sustainability objectives:

- Improve air and water quality.
- Improve protection of natural resources and agricultural lands.
- Increase the availability of affordable housing.
- Improve public health.
- Improve transportation.
- Encourage sustainable land use plans and greater infill development.
- Revitalize urban and community centers in a sustainable manner.
- Reduce GHG emissions.

Local assistance is provided by the SGC through its grant programs that help local governments plan for future population growth and climate change impacts, assist metropolitan planning organizations (MPOs) in developing tools to support SB 375 (2008) requirements, and support various greening projects in urban communities.

In January 2012, the SGC adopted its first Strategic Plan (http://sgc.ca.gov/docs/workplan/strategicplan-01-24-12.pdf), which articulates the SGC's action plan for 2012-2014.

Other State Agencies

There are several additional State entities that affect local land use planning and regulation. These include:

- The California Coastal Commission, which regulates land use planning and development in the coastal zone together with cities, counties, and other local agencies.
- The California Energy Commission, which has exclusive permitting authority for thermal power plants 50 megawatts (MW) or greater and serves as lead agency under CEQA for projects within its jurisdiction.
- The Climate Change, Land Use, and Infrastructure Working Group (CCLU-In) for the Climate Action Team, which coordinates State efforts at the interface of land use and climate change and to ensure that various planning efforts (water resources, housing and development, transportation, public health, etc.) address the linkages between mitigation measures and adaptation strategies. Potential climate change impacts to land use include urban climate and heat island effects, flooding, land use patterns and planning, significant adverse impacts to air quality, population, energy and water consumption, waste issues, public health, vehicle use strategies, and traffic.
- The California Department of Housing and Community Development (HCD), which implements the California Green Building Code (CALGreen). CALGreen, the first in the nation, is designed to lighten carbon footprints and lower energy and water consumption. CALGreen provides a framework for reducing energy consumption and increasing the state's sustainability through statewide building standards that reduce water use, improve air quality, conserve energy, reduce California's carbon footprint, and help mitigate the effects of global climate change. In addition, HCD completes the review of housing elements.
- California Emergency Management Agency (Cal EMA), which is responsible for the coordination of emergency preparedness for California and works cooperatively with all entities to ensure the protection and safety of the populace. The federal Disaster Mitigation Act of 2000 requires that local governments prepare local hazard mitigation plans (LHMPs) as a precondition for receiving certain hazard mitigation grant funds. It also requires that states review LHMPs as part of the State hazard mitigation planning process. The intent is two-fold: (1) to gather hazard, vulnerability, and mitigation information from the local level for use in state-level planning, and (2) to ensure that state and local hazard mitigation planning is coordinated to the greatest extent practical. The Cal EMA Hazard Mitigation Program (HMP) administers the LHMP program for the state. Cal EMA supports and assists local governments in the development of LHMPs and tracks the progress and effectiveness of plan updates and projects. In addition, State planning law requires that a city, county, or city and county General Plan contain specified elements, including a safety element for the protection of the community from any unreasonable risks associated with the effects of seismically induced surface rupture, ground shaking, ground failure, tsunami, seiche, dam failure, slope instability leading to mudslides and landslides, subsidence, liquefaction, and other seismic, geologic, and fire hazards.

Regional Planning Agencies

Several types of regional planning agencies exist in California.

- Regional regulatory land use agencies include the San Francisco Bay Conservation and Development Commission, the Tahoe Regional Planning Agency, the Delta Protection Commission, and the Delta Stewardship Council.

- Regional Councils of Government (COGs) are joint powers agencies that conduct regional planning in most of the state. They differ from region to region in organization and regional responsibilities, but in general, COGs serve as MPOs for federal transportation planning and funding purposes. COGs acting as MPOs prepare Regional Transportation Plans that for larger regions must meet SB 375 requirements. COGs also prepare regional housing needs allocations (RHNAs) that allocate "fair share" housing to cities and counties within their region.
- Local Agency Formation Commissions (LAFCOs) are regional organizations with responsibilities relating to Municipal Services, including water infrastructure. According to the California Association of Local Agency Formation Commissions (CALAFCO), "LAFCOs review proposals for the formation of new local governmental agencies and for changes in the organization of existing agencies … Agency boundaries are often unrelated to one another and sometimes overlap at random, often leading to higher service costs to the taxpayer and general confusion regarding service area boundaries. LAFCO decisions strive to balance the competing needs in California for [the] conservation of natural resources" (California Association of Local Agency Formation Commissions 1971).

Local Agencies

Cities and counties have primary jurisdiction over land use planning and regulation in California. Their authority derives from their rights under the California Constitution to regulate land use to protect the public health, safety, and welfare. The following areas highlight some of the intersections between State and local land use planning.

- **General Plans.** Several State statutes specifically authorize the preparation of local general plans and specific plans, and regulation of land use through zoning and subdivision regulations. OPR publishes the *General Plan Guidelines* (http://opr.ca.gov/docs/General_Plan_Guidelines_2003.pdf), which provides guidance to local governments regarding the inclusion of an optional water element, and other advisory guidance to assist local governments in land use planning and management. The housing element must contain a site-specific inventory and identify adequate sites with appropriate zoning densities and infrastructure to meet the community's need for housing (including its need for housing for low, very low, and extremely low income households and mobile homes, farmworker housing, and emergency shelters) that will be made available during the planning period (Section 65583(c) (1) & Section 65583.2).
- **California Environmental Quality Act (CEQA).** CEQA is an important tool for local land use planning and regulation. Although it is intended as an environmental full disclosure law for discretionary local government decisions, in practice CEQA is often the main forum for local governments to make project-level land use decisions and consider the potential impacts of those decisions. This includes a public comment process to address concerns. CEQA also expressly states that feasible mitigation measures must be adopted for any significant environmental effects resulting from a project.
- **Tribal Consultation.** State planning law, known as SB 18 (2004), requires cities and counties to consult with California Native American Tribes during the local planning process for the purpose of protecting traditional tribal cultural places. OPR's 2005 *Supplemental State General Plan Guidelines* provides advice and requirements for SB 18.
- **Flood Management.** Several laws were created in 2007 to strengthen the link between land use and flood management. The laws, described later in this chapter, establish a

comprehensive approach to improving flood management at the state and local levels. The California Department of Water Resources' (DWR's) *Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities* (http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf) outlines the 2007 California flood risk management legislation affecting cities' and counties' responsibilities related to local planning requirements such as general plans, zoning ordinances, development agreements, tentative maps, and other actions.

Coordinating Land Use Planning and Management with Key California Water Plan Components

Effective land use planning is central to several important components of the California Water Plan (CWP), such as climate change policy, water supply, flood management, water quality, and tribal consultation. Significant progress has been made in coordinating land use planning with each of these components, as described below. This Land Use Planning and Management resource management strategy, which emphasizes additional strategies to promote compact and sustainable urban and rural development, uses these accomplishments as a foundation.

Translating these strategies into action and implementation was a challenge in *California Water Plan Update 2009* (Update 2009). Planners and other stakeholders proposed a land-use decision tool (see the original "decision tree") to provide a basis for comparing business-as-usual to low-impact development (LID) approaches for regional, local, or project-specific planning. A major component of this land-use and water-supply calculator tool is the life-of-the-project maintenance cost for 25, 50, and 100 years. This tool was adopted for the final Update 2009, and a pilot project program was launched for Update 2013. (See Figure 24-1; see also in Volume 4, *Reference Guide*, the article "Suburban Case Study and Locally Adaptable Tool Findings," and in Volume 5, *Technical Guide*, the "User Guide" for the application of the tool.)

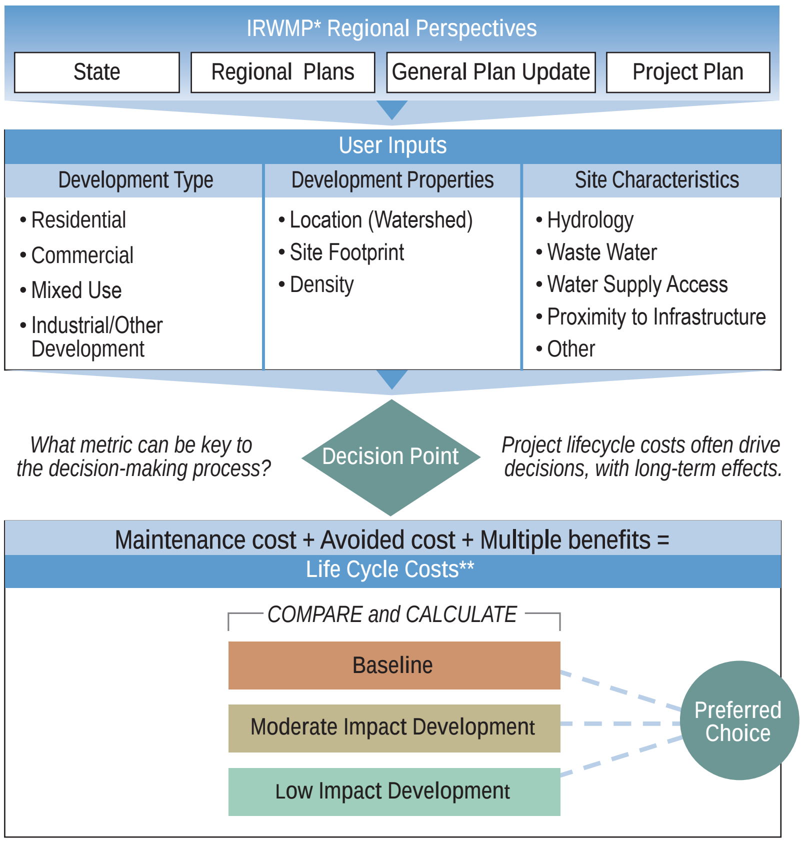
Climate Change

Climate change is expected to entail significant changes to California's water supply, food production systems, and ecosystems (California Department of Water Resources 2008). Our built environment depends on these natural resources and associated processes for food, fiber, recreation, and ecosystem services. Land use patterns Californians adopt in the near future will dramatically affect our ability to mitigate as well as adapt to climate change. Sprawling development patterns encourage vehicular rather than pedestrian or bike travel for work and recreation, increasing emissions and precluding options for climate adaptation. Compact and sustainable development, on the other hand, provides multiple co-benefits that include climate change mitigation and adaptation as well as other water-related benefits.

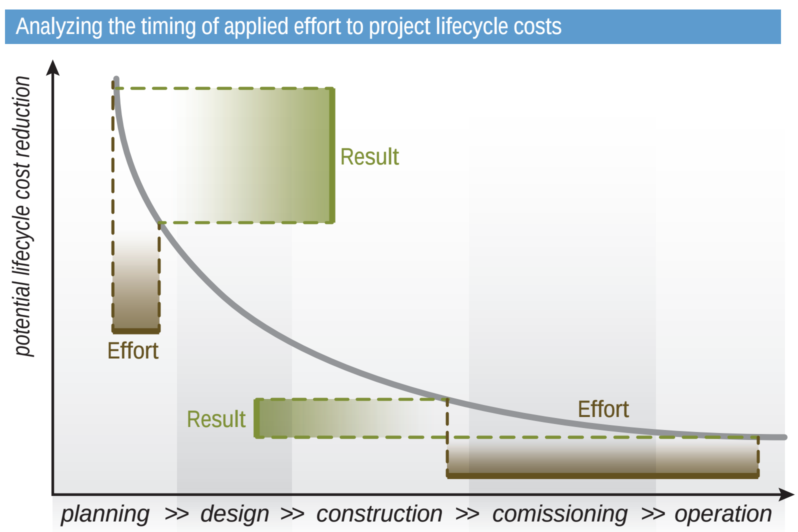
Potential climate change impacts important to consider in land use planning include increased extreme flood events; increased energy and water demand, especially in drought years; an increase in extreme heat days; significant adverse impacts on air quality and public health; and increased wildfire risk in urban areas adjacent to forests or scrublands. Planning for climate adaptation will be most effective when land use planners and water managers work together to understand their regional vulnerabilities to inevitable climate changes and find common goals and actions that will help them prepare.

Figure 24-1 Decision Tree Graphic and Status Report on Pilot Project

Life cycle costing should be done as early in the process as possible when a relatively small effort can result in big changes, as opposed to later in the process when a greater effort yields smaller results.



Note: This schematic was adopted in 2009, and became the framework for a pilot project in collaboration with Sonoma State University Center for Sustainability and DWR. (See *Volume 4, Reference Guide*, the article "Suburban Case Study and Locally Adaptable Tool Findings"; see *Volume 5, Technical Guide*, the "User Guide" for the application of the tool.)



*Integrated Regional Water Management Plan (IRWMP)

** All costs over 50-year time period

Adaptation

Cross-sector collaboration on resources management will be critical for dealing with climate change impacts as they unfold. Urban planners, water managers, and ecosystem managers commonly work independently to plan for the future. Many observe that this "independent planning" is inefficient and ineffective, as these efforts involve activities that are connected and interdependent. However, to address the additional challenges effectively that climate change will bring, it will be imperative that both the built and natural environments are managed in a cohesive fashion at a landscape level rather than as isolated, smaller pieces of the whole, which has been done in the past.

DWR's Integrated Regional Water Management (IRWM) Program is an example of a process that brings diverse stakeholders to the table for coordinated regional planning on water issues. As noted in DWR's White Paper, *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water* (California Department of Water Resources 2008), IRWM planning, in combination with other regional planning efforts, such as for transportation and land use, can serve as the basis for regional climate adaptation planning leading to increased resilience in all sectors.

As mentioned previously, the CCLU-In is the Climate Action Team subgroup that works to coordinate State efforts on climate adaptation in the land use sector. Many planning efforts for the built environment including those related to water resources, housing, transportation, hazard mitigation, and others will need to incorporate both mitigation and adaptation moving forward in the future. A Web portal (http://www.climatechange.ca.gov/action/cclu/) containing information and links about the multitude of State documents and tools on climate change has been developed by the CCLU-In to assist local planners with incorporating climate change into their general plan updates and other key planning documents.

Another key source of climate change information for resource managers is the California Climate Change Portal (http://www.climatechange.ca.gov/). The Climate Change Adaptation Policy Guide (APG) for local governments and other important guidance for planners and resource managers can be found on this Web site. The APG addresses climate change adaptation at the local government level. It provides local government and regions with information and tools to assess anticipated changes and risks for that region due to the effects of climate change including sea level rise, greater flood intensity, and increased local flood risk. Once the assessment is done, the local government can review the APG for mitigation and adaptation measures for existing and future development.

One effort that could be important in coordinating planning efforts for the natural and built environments is the U.S. Department of Interior-led Landscape Conservation Cooperatives (www.fws.gov/science/shc/pdf/LCC_FAQs_2012.pdf). These management-science partnerships inform and promote integrated science, natural resource management, and conservation to address climate change and other stressors within and across ecosystems. Representatives from State and federal agencies, universities, non-governmental organizations, tribes, and other interested parties work together to identify research gaps, fund projects, and disseminate information about climate change and other threats to the sustainability of California's natural resources. The California Landscape Conservation Cooperative (CA LCC) (http://californialcc.org/) has created an "Affiliate" level of participation to engage all parties interested in integrated natural resource management. Urban planners and local government officials working on climate adaptation can become CA LCC Affiliates and will have an avenue for directly connecting with top scientists and managers in California who are planning for landscape-level ecosystem integrity. This important communication channel could provide an unprecedented opportunity for cross-sector information sharing and planning.

Mitigation

There is growing recognition of the relationship between land use policies, water use policies, and production of the GHG emissions that contribute to climate change. AB 32, Sustainable Communities Strategies SCSs pursuant to SB 375, Climate Action Plans, and CEQA are the main vehicles for regional and local governments to identify and reduce GHG emissions related to land use and transportation planning. Collaboration on GHG issues between local governments and water providers, although not currently required by law, can provide opportunities for communities to meet their GHG reduction targets more quickly, and to ensure the longevity and sustainability of their community in the face of climate change.

Coordinating Land Use and Water Supply

Local land use planning and water supply planning are coordinated through a patchwork of existing State laws and policies. Regional water wholesalers, such as Metropolitan Water District and San Diego County Water Authority, base their water supply plans on regional growth projections developed by regional planning agencies. Information sharing is a good first step. However, more reliable water supplies can be achieved by enhanced coordination with land use planners and water managers. The effectiveness of existing programs and regulations in steering development toward areas with existing reliable water supplies and away from areas where new water supplies, must be developed and has not been comprehensively assessed.

Increased coordination, particularly at a regional level, demonstrates the advantages and benefits of proactive growth management planning and water supply planning to support projected long-term regional population growth. SB 610 and SB 221 (2001) are intended to improve the coordination between land use planning and development and available long-term water supplies. These laws require assessment and verification, respectively, of water supply reliability prior to approval of specified large land use projects. SB 610 applies during the CEQA process, and SB 221 applies to subdivision approvals.

Both laws require a demonstration of sufficient, reliable 20-year water supplies to serve both the proposed project and other water users relying on the same water supplies during normal years, a single dry year, and multiple dry years. They require the water agencies responsible for water resource planning to work with the local land use agencies that often have little control over water supplies.

Urban water management plans (UWMPs), as established by the Urban Water Management Planning Act, must be prepared by large water purveyors (3,000 acre-feet/year or 3,000 customers), must evaluate water supplies and demands over a 20-year period, and must be updated every five years. UWMPs are also required to plan for a 20 percent reduction in per capita water use by 2020. These plans can provide the basis on which the justifications for available water supply are made when applying SB 610 and SB 220 assessments.

Other State laws and policies play a more indirect role in coordinating land use and water supply planning. The OPR *General Plan Guidelines* encourage local governments to plan at a watershed level for better regional self-sufficiency and to consider adopting an optional water element in general plans to address water supply and other water-related impacts of land use policies.

In 2002, California voters approved Proposition 50, the Water Security, Clean Drinking Water, Coastal, and Beach Protection Act of 2002. It authorizes the Legislature to appropriate $500 million for IRWM projects. The intent of the IRWM Grant Program is to encourage integrated regional strategies for management of water resources and to provide funding for projects that protect communities from drought, protect and improve water quality, and improve local water security by reducing dependence on imported water. Proposition 84 (2006) allocated $1 billion for integrated regional water management plans (IRWMPs). Subsequent legislation altered the IRWMP requirements. IRWMPs typically include growth forecasts and opportunities exist for increased collaboration between land use planners and IRWMP preparers.

Coordinating Land Use and Flood Management

The potential for flooding is a significant risk for many localities in California. Flood events can cause substantial economic, social, and environmental damage. In addition, many flood management practices can be costly and have considerable effects on the environment. One of the most effective ways to reduce the vulnerability to potential flooding is through careful land use planning that is fully informed by and reflective of applicable flood information and flood management practices.

Integrated flood management considers the benefits of compact development by avoiding putting people and structures at increased risk and the infrastructure and maintenance costs associated with traditional flood protection. Utilizing compact and low-impact development can reduce the need for expensive structures and provide more room for uncertainty associated with climate change and storm and flood events.

Several laws were enacted in 2007 to improve public safety by coordinating flood management and land development within floodplains, consistent with the approach in SB 221 and SB 610 to coordinate the actions of water supply agencies and local land use authorities. See Flood Management on page 24-6 and *Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities* that identifies new code requirements, notes additional factors and actions that jurisdictions should consider, highlights the schedule for compliance, and directs readers to where they can obtain more information and assistance (California Department of Water Resources 2010). Selected 2007 legislation is reviewed below.

Key State Flood Management Legislation

SB 5 Flood Management (2008): SB 5 requires DWR and the Central Valley Flood Protection Board to prepare and adopt a Central Valley Flood Protection Plan (CVFPP) by 2012. The bill also requires cities and counties within the Central Valley to amend their general plans and zoning ordinances within a specified timeframe following adoption of the CVFPP. By 2015 cities or counties in the Central Valley are prohibited from entering into a development agreement, approving any permit, entitlement, or subdivision map unless the city or county makes one of the certain findings, including an urban level of flood protection. SB 5 defines “urban level of flood protection” as the level of protection necessary to withstand flooding that has a 1-in-200 chance of occurring in any given year.” The Sacramento-San Joaquin Valley includes the area subject to flooding by the Sacramento or San Joaquin rivers or their tributaries.

AB 5 Flood Management (2007): AB 5 includes technical cleanup amendments to bills addressing flood legislation.

AB 156 Flood Control (2007): AB 156 provides DWR and the Central Valley Flood Protection Board with specific authorizations that would enhance information regarding the status of flood protection in the Central Valley. The bill specifically directs DWR to map areas at risk of flooding, prepare a status report on the Central Valley's State Plan of Flood Control, identify levee flood protection zones, and notify property owners in levee flood protection zones of flood risk and flood insurance. AB 156 also requires DWR to specify how a State flood project facility needs to be fixed (including a cost estimate) if DWR determines that the facility is not being maintained adequately or the local agency responsible for maintenance requests should be relieved of its responsibility. Components of this bill apply statewide.

AB 70 Flood Liability (2007): AB 70 provides that a city or county may be responsible for its reasonable share of property damage caused by a flood, if that city or county has increased the State's exposure to liability for property damage by approving new development. It applies only to decisions made by local governments after January 1, 2008.

AB 162 General Plans (2007): AB 162 requires the land use element of general plans to annually review areas covered by the general plan that are subject to flooding as identified by flood plain mapping prepared by the Federal Emergency Management Agency or DWR. The bill also requires, upon the next revision of the housing element, that the conservation element of the general plan identifies rivers, creeks, streams, flood corridors, riparian habitat, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management.

Coordinating Land Use and Water Quality

State regulatory authority for water pollution is increasingly affecting land use decisions. The issue of stormwater runoff has led to the creation of many watershed planning efforts that operate on a regional or sub-regional level and may be part of an IRWM planning effort (see Chapter 20, "Urban Stormwater Runoff Management," in this volume). Efforts to control stormwater runoff and non-point source pollution are likely to affect the design, character, and even the location of local urban development by encouraging green stormwater solutions (wetlands restoration, use of pervious surfaces) rather than more traditional engineering approaches such as channelization (see Box 24-2 for descriptions of other planning efforts). Urban development and the paving of large areas of the landscape can have significant negative impacts on water resources. Suburban and rural construction and development can affect water supply (reducing percolation functions) and water quality through erosion. Many rural regions, such as those in the Sierra Nevada, are at the headwaters and origins of major rivers and tributaries. Although growth and land use change may be inevitable in many communities, the way in which the construction and growth takes place affects its impact on water quality. With careful planning and a commitment to protect streams, rivers, and groundwater, watershed-based land use practices can be implemented that balance the need for jobs, housing, and economic development with protection of the natural environment. Effective land use planning can contribute to increased groundwater and surface water protection by protecting these resources from runoff and waste percolation in the water table.

Sustainable planning should include appropriate groundwater and surface water protection measures. This may be implemented through the general plan and zoning development processes where certain activities are prohibited near sensitive areas, such as production wells, water bodies, and recharge areas. Likewise, improved coordination of flood management and land development within floodplains could provide public safety and ecosystem improvements. Development that takes place without such considerations, however, can lead to significant degradation of streams, groundwater, and water supply resulting from pollution.

The location of urban development can affect water quality, which can result in changes to available water supply. An integrated water resource management approach on a watershed basis, such as IRWMPs approved by DWR, identifies the opportunities and constraints for the impacted land uses.

Many jurisdictions use Leadership in Energy and Environmental Design (LEED) for Neighborhood Development as a measurement tool for sustainable development, extending the benefits of LEED beyond the building footprint into the neighborhoods and the watershed context. This LEED approach provides standards for sustainable site development, water quality, and efficiency. Consideration and mitigation of potential water quality impacts in both watershed and project-specific planning can decrease the risk of contamination of water supply sources (see Box 24-3, "LEED for Neighborhood Development").

Land Use Planning, Water, and California Native American Tribes

State planning law, known as SB 18 (2004), requires cities and counties to consult with California Native American Tribes during the local planning process for the purpose of protecting traditional tribal cultural places. The 2005 *Supplemental State General Plan Guidelines* provides advice and requirements for SB 18.

As of March 1, 2005, cities and counties must conduct consultations with California Native American Tribes (Civil Code Section 815.3, a federally recognized California Native American Tribe or a non-federally recognized California Native American Tribes; and Government Code Section 65352, California Native American Tribe) that are on the Native American Heritage Commission's (NAHC) contact list and have traditional lands located within the city or county's jurisdiction prior to adopting or amending their general plans.

Because this is a local government consultation requirement, there is a difference in expectations what SB 18 obligations entail. There is a need to clarify what land use planning efforts trigger the implementation of consultation requirements under SB18.

Nearly every California Native American Tribe has traditional stories about water and recognized sacred water sources (springs, wetlands, lakes, and watersheds), which serve as a place for story, ceremony, healing, subsistence, and other purposes. Local planning and land use decisions relating to watersheds and floodplains affect many of the cultural interests that SB 18 is intended to protect in general plans updates and revisions.

In watershed and floodplain management, there is a need to ensure that regular and early collaboration, communication, and consultation as appropriate occurs between local governments/planners and California Native American Tribes. This will provide California Native American Tribes an opportunity to participate in local land use decisions at an early planning stage for the purpose of protecting or mitigating land use impacts to watersheds and floodplains of which tribes have an interest. Failure to adhere to early and meaningful

Box 24-3 LEED for Neighborhood Development

LEED for Neighborhood Development (LEED-ND) is a collaboration between the U.S. Green Building Council, the Congress for the New Urbanism, and the Natural Resources Defense Council. The LEED-ND Rating System integrates the principles of smart growth, urbanism, and green building into the first national system for neighborhood design. LEED guidelines encourage site planning to consider natural water courses and to utilize the landscape for water conservation and water quality protection.

communication, collaboration, and consultation can result in costly delays in local planning efforts when California Native American Tribal input, knowledge, and concerns are not identified early in these local planning processes.

The ongoing process of early engagement and involvement of California Native American Tribes supports respecting, protecting, and planning to achieve the overall goal for everyone to respect, protect, plan, and partner. This helps ensure:

- Long-term viability of the source.
- The highest level of water quality.
- Watershed and watershed heritage protection.

Compact and Sustainable Development

Need for Compact and Sustainable Development

Changes in the state's demographics, economy, policies, climate, and investments are guiding local land use decisions toward a more sustainable pattern. This change in land use direction creates new opportunities for land use planners and water managers to collaborate. Population growth projections indicate there may be as many as 50 million people in California by 2050, an increase from more than 37 million in the 2010 Census. Land use patterns are changing in many California regions from a post-World War II supply of single-family homes in suburban, auto-dependent locations to mixed-used development that is generally urban-centered and transit-dependent. In the past, local government and private sector decisions on the placement of offices, industrial sites, and retail centers were driven by a combination of workforce availability, and State tax policy reinforced this traditional pattern of development. Private and public investments more commonly supported the traditional pattern of development, which often encouraged the conversion of agricultural and open space lands to developed uses. However, as described in the *Urban Land Institute Housing Opportunity 2013 In Depth: Demographics as Destiny* (http://www.uli.org/centers-initiatives/housing-opportunity-2013-in-depth-demographics-as-destiny/), more and more housing consumers, including empty nesters and young professionals, are choosing to live in more compact areas, closer to their workplaces or services/amenities, and in areas which are less reliant upon new infrastructure development and services.

Local policies, land use plans, and projects are emerging throughout California that reflect these compact and sustainable concepts. Compact sustainable development offers several opportunities for land use planners to meet integrated flood and groundwater management goals, to meet hazard mitigation requirements, and to collaborate with water managers on integrated water management (IWM), and to help achieve the State target of 20 percent reduction in urban per capita water use by 2020 (Water Conservation Act of 2009, or SB X7-7).

Compact and Sustainable Development Improves Water Resources Management

Reduced Water Usage

Traditional suburban-style development landscaped with nonindigenous plants creates high water demand for landscaping. As urban development occurs in hotter regions of the state, this pattern of land use and landscaping is projected to increase water use to a higher amount of residential water demand. More compact mixed-use urban development reduces landscaping-related water demand by minimizing front and back yards and their associated landscape water demands (see chapter 3, *Urban Water Use Efficiency* in this volume). Trends of rural communities creating larger residential lots of half-acre to five-acre forest estates which convert forest and grazing lands also use more water than the indigenous vegetation and trees.

The U.S. Environmental Protection Agency (EPA) recognizes these traditional land use patterns in both urban and rural settings consume more water and increase surface runoff, relative to more compact and sustainable development. In *Growing toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies*, the EPA writes, “Applying smart growth principles can significantly reduce the cost of water provided by communities and the quantity of water demanded by their residents. More compact development allows for shorter transmission systems, making them more efficient to operate and less susceptible to water loss through leakage. Encouraging compact neighborhood design on smaller lots reduces water demand for landscaping. Directing development to areas served by existing infrastructure and maintaining that infrastructure can make systems more efficient” (U.S. Environmental Protection Agency 2006).

Opportunities for Improved Watershed Management

Watershed management is a broad-based method used by planners for resolving water issues by linking land use and water resources within a drainage basin (see Chapter 27, “Watershed Management,” in this volume). Compact sustainable development can result in improved watershed management, particularly in reducing impervious surfaces. Conversely, land use practices on small portions of a watershed can still have significant consequences. For example, impervious surfaces such as roads, buildings, and parking lots result in more rapid and larger amounts of surface water runoff. This change in runoff can alter streamflow and watershed hydrology, reduce groundwater recharge, increase stream sedimentation, and increase the need for infrastructure to control storm runoff. Compact sustainable developments can be designed with native landscapes or other alternatives to traditional lawns to benefit conservation and help with runoff reduction goals for stormwater. It should also be noted that urban seasonal creek runoff and flows can be significantly impacted by infill projects. Collaboration between water managers and planners can identify mutually beneficial opportunities to integrate ecosystem functions and low-impact development practices as part of rural and urban development. These approaches apply to different scales of development, such as more urban-to-rural, within the watershed.

Reducing Flood Impacts

Flooding is a natural process which contributes to replenishing soils through sedimentation and recharging groundwater among many other benefits. When urban development is located within floodplains, the floodplain functions can be diminished or eliminated, which can place residents and structures at greater risk and increase overall cost. By focusing development in established urban areas and avoiding more development in floodplains, this risk can be reduced, protecting critical infrastructure and easing the burden on flood managers. Climate change adaptation includes assessing the increasing probability of flooding intensity and extent, and mitigating or avoiding this future exposure. Collaboration between land use planners, flood managers, and natural resource managers has the potential to produce the co-benefits of reducing flood risk to new developments and creating new developments that help to capture water that would otherwise contribute to flooding in other areas.

Additional benefits using floodplain management include recreational opportunities. The San Joaquin River Parkway and Conservation Trust is one example of how a floodplain can be used for recreation. Planners can incorporate recreational elements into floodplain management and low-impact development. Land set aside for urban greenways can function with designated floodplains, reducing flood impacts and increasing water infiltration, improve public health and residents' qualify of life, increase water and air quality, and increase the economic benefits for the region by supporting recreation and tourism-based businesses, as well as improving the quality of life for residents.

Several tools are available to planners and water managers to coordinate water quality and flood protection (see Box 24-4, "Leadership in Energy Environmental Design"). For example, by utilizing compact urban development approaches where appropriate, and supporting water-wise and storm-runoff building strategies in other areas, costs of expensive flood control structures are avoided. In addition, the use of surface and natural watercourses and floodplains for stormwater and floodwater limits pollution runoff, as the vegetated watercourses and floodplains treat urban runoff. Recreation close to development can be part of LID planning. The U.S. Green Building Council's LEED program has a Water Efficiency category to "encourage smarter use of water, inside and out" (U.S. Green Building Council 2011). Other advantages of these techniques are more fully described in the various resource management strategies in this volume and specifically the Practice Resource Stewardship strategies in this volume.

Reducing Risks and Vulnerabilities to Hazards

Hazard mitigation generally involves alteration of physical environments, significantly reducing risks and vulnerability to hazards by altering the built environment so that life and property losses can be avoided or reduced. Mitigation also makes it faster and less expensive to respond to and recover from disasters. One example of hazard mitigation planning is found in the CAL Fire Forest and Range Assessment, completed in 2010 (http://frap.fire.ca.gov/assessment2010.html). This document identifies communities at risk from wildland fires. Chapter 3.3 is titled "Planning for and Reducing Wildfire Risks" http://frap.fire.ca.gov/assessment2010/pdfs/3.3planning_for_wildfire_risks.pdf).

Climate change is a relatively new and increasingly important factor in hazard mitigation planning. Climate change intensifies the impacts of many natural hazards and is already affecting California. The state has seen rising sea levels, increased average temperatures, more extreme hot days, fewer cold nights, a lengthening of the growing season, and changes in precipitation.

Box 24-4 Leadership in Energy and Environmental Design

LEED certification provides independent, third-party verification that a development's location and design meet accepted, high levels of environmentally responsible, sustainable development. The LEED Green Building Rating System is a nationally accepted benchmark for the design, construction, and operation of high-performance green buildings. Administered by the US Green Building Council, LEED promotes a whole-building approach to sustainability by recognizing performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality.

Extreme weather events, such as heat waves, wildfires, droughts, and floods, are likely to be some of the earliest impacts of climate change. Actions to reduce carbon emissions and adapt to climate change are becoming increasingly important.

The California Natural Resources Agency, in partnership with the California Emergency Management Agency and with technical support from California Polytechnic State University, San Luis Obispo, published the Adaptation Policy Guide (APG) (http://resources.ca.gov/climate_adaptation/local_government/adaptation_policy_guide.html) to provide guidance and support for local and regional collaboratives to address the unavoidable consequences of climate change and to aid in the interpretation of climate science for reducing risks. The APG is not intended to provide a prescriptive set of strategies. Instead, it will provide a framework to guide decision-makers through the critical considerations necessary for adaptation policy development.

Low-Impact Development (LID)

Discouraging traditional large-lot urban development in favor of more mixed-use projects that place jobs, schools, recreation, shopping, and other services close to housing has several benefits, including water use efficiency. Using LID design can mitigate the potential effects of the increased impermeable surfaces associated with compact development projects. Within the range of LID strategies, consideration must be given to the physical conditions of soil, hydrology, and other factors. Mixed-use development reduces vehicle miles traveled (VMT) by making walking an option to driving. A reduction in VMT will have a corresponding decrease of GHG emissions, as well as overall energy use related to fossil fuels.

State Policies Encouraging Compact Sustainable Development

State policies generally support compact sustainable development including higher density and mixed-use development. Mixed-use development combines residential, commercial and retail services, and job centers where appropriate, and can create more efficient patterns of land use. Public and private investment and financing are shaping land development in some of the most densely populated regions of the state. For example, the Bay Area, Los Angeles, Sacramento, and San Diego regions are making headway to grow more compactly, provide jobs closer to housing, and offer public transit to connect people with community resources and centers of employment.

Key State Legislation

AB 857 (2002) establishes three State planning priorities and requires that all State strategic plans and capital improvement plans — including the CWP — to be consistent with them. These priorities, briefly stated, are to promote infill development and equity, protect environmental and agricultural resources, and encourage efficient development patterns.

AB 857 also requires the State's Environmental Goals Policy Report (EGPR), prepared by OPR, to be consistent with these planning priorities (http://www.opr.ca.gov/s_egpr.php). The EGPR is intended to provide a 20- to 30-year overview of state growth and development as well as articulate the governor's environmental goals and policies including, but not limited to, land use, population growth and distribution, development, conservation of natural resources, and air and water quality. The EGPR serves as the basis for judgments about major State investments and capital projects, including the allocation of State resources through the budget and appropriations process.

AB 32 (2006), Global Warming Solutions Act, establishes a target to reduce statewide carbon emissions to 1990 levels by 2020. ARB is responsible for developing a comprehensive program of regulatory and market mechanisms to achieve quantifiable, cost-effective reductions of GHG emissions in accordance with the statutory target. ARB's Climate Change Scoping Plan identifies the framework for implementing AB 32 and recommends modification of development patterns as a means of achieving the State's emissions reduction goal. SB 375 is the primary mechanism for implementation of the Scoping Plan and target reductions.

SB 375 (2008), which builds on AB 32, helps reduce GHG emissions by linking transportation and land use planning to reduce vehicle miles traveled. SB 375 provides emission-reduction targets around which regions can integrate planning activities and provides incentives for local governments and developers to support new sustainable growth patterns. The legislation directed ARB to develop regional GHG emissions reduction targets to be achieved from the automobile and light truck sectors for 2020 and 2035.

The 18 MPOs responsible for preparing Regional Transportation Plans (RTPs) are required to develop a Sustainable Communities Strategy (SCS) to achieve their regional GHG reduction targets, and to base Regional Transportation Plans and Regional Housing Needs Assessments (RHNAs) on the SCS. Local governments must amend their general plan housing elements to be consistent with the RHNA for their region within 18 months of SCS adoption. SB 375 also provides new CEQA provisions for projects consistent with adopted SCSs.

SB 375 does not require SCSs to address water issues specifically. However, to achieve regional GHG reduction targets, SCSs can call for more compact sustainable development that can have water supply, water quality, and flood management benefits. For up-to-date information on SB 375, go to ARB's Sustainable Communities Web site: http://www.arb.ca.gov/cc/sb375/sb375.htm.

SB 732 (2008) provides a statutory framework to implement new programs under Proposition 84, the $5.4 billion initiative voters passed in 2006 for safe drinking water, water quality and supply, flood control, natural resource protection, and park improvements. The bill also establishes the SGC which, as noted previously, is tasked with coordination of programs to improve air and water quality and natural resource protection, increase the availability of affordable housing, improve transportation, meet the goals of AB 32, encourage sustainable land use planning, and revitalize urban community centers in a sustainable manner.

SB 226 (2011) exempts certain rooftop solar projects from CEQA, and also creates a new streamlining tool for infill projects that meet specified criteria and satisfy a set of performance standards. OPR developed guidelines and performance standards for this new streamlined process for infill projects.

SB 244 (2011) requires local agencies to plan for disadvantaged unincorporated communities through the Local Agency Formation Commission (LAFCO) planning process and general plan updates. SB 244 requires that on or before the next adoption of its housing element, a city or county must review and update the land use element of its general plan to include an analysis of the presence of island, fringe, or legacy unincorporated communities, as well as water, wastewater, stormwater drainage, and structural fire protection deficiencies in those communities and financially feasible ways to extend those services. SB 244 offers an opportunity for local governments to plan for the provision of infrastructure in unincorporated communities. To do this effectively and to produce sustainable solutions will require cooperation and collaboration between LAFCOs, the local governments, and the local water and wastewater service providers. These planning efforts will need to address the complex challenges of providing infrastructure to existing communities without promoting sprawl.

AB 900 (2011), the Jobs and Economic Improvement through Environmental Leadership Act, requires the governor to establish procedures for projects, including infill projects, to apply for streamlined CEQA review. The bill sets up specific criteria which must be met by large projects to be eligible for streamlined CEQA review. The Governor's Office guidelines for this bill are available on the OPR Web site at http://www.opr.ca.gov.

SB 1087 (2005) requires local governments to provide a copy of the adopted housing element to water and sewer providers. In addition, water and sewer providers must grant priority for service allocations to proposed developments that include housing units with affordable to lower income households.

AB 685 (2012) ensures universal access to clean water, recognizing that by law "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes." AB 685 requires all relevant State agencies, including DWR, the State Water Resources Control Board, and the California Department of Public Health, to consider this State policy when revising, adopting, or establishing policies, regulations, and grant criteria when those policies, regulations, and grant criteria are pertinent to the uses of water described above. (International Human Rights Law Clinic 2013)

Regional Blueprint Planning Grants

Originally established by the Legislature as a two-year program, the California Regional Blueprint Planning Program is administered by Caltrans and OPR (see Box 24-5, "California Regional Blueprint Planning Program Goals"). The Regional Blueprint Planning Program is a voluntary, competitive grant program for MPOs and their COGs and rural Regional Transportation Planning Authorities (RTPAs) to conduct comprehensive scenario planning that results in informed consent by regional leaders, local governments, and stakeholders to a preferred growth scenario or "blueprint" to achieve certain objectives for a 20-year or longer planning horizon. Through the blueprint planning process, regions throughout California develop preferred land use planning and transportation scenarios that encourage compact sustainable development and also meet GHG emissions reduction targets. In some regions, blueprint plans have served as the starting point for development of Sustainable Communities Strategies under SB 375.

Box 24-5 California Regional Blueprint Planning Program Goals

Foster more efficient land use patterns and transportation systems that:

- Support improved mobility and reduced dependency on single-occupant vehicle trips, and reduce congestion.
- Increase transit use, walking, and bicycling.
- Encourage infill development.
- Accommodate an adequate supply of housing for all incomes.
- Reduce impacts on valuable habitat and productive farmland.
- Improve air quality.
- Increase efficient use of energy and other resources.
- Result in safe and vibrant neighborhoods.
- Provide consumers with more housing and transportation choices.
- Improve California's economic competitiveness and quality of life.
- Establish a process for public and stakeholder engagement that can be replicated to build awareness of and support for critical infrastructure and housing needs.

Nearly $22 million in federal regional transportation planning funds have been awarded by Caltrans since the program was initiated in 2005. For fiscal year 2010-2011, more than $600,000 were granted to eight rural RTPAs to support transportation planning activities across rural California. Since the genesis of the Regional Blueprint Planning Program, there have been a total of 17 MPOs and 15 RTPAs that have participated in the grant program and have enhanced or initiated a blueprint in their regions. The blueprints may provide helpful information to water managers so that they may anticipate patterns of future growth. In addition, the patterns of future infrastructure development may provide opportunities for integration and cost savings if infrastructure is planned and constructed simultaneously instead of serially. For the most up-to-date information on this program, go to http://calblueprint.dot.ca.gov/.

Sustainable Rural Land Use and Water

The Challenge of Sustainable Rural Land Use

Water management strategies can affect the sustainability of rural land use in several ways. For example, agricultural-urban water transfers through "third party effects" can potentially impact the sustainability of agriculture and agriculture-dependent small towns in rural areas if land fallowing is involved (Hanak 2003). Timberland management, including harvesting, can affect watershed capacity. Similarly, large-scale restoration, flood management, and mitigation projects may be proposed on agricultural and timberlands, again potentially affecting the sustainability of agriculture and agriculture and timber-dependent small towns. CEQA documents prepared for water transfers and other water projects offer the opportunity to analyze and mitigate these impacts on rural areas.

University of California, Davis, found that nitrate leaching from agriculture is responsible for 96 percent of the current groundwater contamination in four California counties with the largest agricultural production in the nation. Disadvantaged communities in some rural areas may lack safe and reliable drinking water supplies and safe wastewater systems, and may also be subject to flood hazards. Comprehensive and integrated land use and water management planning offers the opportunity to address these problems in the future.

Key Agricultural Land Preservation Programs

Chapter 21, "Agricultural Land Stewardship," in this volume, provides a detailed description of numerous federal, State, and local laws and programs intended to preserve agricultural lands. Some of the most important programs are summarized below.

The Williamson Act (Government Code Section 51200 et seq.) is California's oldest agricultural land preservation program, dating back to 1965. The Williamson Act offers agricultural landowners reduced property tax assessments if they contract with counties or cities to restrict their land voluntarily to agricultural and open space uses. In return, restricted parcels are assessed for property taxes at rates consistent with their actual uses, rather than potential market value (Revenue and Taxation Code Section 423 et seq.) The State has historically provided subventions to local governments to compensate for reduced property revenues associated with Williamson Act contracts, but these subventions have been eliminated from recent budgets, a cut that places this program and its inherent benefits at substantial risk.

CEQA also plays an important role in agricultural land preservation. Appendix G of the State CEQA Guidelines sets forth an initial study checklist used to determine whether a project's environmental impacts are potentially significant. Under Appendix G, a project would have significant effects on agricultural resources if the project would:

- Convert prime farmland, unique farmland, or farmland of statewide importance, as shown on Department of Conservation's Division of Land Resource Protection (DLRP) maps, to non-agricultural use.
- Conflict with existing agricultural zoning or a Williamson Act contract.
- Involve other environmental changes that could result in the conversion of farmland to non-agricultural use.

Conservation easements are another important tool for agricultural land and open space preservation. A statutory conservation easement is a recorded deed restriction voluntarily executed by a landowner with the purpose of retaining land predominantly in its natural, agricultural, or open space condition (Civil Code Section 815.1). Funding for conservation easements is provided by several programs, including the California Farmland Conservancy Program Act (Public Resources Code Section 10200 et seq.), the Open Space Easement Act (Government Code Section 510070 et seq.), and the Federal Farm and Ranch Lands Protection Program (7 Code of Federal Regulations Part 1491).

Potential Benefits

Land use planning and management that promotes compact and sustainable development has at least six main benefits directly tied to the CWP:

- **Climate change:** Reduces GHG emissions and improves adaptation to climate change impacts.
- **Water supply:** Reduces municipal and industrial water demand through water use efficiency, recycling, capturing and reusing stormwater, recharging and protecting groundwater, protecting ground and surface water from failed septic systems, and encourages growth in areas with sufficient reliable water supplies.
- **Flood management:** Keeps people and structures out of flood hazard zones and reduces runoff volumes and intensity.
- **Water quality:** Reduces runoff volumes, improves runoff water quality, and improves water affordability.
- **Ecosystem preservation:** Encourages ecosystem preservation by planning development in non-critical habitat areas.
- **Recreation:** Provides opportunities for use of floodplains, flood greenways, and LID designs while providing public benefits for walking, biking, and other passive and active activities.

Compact, mixed-use development, can reduce water and energy demand, even with moderate increases in density. Specifically, compact development can reduce landscaped areas and, therefore, reduce landscape-related water use. As a rule of thumb, landscaping irrigation accounts for almost half of residential water use. Although higher density development may actually increase impervious surfaces and increase traffic congestion in localized urban areas, it can reduce the total development footprint in the state and reduce urbanization impacts to farmlands, habitat, watershed functions, and groundwater recharge areas. In addition, LID approaches incorporated in the more dense development further reduce the impact of runoff and water pollution (see Box 24-6, "LID Runoff Control Objectives," and Chapter 20, "Urban Stormwater Runoff Management").

Providing water supply for urban uses consumes a significant amount of energy for capturing, storing, conveying, and treating water. Thus, efficient water use is also an energy conservation and GHG emissions reduction strategy. A smaller urban footprint reduces impervious surfaces. This generates less surface runoff and minimizes intrusion into watersheds and groundwater recharge areas, which receive the runoff. Total infrastructure costs can be reduced in areas of compact development.

Sustainable rural development has several additional specific benefits. Strong agricultural and rural communities can:

- Increase agritourism.
- Provide opportunities for carbon sequestration.
- Provide wildlife habitat on timber and agricultural lands.
- Provide fuels for biomass energy projects that reduce GHG emissions.
- Provide rural transit programs and other initiatives that reduce VMTs.
- Provide local foods for restaurants, farmers markets, and consumers, again reducing GHG emissions.
- Provide recreation and wildlife habitat in both timber and open space.
- Provide watershed management for water quality and supply.
- Provide watershed functions and protection of communities at wildland urban interfaces.

Box 24-6 Low-Impact Development Runoff Control Objectives

Low Impact Development (LID) is a different approach to stormwater management, using site design and suitable stormwater management practices to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall. LID is seen as an alternative to conventional stormwater management. The State Water Resources Control Board (SWRCB) and regional water quality control boards are advancing LID in California through the following:

- Regulating through site-specific and general permits.
- Providing advocacy and outreach to local governments through the SWRCB's Training Academy and regional workshops.
- Seeking ways to incorporate LID language into a Standard Urban Storm Water Mitigation Plan (SUSMP).
- Funding LID-related projects through the consolidated grants program.

- Provide innovative water and wastewater delivery mechanisms that lower costs of infrastructure development (Sacramento Area Council of Governments 2011).

From a flood protection and water supply perspective, sustainable rural development also provides opportunities to avoid costly expansion of traditional flood and water management structures through rural floodplain management.

Potential Costs

Because land use planning includes a broad array of resources including water, energy, and soil, there are hidden costs and assets that are difficult to tease out for the "costs" associated with comprehensive planning. This section identifies costs related to compact sustainable development for urban and rural communities, as they relate to three categories: comprehensive land use planning, infrastructure, and ongoing coordination. For more information on the costs of compact sustainable development as well as its benefits, see Vision California at http://www.visioncalifornia.org/reports.php.

General Plan Updates

Local government has the primary responsibility for comprehensive and project-specific planning. State law requires each land use jurisdiction (cities and counties) to adopt a general plan. The current cost for updating a general plan can vary greatly depending on the size of the community and the degree of the updating required. Local governments will incur significant planning costs in preparing revised general plans and associated environmental impact reports (EIRs) that integrate water resources concerns, implement regional SCSs, and reduce GHG emissions. In addition to cost, the update process may take several years. The timeframe can be extended by litigation.

Local Strategies for Greenhouse Gas Emissions Reduction

State agencies and other governmental and non-governmental agencies are developing cost estimates to implement energy, water supply, and flood conservation strategies that will affect land use. ARB's 2008 adopted Scoping Plan attributes climate change mitigation costs for everything from low-carbon fuel technologies to building improvement. Many of these measures are in developmental stages and the estimated costs, emission reductions, applicable technologies, and other factors will likely change as they move through the regulatory process.

In terms of local and regional governments, economic costs will result from policies to reduce (GHG) emissions by changing how we grow and build our communities (http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf) (California Air Resources Board 2008). ARB estimates the cost to implement this land use strategy within the constraints noted above, as well as part of a cap-and-trade program. The State should provide cap-and-trade monies to local government to incentivize the implementation of this land use planning and management resource management strategy. The potential state, local, and private benefits for promoting higher density and more compact development may offset the costs of implementing this land use planning-and-management resource management strategy.

Transportation Planning and Investments

Transportation planning efforts, which aim to achieve compact and sustainable development, are a major cost to regional and local governments. In addition to planning costs, there are implementation costs for capital projects, road, maintenance yards, bus stops, and intermodal stations. Maintenance and operations are often a separate budget cost, and most funding sources are restricted from being used for sustained operations. The three tiers of federal, State, and local transportation planning and transit programs are supported at various levels of funding. Federal funds support regional transportation, which must be aligned with State and regional programs and policies.

Implementation of compact and sustainable development will incur increased transit costs. Sustainable Communities Strategies may require increased investments in transit facilities and reduced investments in highways, relative to past trends. However, federal, State, and local funding programs may be constrained in their ability to shift highway investments to transit investments.

Water Supply Planning and Investments

Federal, State, and local governments (often water districts) prepare various water supply plans. The federal and State planning is in the larger context of state hydrology and operations. Local governments must prepare the UWMP, and water districts likewise prepare plans, sometimes coordinating these local plans region-wide. State law provides for local land use jurisdictions to identify water supply sources. The cost of water supply planning can be high due to the technical nature of the data.

Although there may be significant new costs associated with changing the way local, regional, and State agencies plan urban areas, there are expected savings from avoided costs, especially in terms of future energy and long-term maintenance of infrastructure and other life cycle costs.

However, immediate costs are projected for increased planning, communication, coordination, and information sharing among land use agencies, water suppliers, agencies which regulate water quality, and climate change benefits of compact development. To achieve development of urban infill, there may also be substantial costs associated with upgrading urban infrastructure needed to support higher density development (see Box 24-7).

Sustainable Rural Development

Rural areas include agricultural land, forests, and floodplains that may contain low-density development and small towns. Many rural California counties have large areas of land owned by the State or federal government, accounting for 50-75 percent in many areas. Some local governments strive to protect the floodplain and natural recharge areas for groundwater and find it challenging to also meet other State mandates.

Sustainable rural development incurs many of the planning and infrastructure costs mentioned above. Smaller rural cities and counties have especially limited financial resources for land use planning and infrastructure improvement due to smaller tax bases. In addition, water and flood management agencies may incur substantial costs to mitigate the impacts of their projects on timber and agricultural land and timber and agriculture-dependent small towns. There may be costs associated with the effects on recreation and resource-dependent communities. These costs may include not just direct land acquisition costs, but also financial assistance to compensate for reduced tax revenues.

Timber and Agricultural Mitigation

In addition, water and flood management agencies may incur substantial costs to mitigate the impacts of their projects on timber and agricultural land and timber and agriculture-dependent small towns. There may be costs associated with the effects on recreation and resource-dependent communities. These costs may include not just direct land acquisition costs, but also financial assistance to compensate for reduced tax revenues.

Recreational Opportunities

More compact development utilizing LID designs will require more public recreational opportunities that may include trails along urbanized, suburban, and rural waterways providing alternative routes for schools and work. Recreation demands will increase and coordinating and combining these recreational needs in an IWM approach services multiple purposes and provides public health benefits at an affordable economic scale.

Infrastructure and Property Values

There are on-the-ground costs associated with developing more compact and sustainable land use patterns. Property values in outlying open space and agricultural areas may be reduced to the extent they reflect development potential that can no longer be realized. However, property values of urban infill sites would tend to increase. To achieve significant urban infill, there may be

Box 24-7 Integrating Water and Land Management

The Integrated Water and Land Management Tool (California Department of Water Resources and Sonoma State University 2013) demonstrates that reducing hardscape is a critical component to minimizing water resource impacts and that it is possible to minimize costs and impacts while using standard building materials.

The tool is user-friendly and easily modified to reflect local conditions for calculating development approaches for low-impact strategies for stormwater runoff and water supply benefits. This tool is a new, open-source application that will grow and develop over time as additional case studies and applications are completed. Because of the range of spatial scales the tool addresses, the results will apply to a wide user base, including homeowners interested in testing possible retrofits to their properties and examining costs versus benefits; residential developers seeking to evaluate different design strategies; local agency officials, including planning and public works staff; and elected and appointed decision-makers, such as council members and planning commissioners.

The tool is intended to be useful for evaluating the effectiveness of water conservation measures being considered in a project or by suggested redesign or conditioning. Local agencies may also use the model to help generate standards that would apply to new developments through general plan, zoning, and subdivision regulations; design guidelines; or other planning documents designed to give guidance to private project proponents.

The tool effectively demonstrates real differences in consumption at the lot and neighborhood levels when applied to case study sites. It is most useful for preliminary planning and conceptual design. In all of the case studies discussed in the report *Integrating Land and Water Management: A Suburban Case Study and User-Friendly, Locally Adaptable Tool* (California Department of Water Resources and Sonoma State University 2013), the environmental and monetary impacts of public infrastructure were sufficiently large that they overwhelmed many of the lot-by-lot choices. Public infrastructure may be the most critical component of a development. With further development of lifecycle costs calculations, it is likely that there will be an increasingly strong case for green infrastructure.

substantial costs associated with upgrading urban infrastructure needed to support higher density development, as discussed below (see Box 24-7).

Major Implementation Issues

Disincentives for Change

Local governments have the authority to make most of the local land use decisions in California. Although many local governments are revising their land use plans and policies to promote compact and sustainable development, some local governments may not promote or implement compact and sustainable development patterns for many legitimate reasons. Their decisions might be guided by one or more of the following reasons:

- Community resistance to infill projects and/or higher density development.
- Traditional and antiquated local zoning ordinances that, for instance, segregate retail uses from residential uses or require higher parking ratios.
- The cost to update general plans, prepare general plan EIRs, and revise zoning codes.

- The cost and potential liability associated with pursuing infill projects, especially on brownfield sites.
- CEQA mitigation strategies that have been shown to inadvertently encourage lower density development.
- Environmental hazards.
- Urban infrastructure limitations.

Fiscal Policy and Constraints

California's development patterns are driven by fiscal policies as local governments seek to balance revenues and expenditures by way of land use decisions, including balancing commercial and residential land uses in their jurisdictions, which may create competing retail centers or inefficient land uses. Additionally, lack of public financing resources due to Propositions 13 and 218, reducing the role of property-based taxation as a local government revenue source combined with the declining federal and State financing for infrastructure, have forced many local governments to focus increasingly on the potential fiscal effects of land use decisions.

Additional federal fiscal policies, such as low capital gains tax rates, make property ownership an attractive investment, adding to the urban development expansion in recent years. These fiscal policies combine to generate potential encouragement for local governments to seek and approve development that increases sales tax revenue, such as regional retail and commercial uses.

Some local governments seek higher priced housing over moderately priced housing because housing development only produces property tax at a fixed rate, which is less than the rate of inflation for providing city-based services such as road repair, infrastructure maintenance, parks, libraries, fire protection, and public safety. Rural communities may seek forest and agricultural estates (large home sites with some agricultural potential) for property tax benefits, but such development may erode the necessary cluster of resource lands for timber or working farms. Therefore, this cluster withers. Focusing on higher end housing has the potential to establish a higher tax base to support the provision of ongoing municipal services. Overall, simple economics dictates that counties and cities will, as a practical matter, favor development that generates higher property and sales tax.

Financially strapped cities and counties are more inclined to favor tax-generating land uses, such as retail and commercial, over housing. For residential projects, communities typically have adopted "development pays its way" policies to cover infrastructure improvements. Developers are assessed a variety of development impact fees to cover the cost of such services and amenities as roads, parks, water, public safety, and other social infrastructure costs. The net result of these fiscal constraints is that the short-term need for revenue generated by this type of land use is often pursued without budgeting for the long-term costs. As a result of these property tax policies, local communities often compete with one another for businesses that generate sales tax. Community needs for jobs and housing are often outweighed by the competition for revenue-driven development.

Coordinating Land Use and Water Policies

Coordination of land use and water policies at multiple levels is a primary challenge in meeting state and local water needs. Increased coordination will also be necessary among all levels of government to facilitate inter-agency planning, to develop reliable and complete data and information which can form the basis for consistent government decision-making, and to interpret and share data and information to optimize the relationship of land use planning and water resources planning. For example, California Government Code and the Water Code require local governments to determine whether there will be enough water to supply a proposed development project before it can be approved. For more information on the relationship between land use and water supply planning, see the Urban Land Institute's report on SB 375 at http://www.uli.org/publications/resource-library/.

Incorporating Regional Transportation with Sustainable Communities Strategies and Local General Plans

An SCS or Alternative Planning Strategy (APS), developed by an MPO or other regional designee, is required under SB 375 as a part of the Regional Transportation Plan (RTP) development process. MPOs prepare land use allocations within the RTP to achieve each region's GHG emissions reduction targets. SB 375 and SB 732 provide incentives to meet emissions reduction targets, and SB 732 authorizes funding for the planning and development of sustainable communities.

SB 375 should result in more certainty to the development community as to where development should occur and the type of development that is encouraged. The path to the development approval process should also be easily comprehensible in order to create more certainty. Currently, there is minimal coordination between SCSs and regional water planning. Additional planning and coordination costs may be incurred by MPOs to incorporate water resources management issues and concerns into future SCSs. Similarly, additional planning and coordination costs may be incurred by DWR and IRWMP preparers to use SCS growth forecasts as the demographic and land use basis for regional water planning

Transportation planning efforts which aim to achieve compact and sustainable urban development mentioned above are a major cost to regional and local governments. SB 375 will require regional planning agencies to incur increased planning costs to develop new land use allocations supporting RTPs. The new RTP EIRs will increase in cost and complexity. In addition to planning costs, there are much greater planning and implementation costs for RTP implementation as listed below in the Recommendations section.

Regulatory Improvement and Streamlining

The existing regulatory framework across federal, State, regional, and local levels contains some inherent conflicts and contradictory directives, such as designated infill priority development areas conflicting with flood zones, environmental guidelines limiting proximity of housing to freeways or school location, and configuration guidelines that favor low density environments. Some State guidance can be considered separately from larger regional land use and transportation policies, which might confuse local jurisdictions on how to comply with multiple policy directions from the State.

Issues for Sustainable Rural Development

Landowner incentives for maintaining agricultural land in agricultural use include the Williamson Act and conservation easements. However, State subventions to local governments for reduced property taxes associated with Williamson Act contracts have been eliminated, which may result in non-renewal of Williamson Act contracts over the long term. Also, funding for conservation easements is threatened by the state’s economic downturn, as well as reduced federal and State discretionary spending in budgets. As noted above, State subventions to local governments for reduced property taxes associated with Williamson Act contracts have been eliminated, which may result in non-renewal of Williamson Act contracts over the long term and thus jeopardize this popular and effective program.

Recommendations

Promote Cross-Cutting Funding and Planning Programs

1. The State should provide additional incentives to developers and local governments to plan and build using more compact and sustainable development patterns. This could be done through further CEQA streamlining for infill development and associated infrastructure, depending on SB 226’s effectiveness, further reductions in brownfields liability for innocent land purchasers (depending upon the restoration of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, also known as Superfund (refer to http://www.epa.gov/superfund/policy/index.htm and http://www.epa.gov/oecaerth/cleanup/revitalization/ilo.html)), prioritizing planning grants, and providing further incentives (financial and other) to encourage compact and sustainable development.

2. The State should develop and promote performance-based planning with metrics. Examples include establishing a baseline for each watershed for impervious surfaces, reduction of vehicle miles traveled per capita, planning and resource management that integrates multiple agencies and viewpoints, comprehensive flood management using floodplain planning, and land coverage. These metrics should be the basis for evaluating projects that request discretionary State funding, grants, and other financial assistance.

3. Local, regional, and State land use and water planning agencies should generally conduct an integrated review of long-range land use planning documents, infrastructure master plans, and financing strategies to ensure adequate support for long-term growth, and sustainable development in urban and rural areas.

4. The State should provide incentives for developing IWM elements in local general plans.

Integrate Regional Water Management and Regional/Local Land Use Plans

5. Regional planning agencies should continue and expand their participation in the regional blueprint planning process.

    A. The State should provide mapping, funding, and technical assistance in order that local governments may consider relevant water management issues.

6. Regional planning agencies should address water management issues in their blueprint plans, groundwater management plans, and SCSs.

7. LAFCOs should consider water management issues in the context of their principal purposes, which include discouraging urban sprawl, preserving open space and prime agricultural lands, efficiently provide government services, and encouraging the orderly formation and development of local agencies based upon local conditions and circumstances (Government Code 56301).

8. Local governments should coordinate with water planning agencies to promote integration of land use and water management planning. Examples of how this is currently being done include:

   A. Reviewing and submitting comments on the UWMPs adopted by water agencies within their jurisdiction.

   B. Participating in the IRWM planning and implementation processes.

   C. Continuing to implement SB 610 and SB 221 (2001) effectively, which require land use approvals to consider whether sufficient water supplies are available to serve new development.

   D. Engaging relevant water management agencies to participate in general plan updates that address water issues.

9. When conducting general plan updates, local governments should address relevant water management issues including water supply, water quality, water affordability, flood risk reduction, and adequacy of services residents. This can be done by adding water management policies to the general plan elements currently required by statute, or by preparing an optional water element not required by statute. The discussion of water issues in general plans should be informed by IRWMPs and CWP Regional Reports applicable to the city or county.

10. Local and regional water management and flood agencies should coordinate with local governments to promote integration of land use and water management planning. This should be done by:

    A. Participating in the general plan process in the communities they serve and submitting comments on general plan updates.

    B. Including local agency representatives, regional water management groups, which are the governing bodies for IRWMPs.

    C. Collaborating with local governments to identify opportunities to maximize water conservation, groundwater recharge, stormwater capture, and other water management strategies that rely on local land use planning for effective implementation.

11. To foster better coordination, collaboration, and communication, the State should facilitate tribal participation in IRWM and the Strategic Growth Council programs and policies, and link State and local funding, grants, and permits. The State should develop model protocols for local land use jurisdictions on working with tribes when feasible.

12. Local governments should implement specific land use planning and regulatory measures to reduce flood risks, as described in the resource management strategy recommendations in Chapter 4, "Flood Management," of this volume.

   A. Technical assistance, data, and community participation should be funded.

13. Local government should consider integrating recreational amenities into flood and water management plans to provide multiple benefits associated with IWM.

Provide Funding, Incentives, and Technical Assistance

14. Increased State funding and technical assistance should be provided for the following programs and policies that promote compact, sustainable development:

   A. Development and implementation of regional blueprint plans.

   B. Development and implementation of SCSs.

   C. General plan updates that implement blueprint plans and SCSs, and address water issues.

   D. General plan updates, zoning code updates, specific plans, and other land use controls that promote compact sustainable development in addition to provisions in blueprint plans and SCSs.

   E. Coordinated State and local government programs that incentivize infill development. These are especially important since tax increment financing by redevelopment agencies is no longer available as a tool to incentivize infill development.

   F. General plan updates and other local government programs that use land use policies to help adapt to climate change.

   G. Local government adoption of green building codes with LID principles that include water conservation and reduction of impervious surfaces.

   H. Continued use of the CEQA process to mitigate the significant impacts of new development on resources including, but not only, prime agricultural land, wildlife habitat, open space, floodplains, recharge areas, wetlands, and water supply.

15. State grant and funding decisions should provide incentives and give priority to projects that are consistent with:

   A. Strategic Growth Council sustainability objectives.

   B. AB 857: State planning priorities that promote urban infill, and protect environmental and agricultural resources.

   C. Regional sustainable communities strategies.

   D. Integrated regional water management plans.

   E. Regional blueprint plans.

   F. Green building codes that incorporate LID principles and reduce impervious surfaces, especially near waterways, and design standards such as LEED-ND and CALGreen.

16. State grant and funding decisions should recognize the unique challenges of promoting sustainable rural development.

17. Regional planning agencies should provide financial incentives and technical assistance to local governments to implement blueprint plans and SCSs in their communities.

18. The State should develop, make available, and provide technical assistance for a land use tool that allows planning and water resources agencies to evaluate the life cycle water resources infrastructure costs of conventional development patterns, as compared to compact and sustainable development patterns.

Enhance Research and Data Gathering

19. The State should provide funding, technical information, and best practices, as well as publicize accurate and relevant water resources information for use by local governments and developers. The State could serve as an information clearinghouse for regional water supply, water quality, flood management, and climate change vulnerability information that local governments can use in preparing general plans. Such information would also provide comprehensive water resources information and policies to land use project applicants during pre-application meetings.

20. The State should encourage and support more scientific, engineering, planning, social, and economic research on the benefits and impacts of resource-efficient development patterns; develop an inventory of best practices by local governments, natural resource managers, and land management agencies; and provide a user-friendly portal for information access.

21. The State should evaluate the effectiveness of the package of flood management laws that were enacted in 2007 (see the "Coordinating Land Use and Flood Management" section in this chapter) in coordinating land use, flood planning, and natural resources and work to provide recommendations for changes to existing laws and their implementation as appropriate.

22. The State should evaluate the effectiveness of SB 610 and SB 221 in coordinating land use and water supply planning, and recommend improvements to these laws or their implementation as appropriate. The State should develop guidance on how SB 610 and SB 221 water supply assessments and verifications should address the effects of climate change and Delta export uncertainties on supply reliability.

Promote Interagency Coordination

23. The State should identify strategies, including performance metrics to improve communication, coordination, and information sharing among local agencies, regional planning agencies, and local water agencies and watershed managers.

24. The State should promote improved coordination between local general plans and LAFCO policies on boundary changes to ensure adequate house and water supply with effective flood management.

References

References Cited

California Association of Local Agency Formation Commissions. 1971. What Is LAFCo? Sacramento (CA): California Association of Local Agency Formation Commissions. [Web site.] Viewed online at: http://www.calafco.org/about.htm.

California Air Resources Board. 2008. *Climate Change Scoping Plan, A Framework for Change*. Sacramento (CA): California Air Resources Board. 133 pp. Viewed online at: http://www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf.

California Department of Water Resources. 2008. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water*. Sacramento (CA): California Department of Water Resources. 34 pp.Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf.

———. 2010. Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities. Sacramento (CA): California Department of Water Resources. 152 pp. Viewed online at: http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf.

Hanak, E. 2003. *Who Should be Allowed to Sell Water in California? Third Party Issues and the Water Market*. San Francisco (CA): Public Policy Institute of California. 196 pp. Viewed online at: http://www.ppic.org/content/pubs/report/r_703ehr.pdfhttp://www.ppic.org/content/pubs/report/r_703ehr.pdf.

International Human Rights Law Clinic. 2013. *The Human Right to Water Bill in California: An Implementation Framework for State Agencies*. Berkeley (CA): University of California, Berkeley, School of Law. 20 pp. Viewed online at: http://www.law.berkeley.edu/files/Water_Report_2013_Interactive_FINAL.pdf.

Sacramento Area Council of Governments. 2011. *Rural-Urban Connections Strategy*. Sacramento (CA): Sacramento Area Council of Governments. 24 pp. Viewed online at: http://www.sacog.org/rucs/pdf/RUCS%20Booklet%202011%20Web.pdf.

U.S. Environmental Protection Agency. 2006. *Growing Toward More Efficient Water Use: Linking Development, Infrastructure, and Drinking Water Policies*. Washington (DC): U.S. Environmental Protection Agency. Smart Growth Program. Development, Community, and Environment Division. 39 pp. Viewed online at: http://www.epa.gov/smartgrowth/pdf/growing_water_use_efficiency.pdf.

U.S. Green Building Council. 2011. Rating Systems. LEED. Washington (DC): U.S. Green Building Council. [Web site.] Viewed online at: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1989.

Additional References

American Planning Association. 2012. *Policy Guide on Smart Growth*. Washington (DC): Update ratified by American Planning Association Board of Directors. [Web site.] Viewed online at: http://www.planning.org/policy/guides/adopted/smartgrowth.htm.

California Department of Transportation. 2009. "Regional Blueprints." Sacramento (CA): California Department of Transportation. [Web site.] Viewed online at: http://calblueprint.dot.ca.gov/. Accessed: Dec., 2009.

California Department of Water Resources. 2008. Draft White Paper: Evapotranspiration Adjustment Factor. 18 pp. Viewed online at: http://www.water.ca.gov/wateruseefficiency/docs/etWhitePaper.pdf.

———. 2009. *California Water Plan Update 2009*. Viewed online at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm.

———. 2010. *Implementing California Flood Legislation into Local Land Use Planning: A Handbook for Local Communities*. Sacramento (CA): Division of Flood Management. 176 pp. Viewed online at: http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/Oct2010_DWR_Handbook_web.pdf.

California Emergency Management Agency, California Natural Resources Agency. 2012. *DRAFT: California Climate Change Adaptation Policy Guide*. Sacramento (CA): 214 pp. Viewed online at: http://resources.ca.gov/climate_adaptation/docs/DRAFT_APG_Public_Review_April_2012.pdf.

California Natural Resources Agency. 2010. *The Future of Natural Resources Management - A White Paper and Action Plan*. Sacramento (CA): California Natural Resources Agency. Viewed online at: http://resources.ca.gov/docs/IRM_Action_Plan12-10.pdf.

City of Santa Monica. 2010. *Land Use and Circulation Element*. Santa Monica (CA): Department of Planning and Community Development. Viewed online at: http://www.shapethefuture2025.net/.

Garrett C, Collins-Burgard E, Waterman R, Klopf A. 2008. Addressing Climate Change through Land Use and Transportation. Planning: California's SB 375 and SB 732 — A Legislative Trend?" New York (NY): Client Alert. Number 770. Dec. 2, 2008. 11 pp. Latham & Watkins LLP. [E-news.] Viewed online at: http://www.lw.com/upload/pubContent/_pdf/pub2390_1.pdf.

Governor's Office of Planning and Research. 2003a. Governor's Environmental Goals and Policy Report. Sacramento (CA): Governor's Office of Planning and Research. 185 pp. Viewed online at: http://www.opr.ca.gov/planning/publications/EGPR—11-10-03.pdf.

———. 2003b. General Plan Guidelines Update. Sacramento (CA): Governor's Office of Planning and Research. 290 pp. Viewed online at: http://opr.ca.gov/docs/General_Plan_Guidelines_2003.pdf.

——— . 2011. *The California Planners' Book of Lists 2011*. Sacramento (CA): Governor's Office of Planning and Research. Viewed online at: http://www.cnps.org/cnps/conservation/conference/2011/pdf/book-of-lists-2011.pdf.

Jacob JS, Crossley D. 2005. "Choices for growth: Quality of life and the natural environment." College Station (TX): Texas Coastal Watershed Program Texas A& M University. .16 pp. TAMU-SG-05-701. [Bulletin.] Viewed online at: http://tcwp.tamu.edu/files/2012/06/urban_growth_primer_5.pdf.

League of California Cities. 2006. *League Smart Growth Principles*. Sacramento (CA): League of California Cities. 2 pp. Viewed online at: www.cacities.org. Accessed: Nov., 2009.

Low Impact Development Center. 2005. *Low-Impact Development Strategies and Tools for Local Governments: Building a Business Case*. Beltsville (MD): Report Summary. Low Impact Development Center. 2 pp. Viewed online at: http://www.lowimpactdevelopment.org/lidphase2/pubs/LMI%20LID%20Report%20Summary.pdf. Accessed: Nov., 2009.

———. 2009. *Low Impact Development Strategies and Tools for NPDES Phase II Communities*. Beltsville (MD): Low Impact Development Center. [Web site.] Viewed online at: http://www.lowimpactdevelopment.org/lidphase2. Accessed: Nov., 2009.

National Association of Realtors. 2009. Smart Growth Program. Chicago (IL): [Web site.] Viewed online at: http://www.realtor.org/programs/smart-growth-program. Accessed: Nov., 2009.

Nelson AC. 2011. *The New California Dream: How Demographic and Economic Trends May Shape the Housing Market A Land Use Scenario for 2020 and 2035*. Executive Summary. Los Angeles (CA): Report prepared for the Urban Land Institute – Los Angeles. 6 pp. Viewed online at: http://www.uli.org/wp-content/uploads/2012/06/ULI-Voices-Nelson-The-New-California-Dream.ashx_1.pdf.

Powell LM, Rohr ES, Canes ME, Cornet JL, Dzuray EJ, McDougle LM. 2005. *Low-Impact Development Strategies and Tools for Local Governments: Building a Business Case*. Executive Summary. Washington (DC). LID50T1. 35 pp. Viewed online at: http://www.lowimpactdevelopment.org/lidphase2/pubs/LMI%20LID%20Report.pdf.

The President's Council on Sustainable Development. 1996. *Sustainable America: A New Consensus for Prosperity, Opportunity, and a Healthy Environment for the Future*. Washington (DC): The President's Council on Sustainable Development. 186 pp.

Union of British Columbia Municipalities, Green Communities Committee, Smart Planning for Communities 2009. "Business Case for Climate Action." British Columbia (Canada): BC Climate Action Toolkit. Union of British Columbia Municipalities, Green Communities Committee, and Smart Planning for Communities, a program of the Fraser Basin Council. Viewed online at: http://www.toolkit.bc.ca/big-picture/business-case. Accessed: Dec., 2009.

Urban Land Institute. 2008. California 2020. Responsible Land Use: A Path to a Sustainable California by 2020. Viewed online at: http://sf.uli.org/wp-content/uploads/2011/05/CA_2020_Chavez-FINAL-REPORT.pdf.

U.S. Environmental Protection Agency. 2001. Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality. Washington (DC): U.S. Environmental Protection Agency. Development, Community, and Environment Division. EPA 231-R-01-002. 102 pp. Viewed online at: http://www.epa.gov/dced/pdf/built.pdf.

U.S. Green Building Council. 2009. Washington (DC): [Web site.] Viewed online at: http://www.usgbc.org/Default.aspx. Accessed: December, 2009.

Waterman R. 2004. "Addressing California's Uncertain Water Future by Coordinating Long-Term Land Use and Water Planning: Is a Water Element in the General Plan the Next Step?" Comment. Ecology Law Quarterly. 31(1):117-142.

Yolo County. 2011. *Climate Action Plan: A Strategy for Smart Growth Implementation, Greenhouse Gas Reduction, and Adaptation to Global Climate Change*. Adopted by Yolo County Board of Supervisors Resolution 11-17. Prepared by AECOM, Ascent Environmental, Inc., Fehr & Peers Transportation Consultants and CTG for The County of Yolo. 236 pp. Viewed online at: http://www.yolocounty.org/Index.aspx?page=2004.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES
CHAPTER 25

Recharge Area Protection

Coachella Valley. The Coachella Valley Water District's Thomas E. Levy Groundwater Replenishment Facility percolates imported Colorado River water into the eastern subbasin of the Coachella Valley aquifer, replenishing 40,000 acre-feet of water annually.

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Chapter 25. Recharge Area Protection

Recharge areas are those areas that provide the primary means of replenishing groundwater. Good natural recharge areas are those where good quality surface water is able to percolate through the sediments and rocks to the saturated zone which contains groundwater. If recharge areas cease to function properly, it will limit groundwater replenishment and/or groundwater quality for storage or use. Protection of recharge areas requires a number of actions based on two primary goals: (1) ensuring that areas suitable for recharge continue to be capable of adequate recharge rather than being covered by urban infrastructure, such as buildings and roads, and (2) preventing pollutants from entering groundwater to avoid expensive treatment that may be necessary prior to beneficial use.

Protection of recharge areas is necessary to maintain the quantity and quality of groundwater in the aquifer. However, protecting recharge areas by itself does not provide a supply of water. Recharge areas are functioning properly when aquifer storage capacity is available, sufficient permeable surface is present, and the adequate supply of good quality water to recharge the aquifer is available. Protecting existing and potential recharge areas allows them to serve as valuable components of a conjunctive management and groundwater strategy. Additional information on this strategy is available in Chapter 9, “Conjunctive Management and Groundwater.”

California Water Plan Update 2013 includes three resource management strategies in this volume related to recharge areas protection:

1. Chapter 9, “Conjunctive Management and Groundwater Storage.”
2. Chapter 16, “Groundwater/Aquifer Remediation.”
3. Chapter 20, “Urban Stormwater Runoff Management.”

Management of a natural resource, especially water, requires integration of various management efforts.

In simple terms, a groundwater system consists of three components: (1) recharge areas where surface water moves to groundwater, (2) storage media consisting of aquifers that store groundwater, and (3) discharge areas consisting of wells, springs, and rivers. As with many natural systems, there is an almost infinite variety in the way these components relate to each other in the real world. Some terms that are used in discussing recharge are defined in Box 25-1.

Managed Recharge Areas in California

The first documented artificial recharge program in California began in Los Angeles basin in 1889. In the early 1900s, water agencies operated recharge areas in the San Joaquin Valley. Additional areas for artificial recharge were established later in Southern California and in the San Francisco Bay area. While a certain amount of recharge takes place in many areas, the areas chosen by water management agencies were those that met three conditions. First, the sediment is coarse enough to allow surface water to infiltrate at a higher rate than through finer sediments. Second, there is hydraulic continuity between the recharge area, the aquifer in which

Box 25-1 Terminology

The definitions are taken primarily from DWR Bulletin 118, *California's Groundwater 2003*.

Abandoned well. Wells that are abandoned but that have not been properly destroyed and provide a vertical conduit for contamination of the aquifer. While there is no accurate count of the number of such abandoned wells in California, one estimate is that there are more than 1 million such wells that are potential vertical conduits for contamination of the aquifer because they have not be properly destroyed. State law requires destroying such wells. Some local jurisdictions require an old well on the property to be destroyed before a permit is issued for construction of a new well (Health & Safety Code Section 115700).

Aquifer. A body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of good quality groundwater to wells and springs.

- **Unconfined aquifer.** An aquifer that is not bounded on top by an aquitard. The upper surface of an unconfined aquifer is the water table.
- **Confined aquifer.** A body of rock or sediment bounded on top by an aquitard and containing groundwater that is under greater than hydrostatic pressure i.e., an artesian aquifer. When a confined aquifer is penetrated by a well, the water level will rise above the top of the aquifer.

Aquitard. A confining bed composed of rock or sediment that retards but does not prevent the flow of water to or from an adjacent aquifer. The movement of groundwater in an aquitard is exceedingly slow (very low permeability) and it does not yield water readily to wells or springs, even though it stores groundwater.

Artificial recharge. The addition of water to a groundwater reservoir or aquifer by human activity, such as putting surface water into constructed spreading basins, allowing surface water to flow in strategically located unlined watercourses and ditches, or injecting water through wells. This may also be referred to as managed or intentional recharge.

Deep percolation. Percolation of water through the ground and beyond the lower limit of the root zone of plants into groundwater. Efficient agricultural and urban irrigation practices limit or eliminate deep percolation.

Discharge area. An area where the recharged groundwater flows out of the aquifer under natural conditions or is removed from the aquifer by wells. In general terms, the Earth consists of recharge areas and discharge areas which may be either very close together (within meters) or are very far apart (many kilometers).

Natural recharge. Recharge of an aquifer that occurs without human interference. This may also be referred to as unintentional recharge.

Recharge area. An area where surface water infiltrates into the ground and reaches a saturated zone in either an unconfined aquifer or a confined aquifer.

The recharge area for an unconfined aquifer is the ground surface above the aquifer. The recharge area for a confined aquifer is always some distance away from the area where wells have been built that extract groundwater from the confined aquifer. In at least one instance in California, a water district overlies a confined aquifer but the recharge area for that confined aquifer lies many miles outside the district's boundaries. In some older publications, the recharge area for a confined aquifer has been called the forebay to the confined aquifer. In other instances, recharge of the confined aquifer may occur only where a stream has eroded through the aquitard into the confined aquifer, allowing recharge to occur through the stream bottom which is below the aquitard.

Restored recharge area. Describes some small basins, usually in the mountains, that have been reclaimed from activities that caused severe erosion and vegetation loss and that are now viable storage sites for groundwater that is released throughout most of the year into the watercourse.

the groundwater is stored and transported, and the discharge area where wells are built to extract the groundwater. Third, a local agency had access to the land on which these first two conditions existed.

Recharge occurs instream, offstream, and through injection wells. Instream recharge allows water to percolate through the stream bed itself. Offstream recharge uses suitable sites outside the streambed. In some operations, the water must be pumped from its distant source to the offstream recharge area. Injection wells are used at locations where the cost to purchase large tracts of land for offstream spreading basins would be prohibitive, due to their small footprint, or when the soil/surface permeability does not allow for surface recharge.

Each method has its pros and cons. Instream and offstream spreading basins eventually become clogged by suspended fine-grained material carried in the surface water. As a result, the rate of recharge declines considerably making the basin much less effective. The fine-grained material must be removed to increase rate of recharge. In urban areas, the cost of land necessary for spreading basins is often prohibitive. Injection wells are expensive to build, but their small footprint make them more affordable than spreading basins in urban areas where land is very expensive. However, they could also clog unless the water is treated, turbidity is minimal, and air is not entrained.

Potential recharge areas are hydrogeologically suited for use if they meet the three conditions cited above — coarser sediments, hydraulic continuity between the recharge area and the discharge area, and local agency ownership. Table 25-1 shows current sites in California that are managed for artificial recharge.

The State Water Resources Control Board (SWRCB) has compiled a hydrogeologically vulnerable areas map shown in Figure 25-1. The map shows areas where published reports and well logs indicate that there is potential hydrogeologic connection between the ground surface and groundwater. An area was defined as vulnerable, if a low permeability soil layer (e.g., clayey layer) of at least a 5-foot thickness did not exist between the groundwater table and land surface.

Contamination of these areas would lead to contamination of the groundwater in the aquifer (State Water Resources Control Board 2011 updated). These areas do not include zones of fractured bedrock that recharge groundwater and can also serve as a conduit for groundwater contamination.

The size of existing recharge areas and the amount of groundwater that is artificially recharged annually is substantial, but there is no procedure in place that quantifies that amount on a statewide basis. The total amount of land devoted to spreading basins and offstream and instream recharge most likely exceeds 50 square miles. The actual area is difficult to determine, partially because many diversion ditches and creeks are active artificial recharge sites during some periods of the year. These active recharge areas and other areas should be protected for recharge purposes.

For purposes of analysis and planning, actual and potential recharge areas can be assigned to one of three categories.

- Category 1. Active recharge areas at the present time under the control of water management agencies. These areas are listed in Table 25-1. The infiltration rate at these areas is high and they are carefully managed to maintain that high infiltration rate and to protect the quality of

Table 25-1 Recharge Sites in California

Agency	Type of Recharge Site
Arvin-Edison Water Storage District	Offstream
Berrenda Mesa Water District	Offstream
Calleguas Municipal Water District	Injection wells
City of Bakersfield	Instream, offstream
Coachella Valley Water District	Instream, offstream
Flintridge-Cañada	Injection well
Fresno Metropolitan Flood Control District	Offstream
Friant-Kern Water Users Authority	Instream
Kern Water Bank	Offstream
Los Angeles County Department of Public Works	Instream, offstream, injection wells
North Kern Water Storage District	Offstream
Orange County Water District	Instream, offstream, injection wells
Pioneer (Kern County Water Agency)	Instream, offstream
San Bernardino Valley Water Conservation District	Offstream
Santa Ana Watershed Project Authority	Offstream, injection wells
Santa Clara Valley Water Disitrict	Instream, Offstream
Semitropic Water Storage Disitrict	Offstream
United Water Conservation District	Instream, offstream

the water undergoing recharge. Most of these sites monitoring activities track groundwater levels, rate of movement of the recharged water into the aquifer, and chemical changes.

- Category 2. Areas that are known to have a fairly high infiltration rate, but are not under the control of a water management agency. There may be little or no monitoring of these areas. Programs should be considered that monitor recharge, prevent potential contaminating activities, and educate the public about the importance of protecting the quantity and quality of their water supply to enable people to select appropriate actions to protect water quality.
- Category 3. Areas with a lower infiltration rate making the area much less suitable for an artificial recharge program managed by a local water agency. These areas may have a lower degree of monitoring and management of potential contaminating activities.

The Drinking Water Source Assessment and Protection Program (DWSAP) administered by the California Department of Public Health (CDPH) defines areas of protection for individual wells. The program could easily be expanded to include larger areas within the watershed to assess and protect groundwater recharge areas.

Figure 25-1 Hydrogeologically Vulnerable Areas Map

* Hydrogeologically Vulnerable Areas are where published studies show geologic conditions are more likely to allow surface contaminants to move to groundwater through percolation; for example: areas without an aquitard. Vulnerable areas not mapped, due to their extensiveness, are fractured rock where contaminants can move directly to water.

Original map courtesy of California Water Boards 2013

Other Methods of Enhancing Recharge

Four other methods of enhancing recharge and reducing runoff are flood water detention basins, reduced hardscape, increased softscape, and utilizing low-impact development practices.

In the first half of the 20th century, the U.S. Army Corps of Engineers, in conjunction with local flood control agencies, built detention dams in the canyons at the foot of Southern California mountain ranges. These detention dams had a three-fold purpose. First, when storms dropped large amounts of water high in the mountains, the dams stopped the uncontrolled rush of water into downstream residential areas. Second, some of the water stored behind the detention dams infiltrated into the coarse sediment in the bottom of the detention area and recharged the local aquifer. Third, the dams were designed to release a smaller controlled amount of water into the flood control channels and streams so that the water would not cause damage downstream. Some of these dams are also used to store excess water for release and use during the dry season. Many of these facilities are still functioning and some provide significant recreational opportunities during the dry season.

In the last half of the 20th century, a different type of detention basin was built in a number of urban areas. These detention basins, excavated so that they are lower than the surrounding land surface, serve as grass-covered parks during most of the year. During the winter, they can fill with runoff from storms. Again, their purpose is three-fold. First, they are used as recreational facilities during the non-storm season. Second, they fill with storm runoff during the wet season, thereby reducing flood risk. Third, some of the water stored in these basins during the wet season recharges the local unconfined aquifer, while some of these basins may be located in the recharge area for a confined aquifer. In any such operation using urban runoff, adequate control must be exercised to prevent contamination of the aquifer by petroleum products and other urban contaminants.

A third method to increase recharge and reduce runoff is being implemented by TreePeople, a non-governmental organization. TreePeople has been working with local government to retrofit playgrounds, school grounds, parking lots, and other parcels of land to collect, treat, and funnel stormwater to dry wells or other small scale infiltration facilities. Such wells are called Class V injection wells. While the goal of TreePeople is to reduce hardscapes and reduce runoff, the use of dry wells for disposal of the urban runoff can affect groundwater quality. To avoid contaminating the aquifer, certain best management practices (BMPs) are recommended, which include:

- Construction of low-flow basins for runoff from industrial and other areas that could be a source of chemical contamination.
- Pre-treatment of stormwater runoff.
- Water quality monitoring.
- Periodic evaluation of project data.
- Implementation of corrective action(s) as necessary (Ben-Horin 2007; TreePeople 2009).

California's 58 counties are required by the California Water Code (CWC) to regulate any type of water-related well, including injection wells, but the effectiveness of that program varies considerably depending upon the county. Class V injection wells are further regulated for groundwater quality purposes by the U.S. Environmental Protection Agency in accordance with the Underground Injection Control program authorized by the federal Safe Drinking Water Act.

A fourth method to increase groundwater recharge is to utilize low-impact development (LID) or BMP features for stormwater capture and reuse. This is to be consistent with both the State Water Resources Control Board Strategic Plan Goal 1, which is to implement strategies to fully support the beneficial uses for all 2006 Clean Water Act Section 303(d) listed water bodies by 2030 and the CWC, Section 10561(e), "stormwater, properly managed, can contribute significantly to local water supplies through onsite storage and reuse, or letting it percolate into ground to recharge groundwater, therefore increasing available supplies of drinking water."

Potential Benefits

The primary benefit of protecting recharge areas is water managers using those recharge areas to store water in aquifers as part of a program to provide a sustainable, reliable, and high quality water supply. In some cases, diverting flood water to recharge facilities may benefit both flood control efforts and maintenance of a local water supply. The availability of a sustainable and reliable water supply may lessen the need to purchase alternative water supplies at greater expense. Efforts to protect groundwater quality by preventing the release of contaminants may reduce the need for expensive groundwater treatment, thereby eliminating or lowering carbon dioxide (CO_2) emissions related to groundwater treatment. Protection of recharge areas does not make a water supply available. A water supply to recharge the aquifer depends on coordination of regional and local governments and water management agencies.

Additional benefits of recharging groundwater include: 1) partial removal of microbes and chemicals while the water moves through the unsaturated zone to the saturated zone, 2) an increase in the amount of groundwater in storage that can later be extracted for local use or export, and 3) in some cases, use of the aquifer itself as the conveyance system from the recharge area to the point of extraction and use. In some cities, recharge basins are combined with flood control basins to reduce the amount of urban runoff. However, this practice may introduce contaminants, especially hydrocarbons, nitrates, and solvents into the aquifer unless there is pre-treatment to remove the contaminants.

Potential Costs

Some of the costs that may be associated with protecting recharge areas are:

- Purchase or lease price of the land that may be used for a recharge area.
- Design and construction of facilities.
- Land reserved for recharge areas cannot be used for other purposes that might provide a significant income for the landowner and tax revenues for the government.
- No tax revenue for the county if a local government agency owns the land.
- Periodic well field monitoring that warns about contamination.
- Groundwater remediation used to control contaminant releases near recharge areas.

Water supply can be lost by not protecting recharge areas. The growth of urban areas with large impervious roads, freeways, parking lots, and large warehouse-type buildings means that these areas no longer allow runoff to infiltrate into the ground. Instead, the runoff flows rapidly into streams which peak more quickly and at higher flow rates than before these urban structures were built. This runoff may create more frequent flood flows, losing the opportunity and effectiveness for natural groundwater recharge. Facilities are then needed to artificially recharge the groundwater at a cost to ratepayers. In a few urban areas, injection wells have been built to take the place of recharge areas that were lost to urban development. Injection wells are expensive, require careful technical control, and are not always successful. However, they may be cost-effective compared to the high cost of urban land in many cities.

Many potentially contaminating activities occurring on areas such as farms, dairies, and industrial complexes routinely have been allowed in recharge areas and contaminants have been carried into the aquifers. Because groundwater processes and the potential for contamination are not well understood by the public, many of these practices continue today. Remediation of contaminated aquifers can take decades or longer, cost millions or billions of dollars, and increase the rate of global climate change due to CO_2 emissions from remediation systems. Groundwater remediation may never remove the contaminant completely from the aquifer. In such cases, the extracted groundwater must be treated at the wellhead at a significant expense before it is suitable for potable and other uses.

A lack of protection of recharge areas could decrease the availability of usable groundwater. Studies by the U.S. Geological Survey show contaminants present in recharge areas for aquifers in the Los Angeles area. Because of the low velocity of groundwater movement through the aquifer, contamination that occurs today may not arrive at down-gradient wells for 10 years or longer. When the contamination does arrive at the down-gradient wells in 10 or more years, treatment may be needed before the groundwater can be used thereby increasing the cost of water to future users. Protecting recharge areas now may help to prevent costs from escalating excessively in the future by reducing the need for expensive groundwater treatment. Protecting recharge areas by retaining those areas for recharge and preventing contamination today will reduce future costs of drinking water. Restoration of recharge areas may also help to keep future costs lower.

Major Implementation Issues

Climate Change

Changing precipitation patterns may affect the availability of surface water supplies capable of recharging groundwater basins. In the past decades, there has been a gradual shift in snowpack and runoff timing in California where runoff is occurring earlier in the year. This shift may also reduce groundwater recharge during the summer months. In addition, sea level rise may impact coastal aquifers by decreasing their capacity for recharge and storage of groundwater.

Adaptation

Monitoring, maintaining, and enhancing the health of recharge areas and groundwater basins are important adaptive strategies. Groundwater use may be a central response to droughts. During drought periods, cities and regions that have adequate groundwater supplies may be less likely to rely upon distant water supply sources. Protecting recharge areas allows for additional recharge during wet winters, which can provide a better reserve for drought periods. Coastal regions that recharge and maintain groundwater aquifers may be less likely to lose aquifer capacity due to sea level rise. Maintaining recharge areas may also enhance flood management by reducing the volume of flood flows to populated areas.

Mitigation

Recycled water of adequate quality can supplement other sources of recharge water and provide additional water to groundwater basins. More recharge areas may be needed to fully utilize the state's available recycled water supply used for groundwater recharge. Greater reliance upon local groundwater in many areas of the state is less energy intensive than relying upon imported or desalinated water. Reduced energy use for water supply results in lower greenhouse gas emissions.

Zoning

Zoning can play a major role in protecting recharge areas by amending local codes to establish minimum softscape requirements for parcels so these sites are retained as recharge areas. Some areas that would provide good rates of recharge have been paved over or built upon and are no longer available to recharge the aquifer. Local governments often lack a clear understanding of recharge areas and the need to protect those areas from development or contamination. Land use zoning staff should consider the need for recharge area protection for water quantity and water quality.

Vector and Odor Issues

Standing water in recharge ponds or spreading basins attracts mosquitoes, dragonflies, and other insects whose egg, larval, and pupal stages mature underwater. Dragonflies eat insects they catch on-the-fly, including mosquitoes, which can be vectors for a number of serious or deadly diseases. Existing recharge programs use large numbers of mosquitofish which feed on the mosquito larvae in the water. Odors can be generated by growth and decay of algae and other water-borne vegetation. Both vectors and odors must be addressed in any recharge program that involves standing water.

Recommendations

The State can help promote additional protection of recharge areas implementing the following recommendations:

1. Increase State funding for programs to identify and protect recharge areas including incentives for locating and for the proper destruction of abandoned water wells, monitoring wells, cathodic protection wells, and other wells that could become vertical conduits for contaminating the aquifer.

2. Provide funding and staff for the CDPH to initiate a program that would provide guidance and funding for tribes, local governments, and agencies to implement source water protection measures that are logical outgrowths of the Drinking Water Source Assessment and Protection Program.

3. Continue and expand research into surface spreading as a means of groundwater recharge and the fate and transport of chemicals and microbes contained in the recharge water.
4. Develop a statewide program to identify and inventory actual and potential recharge areas throughout the state and provide that information to tribal, city, and county governments.
5. Engage the public in an active dialogue using a value-based decision-making model in planning land use decisions that involve recharge areas.
6. Adopt a State-sponsored media campaign to increase public awareness and knowledge of groundwater and the importance of recharge areas.
7. Local governments should coordinate with groundwater management agencies to identify recharge areas and appropriate groundwater protection actions to include in the groundwater protection section of each local government's general plan.
8. Ensure that federal and State programs regulating subsurface disposal in accordance with the federal Safe Drinking Water Act's Underground Injection Control program and the California Clean Water Act's waste discharge requirements are fully funded and staffed.
9. Require local governments to coordinate with groundwater management agencies to provide protection of recharge areas for aquifers that have been identified as "sole source aquifers" pursuant to the Safe Drinking Water Act of 1974 and Amendments.
10. Develop educational programs, that are coordinated through local groundwater management agencies, for public works officials and other officials of local agencies and governments that help them to develop programs that realistically deal with the interaction of groundwater, surface water, stormwater, recycled water, other surface flows, and the effect of contaminants in surface flows on contaminant levels in the aquifers.
11. Require that source water protection plans include an element that addresses recharge areas if groundwater is a part of the supply.
12. Convene a statewide panel to recommend changes to public schools and higher education curricula relating to groundwater. Encourage an integrated academic program on one or more campuses to promote groundwater (quantity and quality) protection strategies and why recharge areas are critical components.
13. Develop a uniform method for analyzing the economic benefits and cost of recharge areas. Provide guidance and assistance for economic feasibility analyses that could be used by project planners and funding agencies to assess different recharge options as compared with long-term reduction of water supplies, wellhead treatment, recharge (injection) wells, surface spreading areas, or conversion to other land uses.
14. Develop a signage program, modeled on similar programs in other states, to notify people that they are entering an area of critical recharge for the groundwater they use daily, and that improper disposal of wastes can contaminate their drinking water.
15. Support implementation and research for stormwater low-impact development (LID) and BMP techniques for groundwater recharge under the provisions of the Stormwater Resource Planning Act (CWC Section 10560 et seq.).

16. Support leak prevention protocols for stored contaminants to minimize the potential of surface and groundwater contamination, thus mitigating carbon dioxide (CO_2) emissions related to groundwater remediation.

References

References Cited

Ben-Horin E. 2007. *Rainwater as a Resource: A Report on Three Sites Demonstrating Sustainable Stormwater Management*. Beverly Hills (CA): TreePeople. 56 pp. Viewed online at: http://www.treepeople.org/sites/default/files/images/about/Rainwater_as_a_Resource.pdf.

State Water Resources Control Board. 2011 (updated). Hydrogeologically Vulnerable Areas Map. Sacramento (CA): Viewed online at: http://www.waterboards.ca.gov/water_issues/programs/gama/docs/hva_map_table.pdf.

TreePeople. 2009. "TreePeople." Beverly Hills (CA): [Web site.] Viewed online at: http://www.treepeople.org/. Accessed: Nov. 16, 2009.

Additional References

Aiken GR, Kuniansky EL, editors. 2002. *U.S. Geological Survey Artificial Recharge Workshop Proceedings*. April 2-4. Sacramento (CA): U.S. Geological Survey. 92 pp. Viewed online at: http://water.usgs.gov/ogw/pubs/ofr0289/.

Bachman SB. 1997. *California Groundwater Management*. Sacramento (CA): Groundwater Resources Association of California. 145 pp.

Blomquist WA, Schlager E, Heikkila T. 2004. *Common Waters, Diverging Streams; Linking Institutions and Water Management in Arizona, California, and Colorado*. Washington (DC): Resources for the Future. [Book.] 205 pp.

California Department of Public Health. 1999. *Drinking Water Source Assessment and Protection (DWSAP) Program*. Sacramento (CA): California Department of Health Services. Division of Drinking Water and Environmental Management. 209 pp. Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/Documents/DWSAPGuidance/DWSAP_document.pdf.

———.2007. Drinking water source assessment and protection (DWSAP) program. Sacramento (CA): California Department of Public Health. [Web site.] Viewed online at: http://www.cdph.ca.gov/certlic/drinkingwater/pages/dwsap.aspx. Accessed: Nov.16, 2009.

California Department of Water Resources. 2003. *California's Groundwater Update 2003*. Bulletin 118. Sacramento (CA): California Department of Water Resources. 246 pp. Viewed online at: http://www.water.ca.gov/groundwater/bulletin118/bulletin118update2003.cfm.

Driscoll FG. 1986. *Groundwater and Wells*. 2nd edition. St. Paul (MN): Johnson Division. [Book.] 1089 pp.

Dunne T, Luna LB. 1978. *Water in Environmental Planning*. San Francisco (CA): W.H. Freeman and Co. [Book.] 818 pp.

Fetter CW. 1994. *Applied Hydrogeology*. 3rd edition. Englewood Cliffs (NJ): Prentice-Hall Inc. [Book.] 691 pp.

Focazio MJ, Reilly TE, Rupert MG, Helsel DR. 2002. *Assessing Ground-water Vulnerability to Contamination: Providing Scientifically Defensible Information for Decision Makers*. Circular 1224. Washington (DC). 33 pp. Prepared for the U.S. Geological Survey. Viewed online at: http://pubs.usgs.gov/circ/2002/circ1224/.

Freeze RA, Cherry JA. 1979. *Groundwater*. Englewood Cliffs (NJ): Prentice-Hall Inc. [Book.] 604 pp.

Heath R. 1983. *Basic Ground-water Hydrology*. Water-Supply Paper 2220. Washington (DC): U.S. Geological Survey. 84 pp.

Madrid C. 1989. "Artificial ground water recharge in Northern California." In: Johnson AI, Finlayson D, editors. *Artificial Recharge of Ground Water: Proceedings of the International Symposium*. August 23-27, 1988. Anaheim (CA): American Society of Civil Engineers.

Sherman LK, Musgrave GW. 1942. "Infiltration." In: Meinzer, OE, Baver, LD, editors. *Hydrology*. Volume IX. Physics of the earth. 1st edition. New York (NY): McGraw-Hill. [Book.]

State Water Resources Control Board. 2009. GAMA – Groundwater Ambient Monitoring & Assessment Program. Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: *www.waterboards.ca.gov/gama*. Accessed: Nov. 16, 2009.

University of California Center for Water Resources. 2001. *Managing California's Groundwater: the Challenges of Quality and Quantity; Abstracts from the 23d Biennial Groundwater Conference*. Biennial groundwater conference and annual meeting of the Groundwater Resources Association of California. October 30-31. Sacramento (CA). 83 pp.

Winter TC, Harvey JW, Franke OL, Alley WM. 1998. *Ground Water and Surface Water, A Single Resource*. Circular 1139. Washington (DC). Prepared for U.S Geological Survey. 79 pp. Viewed online at: http://pubs.usgs.gov/circ/circ1139/.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 26

Sediment Management

Monterey County. One goal of the Carmel River Reroute and San Clemente Dan Project, the largest dam removal project in California history, is to restore the river’s natural sediment flow, thereby helping to replenish sand on Carmel Beach and improve habitat downstream of the dam for steelhead.

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Chapter 26. Sediment Management

> The management of sediment in river basins and waterways has been an important issue for water managers throughout history — from the ancient Egyptians managing sediment on floodplains to provide their crops with nutrients, to today's challenges of siltation in large reservoirs. The changing nature of sediment issues, due to increasing human populations (and the resulting changes in land use and increased water use), the increasing prevalence of man-made structures such as dams, weirs and barrages and recognition of the important role of sediment in the transport and fate of contaminants within river systems has meant that water managers today face many complex technical and environmental challenges in relation to sediment management.
>
> *—International Sediment Initiative, Technical Documents in Hydrology 2011*

Sediment in California is a valuable resource when it is properly managed, which results in multiple water benefits, environmental health, economic stability, and coastal safety. Sediment definitions vary among the professional disciplines. Sediment, as reflected in this resource management strategy (RMS), is composed of natural materials and used contextually as follows:

1. Geology considers sediment to be the solid fragmented material, such as silt, sand, gravel, chemical precipitates, and fossil fragments, which has been transported and deposited by water, ice, or wind, or that accumulates through chemical precipitation or secretion by organisms, and that forms layers on the Earth's surface. Sedimentary rocks consist of consolidated sediment.

2. The U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers (USACE) regard sediment as material, such as sand, silt, or clay, suspended in or settled on the bottom of a water body.

Sediments can come from anywhere and be just about anything. Organic and inorganic material alike can become bits of matter tiny enough to be picked up and carried along with a moving fluid. Organic sediments are made up of mostly plant and animal debris. Inorganic sediments are divided into two main groups — coarse-grained sediments and fine-grained sediments. Coarse-grained sediments are boulders, cobbles, gravel, and sand. Fine-grained sediments are silts and clays. Sediment deposits, like tree rings, can serve as a record of natural history.

A further important distinction is whether they are clean sediments or contaminated sediments, as this greatly affects the manner in which they can be used as beneficial material or if they must be isolated from their surrounding environment. For this RMS, the term *sediment* will mean clean sediment, and if the sediment is contaminated, the term *contaminated sediment* will be used.

Debris management is also associated with sediment management. Debris may contain sediment, but it is not entirely composed of sediment. Likewise, debris is not trash. Debris consists of fragmented materials that are organic (trees, brush, and other vegetation) and are inorganic (soil, rocks, boulders, and other sediment) that is primarily moved by floodwaters. Large woody material is key to sorting material and creating scours and pools. Pools provide an important habitat for juvenile fish, as well as refugia during flood events. Large woody debris also creates turbulences that clean spawning gravels. Debris basins are built-in areas subject to debris flows to save lives and protect property. Trash consists of discarded human-made products (e.g., litter) that sometimes comingles with debris. Typically, trash racks are placed on critical equipment, such as pump stations, to prevent mechanical failure caused by litter build-up during a flood. Trash racks also are placed at debris basins and dams for the same purpose.

Debris management is critical in flood management and includes the post-disaster removal of materials — natural and human-made — generated by a flood and extreme weather events. Debris in these situations can range from boathouses to gravel bars to zoo enclosures.

While debris management is related to issues of sediment management, this chapter focuses primarily on sediment management. Sediment management tools are essential for successful integrated water management as the presence or absence of sediment has a significant impact on water and its beneficial uses.

Sediment Management

Sediment, like fresh water, is limited in supply and is a valuable natural resource. Sediment management is critical for the entire watershed, beginning with the headwaters and continuing into the coastal shores and terminal lakes. However, from a human perspective, sediment has a dual nature; it is desirable in some quantities and locations and unwanted in others. Sediment contributes to many positive outcomes and has many positive uses, such as beach restoration and renewal of wetlands and other coastal habitats. Sediment also is needed to renew stream habitat. Spawning gravels need replenishment from course-grained sediment, and fine-grained sediment is needed to maintain, enhance, or restore good quality native riparian vegetation and wetlands. Flood deposits of fine-grained sediment into floodplains are the source of much of California's richest farmland. Sediment, particularly sediment adjacent to hot springs, has been considered for centuries as having healing properties. Sediments also can be used for habitat restoration projects, beach nourishment, levee maintenance, and construction material.

The key to effective water-sediment management is to address excessive sediment in watersheds. Potential impacts of excessive sediment, generally associated with fine-grained sediments, are:

- Clouded water; degraded wildlife habitat; barriers to navigation; and reduced storage capacity in reservoirs, which affects flood protection and water supply.
- Increased turbidity and suspended sediment concentrations; negative effects on the ability of surface water to support recreation, drinking water, habitat; etc.
- Reduced ability of sight-feeding predators to capture prey.
- Clogged gills and filters of fish and aquatic invertebrates, covered and impaired fish spawning substrates, reduced survival of juvenile fish, reduced fishing success, and smothered bottom dwelling plants and animals.
- Physically altered streambed and lakebed habitat.

Other excess sediment issues sometimes include:

- Reduced hydraulic capacity of stream and flood channels, causing an increase in flood crests and flood damage. Sediment can fill drainage channels, especially along roads; plug culverts and storm drainage systems; and increase the frequency and cost of maintenance.

- Decreased useful lifetime of a reservoir, as a result of reducing storage capacity. This loss in storage capacity affects the volume of stored water available for municipal supplies and the volume available for floodwater storage.
- Higher maintenance costs and potential problems associated with excess sediment in shipping channels, harbors, and drainage systems and disposing removed sediment. Excess sediment, which accumulates in ports, marinas along the coast, working rivers, and recreational lakes, affects boating and shipping activity and can lead to demands for dredging to restore or increase depths.

Pollutants, including those from stormwater, may also be absorbed onto fine-grained sediments and complicate management of contaminated sediment. Concentrated pollutants can greatly impair water quality and aquatic life if they are remobilized from this sediment back into the environment. Potential contamination issues are:

- Immediate direct effects on aquatic life from pollutants.
- Long-term effects as contaminates in sediments bioaccumulate or magnify in the food chain, and cause problems for aquatic plants, animals, and humans.
- Suspension of fine-grained sediment containing such nutrients as nitrates, phosphorous, and potassium; and toxic contaminants, such as trace metals and pesticides. In some cases, suspended sediment particles increase algal growth, causing nuisance conditions in waterways.

An effective strategy for managing sediment is to address the sediment at its source before it is mobilized. This strategy prevents contaminated sediments from entering waterways. Sediments and debris may have to be managed together, as discussed in Box 26-1. Management of watershed sediment location and movement can also have positive and negative consequences, as well as large economic and ecological consequences. For example, excess sediment in shipping channels may cost ports millions of dollars in delayed or limited ship access, while in other locations insufficient sediment deposits could result in the loss of valuable coastal wetlands, beaches, recreation, and tourism, which are worth billions of dollars. The term *regional sediment management* has been developed to address this condition.

Sediment processes are important components of the coastal and riverine systems integral to environmental and economic vitality. Sediment management relies on knowledge about the context of the sediment system and forecasts about the long-range effects of management actions when making local project decisions. A strategy to stabilize and/or restore the watershed for sediment production, by mimicking natural sediment production, would maintain and enhance the various ecological and beneficial uses.

Numerous factors including geology, climate, development and population, and the location of littoral cells affect sediment management issues. The transport of course-grained sediments from the inland watersheds and from local coastal erosion areas into the near-shore coastal waters of California is important in maintaining the beaches. The near-shore coastal area running the entire length of the state contains littoral cells. Littoral cells are self-contained sections, or a compartment, along the coast wherein sand enters (streams, cliff erosion) temporarily resides (beaches), and exits (submarine canyons, offshore shelf). These factors vary significantly throughout the state. For that reason, sediment is best managed on a watershed-littoral cell basis, taking into consideration the sediment source and needs from the top of the watershed to the coast where sediment will ultimately end. Adjacent littoral cells do not typically share sand

Box 26-1 Sediment and Debris

The Sediment resource management strategy (RMS) relates to organic materials. However, sediment and debris are often considered commingles.

Approximately 80 percent of marine debris in the world's oceans originates from land-based sources, primarily trash and debris in stormwater and urban runoff. Studies have found that significant quantities of small plastic debris originating in urbanized land areas pollute the Pacific Ocean both near shore and on beaches and segments of the ocean thousands of miles from human habitation.

Studies of debris in Southern California coastal waters demonstrate that significant quantities of trash and debris originate from urban areas and are comprised of pre-production plastics from plastic industrial facilities, trash and litter from urban areas, and boating and fishing-related debris.

More about this topic may be found in Chapter 18, "Pollution Prevention," and Chapter 20, "Urban Stormwater Runoff Management."

Source: California Coastal Commission and Algalita Marine Research Foundation, n.d.

whereas fine-grained sediments exhibit different behavior along the coast (e.g., turbidity plumes cross over cell boundaries). Regional sediment management recognizes sediment as a valuable resource and supports integrated approaches to achieve balanced and sustainable solutions for sediment related needs.

Management Framework

The regional water quality control boards (RWQCBs) provide regulatory oversight for water quality problems associated with sediment. The USACE, EPA, State Lands Commission, and San Francisco Bay Conservation and Development Commission also have authority for aspects of sediment management and dredging in their respective jurisdictions.

A stream that has excessive erosion, suspended sediments, and/or sedimentation may be determined by a RWQCB to be unable to support its designated beneficial uses with regard to water quality and may be listed as impaired under the Section 303(d) of the federal Clean Water Act. The RWQCBs are working to reduce excessive sediment within streams when it occurs within their regions, by establishing total maximum daily load (TMDL) requirements. *The National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle* shows that sediment is a major water quality problem in the nation's streams (U.S. Environmental Protection Agency 2009).

Partnerships have been formed throughout California to better manage sediments in a variety of ways. For example, the USACE, EPA, San Francisco Regional Water Quality Control Board, San Francisco Bay Conservation and Development Commission (BCDC), and State Lands Commission formed a partnership to address the disposal and beneficial reuse of sediment dredged from the San Francisco Bay. The Long-Term Management Strategy for the Placement of Dredged Sediment in the San Francisco Bay Region (LTMS) reduces in-bay aquatic disposal of sediments in favor of reusing that sediment beneficially in habitat restoration projects, levee maintenance, agricultural enhancement, and construction projects. LTMS emphasizes using sediment as a resource while simultaneously reducing impacts from aquatic disposal in the bay.

This program coordinates and manages approximately 110 maintenance-dredging projects, regulated by eight State and federal agencies under a common set of goals and policies. The LTMS policies and management practices also enable streamlining the permitting process, including coordinating programmatic consultations with the resource agencies, standardizing testing protocols, and increasing predictability for organizations in obtaining their permits. There is also a quasi-LTMS process in the Sacramento-San Joaquin Delta (Delta).

On a statewide basis, the California Coastal Sediment Management Workgroup (CSMW) was established to develop regional approaches to restore coastal habitats, such as beaches and wetlands, which have been affected by human-induced alterations to natural sediment transport and deposition through federal, State, and local cooperative efforts. CSMW is comprised of many State, federal, and local interests whose mission is to identify, study, and prioritize regional sediment management needs and opportunities along the coast and provide this information to resource managers and the public.

The CSMW was formed in response to concerns that shore protection and beach nourishment activities were being conducted on a site-specific basis, without regard to regional imbalances that could exacerbate the local problem. The consensus was that a regional approach to coastal sediment management is a key factor in developing strategies to conserve and restore California's coastal beaches and watersheds. The CSMW's main objectives include reducing shoreline erosion and coastal storm damages, restoring and protecting beaches and other coastal environments by reestablishing natural sediment supply from rivers, impoundments and other sources to the coast, and optimizing the use of dredged sediment from ports, harbors, and other opportunistic sources.

The CSMW oversees the development of the California Coastal Sediment Master Plan (SMP) (Coastal Sediment Management Workgroup 2014). The SMP will identify and prioritize regional sediment management (RSM) needs and opportunities along the coast, provide this information to resource managers and the public, and streamline sediment management activities. A series of Coastal RSM Plans (strategies) are being developed for one or more individual littoral cells focusing on issues specific to each region. Tools, documents, and RSM strategies developed to date are available on the CSMW Web site (www.dbw.ca.gov/csmw).

Sediment Management and Flood Management

Sediment management is a key consideration in flood management. Sediment deposition in a channel, floodplain, or behind a dam can decrease flood capacity/flood management. Sediment-starved channels can increase velocity. High-velocity flows can scour soft-bottom channel banks, which can damage channel structures and increase flooding.

When a river breaks its banks and floods, it leaves behind deposits of sediment. Bank overtopping also results in depositions of sediment in the floodplain, which affects flood management. Sediment deposition within the river channel itself raises the bed elevation of the river and allows overtopping of the banks to occur more easily. These depositions can reduce flood capacity. Rivers can also erode their banks and potentially erode levees or flood control structures. The deposited sediments gradually build up to create the floor of floodplains. Floodplains generally contain unconsolidated sediments, often extending below the bed of the stream. These are accumulations of sand, gravel, silt, and/or clay, and are often important to aquifers because the water drawn from them is pre-filtered compared with the water in the river.

Geologically ancient floodplains are often represented in the landscape by fluvial terraces. Fluvial processes include erosion and the movement of sediment and organic matter, which are deposited on a riverbed and the landforms this process creates. Fluvial terraces are old floodplains that remain relatively high above the present floodplain and indicate former courses of a floodplain or stream.

When floodplains are separated from the water source, through levees or other means, the natural process of equilibrium, which elevates the land through sediment deposits, is interrupted. This alters the historic flooding and sediment distribution patterns. In some cases, sediments remain within the restrained channel, settling and reducing the capacity of the channel, and increasing the likelihood of flooding. In many cases, this can be avoided by dredging the channel and then mechanically depositing the sediment in desirable locations.

Alluvial fans are another form of flood sediment deposit. Over geologic time, sediment, debris, and water emerge from the mountain front along different courses. Alluvial fans are found where these materials gather speed in narrow passages then emerge into less confined areas where they can change course. A number of factors contribute to the dynamics of these flows, including the differential between the steep mountain grades and the flatter depositional surface. Sediment, debris, and water spill out in a fan shape, settling out and depositing on its way. The channels on these fans range from shallow to very deep (several meters) with a flow speed that can move boulders that are sometimes taller than a house. These conditions are found in California at mountain fronts, in intermountain basins, and at valley junctions. Alluvial fans are found where sediment loads are high, for example, in arid and semiarid mountain environments, wet and mechanically weak mountains, and environments that are near glaciers.

Historic Context

A combination of both natural and human-made impacts to California waterways has led to today’s sediment management challenges and solutions. Historically and prior to California becoming a state, sediment flowed naturally from the mountains into streams, meadows, rivers, lakes, and the ocean. California Native Americans understood the seasonal and climate impacts of waterway flows and drought, which affected levels of sediment. This environment provided a wide variety of flora and fauna that was useful as food and tool manufacturing sources for native people (Theodoratus and McBride 2009). As Europeans encountered the territories that became California, they altered this landscape by dredging passages of interior waterways for navigation, and captured a reliable water supply for their new settlements.

In addition to alterations to facilitate agrarian settlements, many of California’s current sediment management issues also can be traced to historic gold dredge activities in the 1850s. California’s Central Valley and Bay-Delta waterways experienced significant alteration caused by billions of cubic yards of sediment and debris sent downstream from hydraulic mining operations. Court action stopped these activities. However, impacts from these activities continue today. Ditches used for mining are still in use for agriculture and public water supply. The channel infilling that occurred in many of the gold bearing streams is still in evidence and many streams, such as the Feather and Yuba rivers, and these are still adjusting their watercourses 150 years later.

Some early reservoirs (e.g., Clementine, Englebright, Camp Far West) were initially built to capture the sediment. There are still millions of tons of mining debris remaining on the floodplain. The U.S. Geological Survey has measured the amount of sediment entering the San

Francisco Bay from numerous tributary streams and determined the historic changes in sediment yield over the long term. Today, scientists have concluded that much of the hydraulic mining sediments have moved through the Delta and potentially through much of San Francisco Bay. However, multiple institutions, laws, and human settlement patterns created during this era remain, and, ironically, wetlands that were established as a result of the inundation are now undergoing erosion.

Beyond the Delta and Central Valley, impacts from historic and current road building and land management practices continue to contribute to existing problems. Landslides resulting from natural and human processes are a major producer of sediment.

Additional system alterations also occurred as dams and channels were built for both water supply and flood protection. More and more structures changed what had been the natural hydrology, which then altered system stability for sediments. As a result, the normal function of waterways has also been changed to produce sediment, move it through the watershed, with some settling occurring in low areas that are now typically used for farming or urbanization, and ultimately depositing it at the shoreline, replenishing the coastline or terminal lakes. In addition to sediment being trapped in flood control structures, peak velocities during storm events has also been reduced, limiting the ability of the stream to move coarse-grained sediment downstream to the coast.

Many ports and harbors were constructed in the 1940s and 1950s along the coastline without regard to the natural process of sand transport along the coast. This natural transport activity has been interrupted by the entrance channels to the harbors, such that the sand being transported down the coast is deposited instead within the entrance channels. This shoaling results in shallower depths and potentially hazardous conditions within the channel, necessitating the ongoing dredging of the channels to restore function and safety. Beneficial reuse of the dredged material is an opportunity for regional sediment management.

Due to the desire to work, live, and play along the coast, significant development along the shoreline has occurred without consideration of the impacts to such development by natural processes. As a result, much of the shoreline has been armored to reduce erosion at specific locations to protect specific structures. Such armoring has reduced the natural supply of sediment to the beaches from bluff erosion. This causes beaches to become narrower and there is an associated loss of habitat and access from passive erosion and accelerating erosion of adjacent areas due to wave focusing.

Land use has also altered patterns of natural alluvial fans and plains. As one example, much sediment in Los Angeles County is the result of the naturally erosive mountains. The San Gabriel Mountains are mostly undeveloped because they are within the Angeles National Forest. Other mountain ranges (e.g., Santa Monica, Verdugos, Puente Hills) also have large areas of undeveloped land. The basins and valleys below these mountains are large, relatively flat, alluvial plains. The depth of the sediment deposits indicates that a significant portion, and possibly the majority, of the sediments are from the adjacent mountains.

Starting in the late 1800s and early 1900s, many Los Angeles County residents and businesses moved into these naturally occurring sediment disposal areas. The settlers and newcomers, experiencing the impacts of frequently fluctuating watercourse alignments caused by high amounts of sediment deposition, wanted more stable river and stream alignments to accommodate the agricultural and urban development that was occurring. The inhabitants also started moving into the highly erosive foothills and were directly affected by sediment flows. These inhabitants also wanted to capture stormwater to meet their water needs. This situation led to the construction of dams, debris basins, channels, and spreading grounds in Los Angeles County. Many inhabitants are unaware that they are sitting on still-active alluvial fans that require the upkeep of infrastructure to protect them from most of the worst effects of the region's natural sediment transport processes.

Management Approach

Understanding the cumulative impacts of all past, present, and proposed human activities in a watershed (and/or littoral cell) is important in predicting the impacts of sediment on surface waters. Sediment management in water bodies typically focuses on addressing three issues:

1. The type and source of sediment.
2. The systems transporting sediment.
3. The location where sediment deposits.

Management actions are tailored to the situation, depending on where the management actions will occur and whether the management actions involve a natural environment (e.g., rivers, streams, creeks, floodplains) or a built environment (e.g., water control structures, flood levees, dams).

Source Management

Source management is preventing soil loss and adverse sediment flows from land use activities that may, without proper management, cause erosion and excessive sediment movement. Routine source management activities prevent or mitigate excessive sediment introduced into waterways due to recreational use, roads and trails, grazing, farming, forestry, and construction. Excessive flows affecting erosion and sedimentation may also result from land-based events such as extreme weather, fires, high water volumes, wind, and other factors. The Station Fire, a large fire in the mountains near Los Angeles, caused a significant increase in debris and sediment, which filled debris basins the following rainy season (see Box 26-2).

Poor farming practices, such as those that led to the Dust Bowl of the 1930s, can create substantial soil loss. Fortunately, soil conservation practices can prevent this type of catastrophic situation and its impacts.

In many regions, land-disturbance activities associated with urban development are a major source of sediment disturbance. The RWQCBs regulate related construction activities occupying one acre or more to mitigate for sediment-related issues.

Road construction and maintenance in or near streams can also be a source of sediment. Photo 26-1 depicts the Caltrans I-5 Antlers Bridge realignment project on Shasta Lake. The photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters (Central Valley Regional Water Quality Control Board 2011).

Box 26-2 Case Study: L.A. County Flood Control District and Impacts of the 2009 Station Fire

The Los Angeles County Flood Control District (LACFCD) was created in 1915 after a series of catastrophic floods resulted in loss of life and property during the 1800s and early 1900s. Encompassing most of Los Angeles County, including the highly erosive San Gabriel Mountains and other mountain ranges, the LACFCD provides flood risk management, conserves flood waters and stormwaters, and operates and maintains 14 dams and reservoirs, 162 debris basins, 500 miles of open channel, and other infrastructure.

Given the region's highly erosive mountains, managing flood risk and conserving water go hand in hand with removing and managing the sediment deposited at the LACFCD facilities. Sediment accumulates as mountain runoff picks up and carries eroded material. The amount of sediment reaching a facility in any given year depends on the size of the watershed, its vulnerability to erosion, watershed conditions (e.g., vegetated versus burned area), and weather conditions.

Wildfires greatly increase the amount of runoff and erosion from mountainous watersheds. As much as 120,000 cubic yards of sediment and debris can be produced per square mile of a burned watershed after a major storm. The Station Fire of 2009 was one such fire; it burned for over 50 days and covered approximately 250 square miles. The burned watersheds created a mass of sediment and debris, which eroded from the hillsides and made its way into debris basins and reservoirs. After a short but powerful burst of rain in mid-November, 2009, Mullally Debris Basin, in La Cañada-Flintridge, filled up in 30 minutes. Storms in January and February, 2010, also delivered tremendous amounts of sediment to the facilities.

Photo A Mullally Debris Basin Before Feb. 2010 Storms

Photo B Mullally Debris Basin After Feb. 2010 Storms

Emergency operations involved day and night work and trucking of sediment through neighborhoods. The total amount of sediment removed that year was the largest removed in any year since the LACFCD began managing debris basin sediment accumulation in the 1930s. Notably, the amount of sediment inflow to the debris basins was small compared with the amount of sediment that affects LACFCD's reservoir operations. Here sediment concerns were compounded because significant amounts of sediment had accumulated before the Station Fire.

High sediment inflows into both reservoirs and debris basins will continue until the watersheds recover, usually a minimum of four years. Given the current volume of sediment and the high potential for continued large sediment inflows, the LACFCD plans to remove sediment at the four reservoirs affected by the Station Fire. They aim for a reduction of 14 million cubic yards of sediment over the next eight years, with each project lasting three to five years and costing as much as $50 million.

The wildfire-sediment nexus is a major concern for LACFCD. Besides operational costs, other management factors include incorporating diverse stakeholder interests on the best methods of sediment removal, transportation, and placement that should be used for a project. Because a project of this scale involves so many other jurisdictions, LACFCD will also need to navigate sometimes conflicting regulatory requirements and restrictions imposed by other agencies.

— Data courtesy of Los Angeles County Flood Control District

Photo 26-1 Caltrans I-5 Antlers Bridge Realignment Project on Shasta Lake

This photo shows the dramatic erosion and sediment controls required for a massive cut and fill project that threatens surface waters.

Source: Central Valley Regional Water Quality Control Board. 2011

Another transportation-related source is off-highway vehicle (OHV) use. OHV use is a popular form of recreation in California. State, federal, and local agencies, as well as private entities, provide recreational areas for this purpose. These OHV recreation areas are required to implement a range of sediment management and stormwater best management practices (BMPs) to protect water quality. Unfortunately, unauthorized and unmanaged OHV areas can become erosion problems and discharge sediment-laden stormwater (see Box 26-3). With limited resources, maintaining and policing these areas can be a challenge.

Sedimentation can be a problem in the construction and operation of many mines. Increased potential for erosion and sedimentation at mines are related to mine construction and facility location. Tailings dams, waste rock and spent ore storage piles, leach facilities, or other earthen structures are all potential sources of sedimentation to streams. Road construction, logging, and the clearing of areas for buildings, mills, and process facilities can expose soils and increase the amount of sediment-laden surface runoff that reaches streams and other surface water bodies.

Agencies and Organizations Involved in Source Sediment Management

Many agencies and organizations contribute to sediment source management as land managers, land use planners, advisors, and regulators, and through training, technical and financial assistance, and promotion of good policy. An overview of some of those key entities and their activities are in Table 26-1.

Box 26-3 Case Study: Sediment Management Related to Recreational Use

Off-highway vehicle (OHV) use is a popular form of recreation in California. State and federal agencies provide recreational areas for this purpose. These OHV recreation areas need to implement a range of stormwater best management practices (BMPs) to protect water quality. In addition, unauthorized and unmanaged OHV areas can become erosion problems and discharge polluted stormwater. With limited resources, maintaining and policing these areas can be a challenge.

In 2009, the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) found that portions of the Rubicon Trail located in El Dorado County were severely eroded, the erosion having been accelerated by OHV use, and as a result sediment was being discharged to surface waters. (See the following photos, provided courtesy Monte Hendricks.) To address this problem, as well as other OHV-related water quality issues, the Central Valley RWQCB issued a Cleanup and Abatement Order (Central Valley Regional Water Quality Control Board 2009) to El Dorado County and Eldorado National Forest to develop and implement plans to improve management of the trail and protect water quality.

The Rubicon Trail Foundation, in response to criticisms over OHV use of the Rubicon Trail, has been involved in restoration activities and, in testimony to the Central Valley RWQCB, provided some photos of improvements. These photos (see also the actual slides from the testimony to the Central Valley RWQCB) show the “before” and “after” states of an eroded site.

Photos A and B Rubicon Trail, before and after cleanup

In 2012, the Central Valley RWQCB found that sediment disturbed by recreational vehicle activity and transported in stormwater runoff to Corral Hollow Creek, was a water quality problem at the Carnegie State Vehicle Recreation Area. The Central Valley RWQCB also identified metals, such as copper and lead, as a potential concern. To address these problems, the Central Valley RWQCB issued a Cleanup and Abatement Order to the California Department of Parks and Recreation (California State Parks) (Central Valley Regional Water Quality Control Board 2012). The order recognized that California State Parks had developed a Storm Water Management Plan that describes the BMPs that need to be implemented to address erosion and sedimentation. The order required California State Parks to implement the Storm Water Management Plan update.

— Betty Yee, Central Valley Regional Water Quality Board

Table 26-1 **Agency Roles and Activities in Sediment Management**

Type	Agency	Role	Sample Activities
Federal	US Department of Agriculture (USDA) USDA Forest Service Natural Resources Conservation Service Dept. of Interior (DOI) Bureau of Land Management US Geological Survey National Park Service Dept. of Defense U.S. Army Corps of Engineers (USACE)	Land managers Advisors	Supports California land management practices that incorporate erosion control and sediment management. Provides technical and financial assistance directly to farmers for the planning and implementation of conservation practices on agricultural lands for the protection of natural resources, including soil erosion and sedimentation.
Federal	DOI U.S. Fish and Wildlife Service Dept. of Commerce National Oceanic and Atmospheric Administration (NOAA) U.S. Environmental Protection Agency (EPA) USACE	Regulators Advisors	Oversees dredging, fisheries, and total maximum daily load (TMDL) issues.
Tribal	Tribal Governments	Land managers Planners	Plans and manages for sediment management considerations.
State	California Department of Forestry and Fire Protection (CAL FIRE) Board of Forestry and Fire Protection (BOF) State Lands Commission California Dept. of Parks and Recreation (California State Parks) California Dept. of Fish and Wildlife (DFW)	Land managers Advisors Planners Regulators	Promotes sediment management through best forest management practices. For over 20 years, a group of advisors called the Monitoring Study Group (MSG) has continued to: (1) develop a long-term program of testing the effectiveness of California's Forest Practice Rules, and (2) provide guidance and oversight to CAL FIRE in implementing the program. The MSG has sponsored significant research on sediment management. This research informs CAL FIRE-funded monitoring efforts designed to ascertain if forest practice rules, as well as measures to reduce unnatural sediment loads and protect beneficial uses of water, are being implemented and are effective.

Type	Agency	Role	Sample Activities
State	California Dept. of Food and Agriculture California Dept. of Conservation DFW The University of California Extension Farm Advisors	Advisors Grant administrators Training & technical assistance	Provides significant leadership in source sediment management through the development of best management practices (BMPs).
State	State Water Resources Control Board and Regional Water Quality Control Boards	Regulators Training & technical assistance	Protects water quality through the issuance of regulations and permits, which also serve as National Pollutant Discharge Elimination System (NPDES) permits for point-source discharges subject to the Clean Water Act. Permits related to sediment control include stormwater permits for municipal stormwater systems, highways and other thoroughfares, and construction activities. The Water Boards administer grant funding to develop and implement management practices to address non-point-source pollution, such as development and implementation of the California Rangeland Water Quality Management Plan (http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf).
Regional	Sierra Nevada Conservancy	Planning Financial assistance Training & technical assistance	Promotes land use practices that support optimum source sediment management.
Regional	Tahoe Regional Planning Agency	Planning Regulation	Promotes land use practices that support optimum source sediment management.
Local	Local Governments, Districts, Water Agencies, Reclamation Districts, and Planning Commissions	Planning Regulation	Promotes land use practices that support optimum source sediment management. Some local governments (city and county) support lowimpact development (LID), including it as part of their planning and development ordinances. LID features design elements, including hydromodification, which address sedimentation at the source. Resources, including model regulations, are available to help municipalities interested in incorporating sediment source management into their planning portfolios. Local governments may also be involved in flood protection and water supply. For more information, visit these Web sites: http://www.epa.gov/owow/NPS/lidnatl.pdf http://www.epa.gov/region1/topics/water/lid.html http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf

Type	Agency	Role	Sample Activities
Local	Cities Counties Joint Powers Authorities Commissions	Advisors	Develop a land stewardship ethic that promotes long-term sustainability of the state's rich and diverse natural resource heritage.
Local	Resource Conservation Districts (RCDs)	Planning, technical, and financial assistance	RCDs implement projects that improve sediment management on public and private lands and educate landowners and the public about resource conservation. They work together to conduct: • Watershed planning and management. • Water conservation. • Water quality protection and enhancement. • Agricultural land conservation. • Soil and water management on non-agricultural lands. • Wildlife habitat enhancement. • Wetland conservation. • Recreational land restoration. • Irrigation management. • Conservation education. • Forest stewardship. • Urban resource conservation.
NGO	California and local Farm Bureaus California Rangeland Trust The Nature Conservancy	Advisors Advocates Training & technical assistance	Information development and dissemination, policy advocacy Land holding services
NGO	California Association of Storm Water Quality Agencies (CASQA)	Advisors Advocacy Training & technical assistance	Assists the Water Boards and municipalities throughout California in implementing the National Pollutant Discharge Elimination System (NPDES) stormwater permits. One of the accomplishments of CASQA has been the development and dissemination of BMP handbooks. The BMPs help reduce unwanted delivery of sediment. The handbooks are designed to provide guidance to the stormwater community in California regarding BMPs for a number of activities affecting water quality and sediment management, including new development and redevelopment, construction activities, industrial and commercial activities, and municipal activities. For more information, visit these CASQA Web sites: http://www.casqa.org/ http://www.cabmphandbooks.com

Type	Agency	Role	Sample Activities
Private Interests and Land Managers	Pacific Gas & Electric Co. (PG&E), Southern California Edison, and other major private utilities with large land and water holdings and infrastructure Tejon Ranch, Irvine Ranch, etc. Timber & Rail companies (e.g., Sierra Pacific, Catellus Corporation, a successor to the Southern Pacific Land Company and affiliated with Santa Fe Pacific) Agriculture	Land management	Pacific Forest and Watershed Lands Stewardship Council (PG&E) Irvine Ranch Conservancy Tejon Ranch Conservation and Land Use Agreement

Sediment Transport Management

Sediment, like water, flows downstream and supports both shorelines and habitats through the length of the riverine system to the end of the line. Rivers and streams carry sediment in their flows. Different size sediment particles can settle throughout a waterway, based on the energy and flow of the water and the size and weight of the particle, resulting in similar size sediments being located together, as in sand or gravel bars in creeks and rivers. Three types of sediment loads are described in Box 26-4.

Sediment, primarily sand, also moves along the coastline as littoral drift. This "river of sand" is driven by wind and waves interacting with the shoreline and its orientation. Sand enters the littoral cell from streams and rivers, moves downcoast picking up additional contributions from eroding bluffs, and leaves the littoral cell when it reaches a submarine canyon. Some sand is also lost off shore during large storm events. The sand resides temporarily along the coast as beaches, and fluctuations in the supply, or the loss, of sand to the system will affect beach widths.

Sediment transport management is the process of introducing or leveraging natural functions that create optimal sediment transport. This involves managing the speed and flow of the sediment conveyance and the natural or built structures to achieve a properly distributed balance of sediment types in the habitat. Properly managed transport of sediments will result in the optimal sediment deposition.

For example, sand bypass structures in flood control channels are starting to be used. Such structures placed into flood channels allow the coarse-grained sediments to remain in the channel and continue downstream toward the coast, while fine-grained sediments are diverted to a settling pond where they can be excavated and used for construction or diverted to a wetland where they add to the size of the wetland. More information on this method is available in the *California Beach Restoration Study* (California Department of Boating and Waterways and California Coastal Conservancy 2002).

Sand transport management along the coast includes dredging harbor entrance channels that have become clogged with the migrating sands, and transporting the dredged materials to some other location. In some areas, sand traps have been constructed to facilitate such transport prior to the sands entering the harbors. Elsewhere along the coast, retention structures (e.g., groins) have been constructed to slow the alongshore transport, maintaining beach widths for longer periods. If the area upcoast of the groins is not properly filled with sand, beaches downcoast of the groins can experience accelerated erosion.

Sediment Deposition Management

The goal of sediment deposition management is to achieve optimum benefits from sediment deposits and mitigate negative impacts. As noted previously, properly distributed sediment has numerous beneficial outcomes, such as:

- Fine-grained sediments supporting existing habitat and adapting to sea level rise.
- Gravel remaining in rivers and streambeds for habitat and riverbed stability.
- Sand sustaining beaches for recreation and habitat.
- Fine silts and clays introducing nutrient-rich materials and nutrient cycling.
- Deposits creating buffers, particularly offshore, which reduce climate-change and storm-surge impacts. Coastal areas that benefit from sediment can also include offshore mudbelts.

Deposition management also includes techniques to prevent and mitigate the negative aspects of excessive sediment, including:

- Siltation, creating an impact on the capacity of floodways, reservoirs, and water supply systems, including dams.
- Siltation, creating unsafe shipping and transportation channels and having an impact on other commercial and recreational navigation.
- Siltation, inundating wetlands.
- Deposition, filling pools and embedding riffles, which reduces stream habitat.

The USACE maintains the primary federal permitting and operational responsibility over waterway and navigational dredging, flood control, and the operation of many dams. The EPA oversees USACE's implementation of its Clean Water Act and its Marine Protection, Research, and Sanctuaries Act (MPRSA) responsibilities, establishes water quality criteria, and implements certain TMDLs. Additionally, the U.S. Bureau of Reclamation maintains a significant federal role in maintenance, construction, and even deconstruction of dams.

The California Coastal Commission, California Department of Water Resources (DWR), State Lands Commission, State Water Resources Control Board, RWQCBs, and BCDC serve as State counterparts. Additional federal and State resource agencies are responsible for fisheries and recreation.

Box 26-4 Types of Sediment Loads

Suspended load is the portion of the sediment that is carried by a fluid flow that settles slowly enough such that it almost never touches the bed. It is maintained in suspension by the turbulence in the flowing water and consists of particles generally of the fine sand, silt and clay size.

Bed load describes particles in a flowing fluid (usually water) that are transported along the bed of a waterway.

Wash load is the portion of sediment that is carried by a fluid flow, usually in a river, such that it always remains close to the free surface (near the top of the flow in a river). It is in near-permanent suspension and is transported without deposition, essentially passing straight through the stream. The composition of wash load is distinct because it is almost entirely made up of grains that are only found in small quantities in the bed. Wash load grains tend to be very small (mostly clays and silts, but some fine sands) and thus have a small settling velocity, being kept in suspension by the flow turbulence.

Dredging and Sediment Extraction

Dredging is an excavation activity or operation usually carried out, at least partially underwater, in shallow water areas with the purpose of gathering up bottom sediments and disposing of them at a different location. This technique is often used to keep waterways navigable.

Other forms of sediment extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel, and sluicing. Sluicing is a sediment removal method that employs water flow to remove smaller particle sediment (i.e., sands and silts) to remove sediment accumulated in reservoirs. Sluicing is one of the two methods the Los Angeles County Flood Control District has used since the 1930s to remove sediment from its reservoirs.

Extraction methods are often used to maintain the capacity of flood and water supply infrastructure and mine sediment, sand, and gravel for multiple purposes such as commercial construction, levee stabilization, and environmental restoration. Determining how the extracted sediment will be managed involves a variety of factors including environmental acceptability, and technical and economic feasibility.

Dredging is a critical sediment-deposition management activity supporting commercial shipping, homeland security, fishing, recreation, and environmental restoration. Detailed descriptions of dredging equipment and dredging processes are available in Engineer Manual (EM) 1110-2-5025 (U.S. Army Corps of Engineers 1983; Houston 1970; Turner 1984).

In San Francisco Bay alone, dredging facilitates a substantial maritime-related economy of more than $7.5 billion annually. By necessity, maritime facilities are located around the margins of a bay system that averages less than 20 feet deep, while modern, deep-draft ships often draw 35 to 50 feet of water or more. In order to sustain this region’s diverse navigation-related commercial and recreational activities, extensive dredging — in the range of 2 to 4 million cubic yards (mcy) per year — is necessary to maintain adequate navigation channels and berthing areas. Effective management of the large volumes of dredged material generated throughout this estuary is both a substantial challenge and an opportunity for beneficial reuse. Both are addressed by the Long

Term Management Strategy for Dredging (see http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf) and the interagency Dredged Material Management Office. Navigational dredging in Southern California is similarly managed to encourage beneficial reuse wherever possible under the Los Angeles Basin Contaminated Sediment Management Strategy's Master Plan and the interagency Dredged Materials Management Team.

There are some known issues related to dredging and other forms of sediment extraction:

- Dredging and sediment extraction can directly affect water quality, habitat quality, and contaminant distribution. Operations may reduce water quality by introducing turbidity, suspended solids, and other variables that affect the properties of the water such as light transmittance, dissolved oxygen, nutrients, salinity, temperature, pH, and concentrations of trace metals and organic contaminants if they are present in the sediments (San Francisco Bay Conservation and Development Commission 2001).
- Depending on the location of the dredging, deepening navigation channels can increase saltwater intrusion because saline water is heavier than freshwater, and this may cause a net movement upstream of the deeper waters, potentially resulting in an impact on freshwater supplies and fisheries (e.g., deepening of the Sacramento and Stockton deep-water ship channels in the Delta). Dredging can also increase saltwater intrusion into groundwater aquifers (e.g., the Merritt Sand/Posey formation aquifer in the Oakland Harbor area), with consequent degradation of groundwater quality in shallow aquifers.
- Sediment removal operations may also reintroduce contaminants into the water system by re-suspending pollutants. Metal and organic chemical contamination is widespread in urban shipping channels due to river runoff and municipal/industrial discharges. Chemical reactions that occur during removal may also change the form of the contaminant. These chemical reactions are determined by complex interactions of environmental factors, and may either enhance or decrease bioavailability, particularly those of metals. At the same time, dredging can aid in overall reduction of pollutants in a water body when contaminated sediments are removed from the system or sequestered in habitat restoration projects.

Many things have been done to address these existing issues. There are pre-dredging and real-time monitoring programs that have been developed to test the quality of sediments to be dredged, and there are alternative disposal sites where different quality sediments can be taken. Time windows for when some dredging can occur have been established to accommodate certain ecological cycles. Upland sediment-disposal sites can be designed to mitigate for many contaminants, and extremely contaminated sites can be capped in-place underwater. Evaluation of dredged material for ocean disposal under the Marine Protection, Research, and Sanctuaries Act (MPRSA) relies largely on biological (bioassay) tests. The ocean testing manual, *Evaluation of Dredged Material Proposed for Ocean Disposal — Testing Manual*, commonly referred to as the Green Book, provides national guidance for determining the suitability of dredged material for ocean and near-coast disposal. Evaluation of dredged material for inland disposal under the Clean Water Act (CWA) relies on the use of physical, chemical, and/or biological tests to determine acceptability of material to be disposed. The USACE's inland testing manual, *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. — Testing Manual*, provides national guidance on best available methods.

Beneficial reuse of dredged and extracted sediments can solve what can otherwise be a dilemma of how to dispose of dredged and extracted sediments as a waste by repurposing it in a variety of ways. These can be used to raise subsided lands to allow restoration as an agricultural supplement and to support levees. When this occurs, the economics of disposal may be altered. In particular, the initial cost to the dredger for sediment removal and placement may be increased. For example, reusing the sediment may require different equipment, the transportation distance to the reuse site may be greater than to the traditional disposal site, and the amount of time needed to complete the dredging work may be extended.

Many sediment management activities involve public trust lands. Because these lands are held in trust for all citizens of California, they must be used to serve statewide, as opposed to purely local, purposes. In these cases, sediment as a trust asset may be subject to State mineral extraction fees and other restrictions.

Dam Retrofit, Reoperation, and Removal

Dams are an important part of California's water and flood management and will remain so for the foreseeable future. Sediment deposits naturally behind dams and reservoir sediment management includes a range of options including sluicing of sediment, dredging, redesign, retrofit, and removal.

Dam retrofit is an option for deposition management. The Natural Heritage Institute, a non-governmental and non-profit organization, has been a pioneer in this area. They are investigating the feasibility of re-operating some dams in order to restore a substantial measure of the formerly productive floodplains, wetlands, deltas, and estuaries located downstream in ways that do not significantly reduce — and can sometimes even enhance — the irrigation, power generation, and flood control benefits for which the dams were constructed.

In addition, having the ability to re-operate reservoirs without the need to retrofit existing infrastructure (i.e., the ability to adjust hydraulic gates) could include sediment pass-through during stream forming flow events. Allowing coarse and finer sediments to pass through a reservoir during a stream-forming event can provide many benefits. Using sediment pass-through as a sediment management strategy can functionally create and/or maintain storage capacity; significantly decrease the frequency of sluicing or dredging; increase power generation efficiency (e.g., increased head); reduce debris intrusion and accumulation at intake structures; and restore to some degree the natural recruitment of coarse and finer sediments essential for the support of a diverse benthic community, thus resulting in a healthy aquatic environment.

Dam removal is sometimes a result of sediment management, or it creates a need for sediment management. As noted earlier, sediments trapped behind dams or in reservoirs may require periodic sediment removal to maintain function and capacity. However, this is sometimes extremely challenging owing to the facility's location and the lack of disposal or beneficial reuse opportunities at nearby locations. In recent years, there has been increased interest in dam removal for sediment-related reasons, such as the loss of capacity of the facility to hold water due to accumulated sediment (see Box 26-5 on the removal of San Clemente Dam). In other cases, the reasons may be unrelated, such as a need to upgrade hydrogeneration or improve a stream fishery. Analysis of dam removal proposals requires significant discussion of sediment deposition management. Management of sediments behind such dams has been an important element of negotiations related to dam decommissioning.

Box 26-5 Case Study: California American Water Files Application for Removal of Silted-Up Dam — Dredging Not Feasible

Dams that have filled with sediment over the decades create management dilemmas. This news article about San Clemente Dam on the Carmel River describes some of the possible solutions and costs.

News — September 27, 2010

California American Water has filed an application with the California Public Utilities Commission requesting permission to remove the San Clemente Dam on the Carmel River in order to resolve seismic safety concerns associated with the dam and restore critical habitat for the steelhead trout.

"From an engineering and environmental perspective, this is a landmark project," said California American Water president Rob MacLean. "Our innovative method for dealing with the sedimentation behind the dam and the level of public-private cooperation which has made this plan a reality will serve as a template for the removal of other obsolete dams across the country."

California American Water is partnering with the National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service and the California State Coastal Conservancy to implement the dam removal project while minimizing cost to its ratepayers. California American Water has committed $49 million and the dedication of 928 acres where the dam is located as parkland.

The Coastal Conservancy and NOAA committed to raise the additional $35 million needed for the removal project through a combination of public funding and private donations.

The San Clemente Dam is a 106 feet high concrete-arch dam built in 1921, 18 miles from the ocean on the Carmel River, to supply water to the Monterey Peninsula's then-burgeoning population and tourism industry. Today the reservoir is over 90 percent filled with sediment and has a limited water supply function.

In 1991, the California Department of Water Resources, Division of Safety of Dams agreed with a California American Water consultant's assertion that San Clemente Dam did not meet modern seismic stability and flood safety standards.

The Department of Water Resources and Army Corps of Engineers studied many ways to ameliorate the safety issues including strengthening the dam and removing it.

The January 2008 Final Environmental Impact Report and Environmental Impact Statement ("EIR/EIS") regarding San Clemente Dam's stability contains analysis of a Reroute and Removal Project, which would address the seismic and flood safety risks associated with San Clemente Dam by permanently rerouting a portion of the Carmel River and removing the dam.

Under this proposal, the Carmel River would be rerouted to bypass the 2.5 million cubic yards of silt that have accumulated behind the dam thereby avoiding dredging, which has been deemed infeasible.

The primary benefits of the Reroute and Removal Project are that it improves the Carmel River environment by removing the dam, which serves as a barrier to fish passage, and satisfies government agencies' concerns that strengthening the dam, as opposed to removing it, could further threaten the South Central California Coast Steelhead and violate the federal Endangered Species Act.

Source: Dredging News Online 2010

Regional Sediment Management

Regional sediment management (RSM) refers to the practice where sediment is managed over an entire region. Managing sediment to benefit a region potentially saves money, allows use of natural processes to solve engineering problems, and improves the environment. RSM as a management method:

- Includes the entire environment, from the upland source areas to the sea.
- Accounts for the effect of human activities on sediment erosion, as well as its transport in streams, lakes, bays, estuaries, and oceans.
- Protects and enhances the nation's natural resources while balancing national security and economic needs.

RSM is an approach for managing projects involving sediment that incorporates many of the principles of integrated watershed resources management, applying them primarily in the context of coastal watersheds. While the initial emphasis of RSM was on sand in coastal systems, the concept has been extended to riverine systems and finer materials to completely address sources and processes important to sediment management. It also supports many of the recommendations identified by interagency working groups for improving dredged material management. Examining RSM implementation through demonstration efforts can provide lessons regarding not only improved business practices, techniques, and tools necessary for managing resources at regional scales, but also roles and relationships that are important to integrated water resources management.

This is a growing concept nationwide, which also has economic benefits. The USACE has a primer on Regional Sediment Management at http://www.iwr.usace.army.mil/Portals/70/docs/nsms/rsmprimer.pdf.

More information about RSM can be found in the American Society of Civil Engineers written Policy Statement 522, on Regional Sediment Management at http://www.asce.org/Content.aspx?id=8638.

Connections to Other Resource Management Strategies

Many other RMSs in *California Water Plan Update 2013* share a connection with sediment management. More information on each of these RMSs can be found in these chapters in Volume 3, *Resource Management Strategies*:

- Chapter 4, "Flood Management." Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of the floodplain, the depth and composition of soils, and the type and density of vegetation. Sediment transport dynamics can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying capacity of natural channels through increased sedimentation. Sediment is also a major component of alluvial fan and debris-flow flooding.
- Chapter 5, "Conveyance — Delta," and Chapter 6, "Conveyance — Regional/Local." Depending on design, conveyance facilities can trap, scour, or result in other unnatural distribution of sediments. Sediment overload can significantly reduce system capacity.

- Chapter 12, "Municipal Recycled Water." Municipal recycled water is increasingly being utilized for irrigation. An emerging concern in some areas is that sodium loading may be found in soils irrigated with recycled waters. The sodium, through a chemical interaction, can alter the permeability of the soil and reduce its capacity for infiltration. Reduced infiltration rates cause increased run-off and, consequently, increased sediment transport.
- Chapter 13, "Surface Storage — CALFED," and Chapter 14, "Surface Storage — Regional/ Local." Similar to conveyance, sediments may be trapped behind infrastructure or otherwise unnaturally distributed. This results in a loss of system capacity.
- Chapter 18, "Pollution Prevention." Well-designed pollution prevention efforts improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion, and sedimentation of streams.
- Chapter 20, "Urban Stormwater Runoff Management." Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways and the timing and extent of sediment introduction into the system. The impervious surfaces increase runoff volumes and velocities, resulting in stream bank erosion and potential unnatural sediment distribution downstream. Watershed approaches to urban runoff management attempt to manage sediments to mitigate negative impacts and support beneficial uses in a manner that mimics the natural hydrologic cycle.
- Chapter 21, "Agricultural Lands Stewardship." Agricultural land stewardship directly links to management of erosion and soils protection. Proper management in both private and public land ownership prevents disruptive development patterns and supports sediment aware farming and ranching practices.
- Chapter 22, "Ecosystem Restoration." Native riparian, aquatic, animal, and plant communities are dependent on effective sediment management. These ecosystems are dynamic and are highly productive biological communities given their proximity to water and the presence of fertile soils and nutrients. Many opportunities for improvement in both sediment management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains. Sediment management projects that result in protected and restored ecosystems will likely create increased effectiveness, sustainability, and public support.
- Chapter 23, "Forest Management." Forestation practices can influence sediment transport from upland streams. Wildfires can reduce surface water infiltration, which can cause additional erosion and debris flooding.
- Chapter 24, "Land Use Planning and Management." The way in which land is used — the type of land use, transportation, and level of use — has a direct relationship to sediment management. One of the most effective ways to reduce excessive sediment loads is through land use planning that is fully abreast and reflective of applicable sediment and hydrology practices. This includes site design to reduce the introduction of excessive loads of sediment into waterways.
- Chapter 27, "Watershed Management." Watersheds are an appropriate organizing unit for sediment management. Restoring, sustaining, and enhancing watershed functions are goals of sediment management in the context of integrated watershed management.
- Chapter 29, "Outreach and Engagement." Outreach is needed to educate the public regularly on sediment management concerns. Outreach is also needed to educate the public on the natural beneficial functions of sediment.

- Chapter 30, "Water and Culture." Sediment is used in traditional ceremonies and considered to contain healing, and in some cultures, it has spiritual properties. Mud structures are important to native peoples; for some, mud has ties to the creation story. See *Tribal Water Stories* at http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.
- Chapter 31, "Water-Dependent Recreation." Water and land-based recreational activities can contribute to unnatural erosion and sediment production. Conversely, high sediment loads can negatively affect recreation, particularly boating, fishing, and swimming. Adequate supply of sand and gravel sediments is essential for many beach recreational activities.

Potential Benefits

The ultimate benefits of sediment management relate to preventing the negative results of too little or too much sediment and repurposing sediment for beneficial uses. As noted above, benefits associated with reducing impacts just to navigation and commerce may achieve cost savings of millions. A similar statement can be made about the management of sediment that accumulates at reservoirs and debris basins and is prevented from flooding communities downstream.

Source Sediment Management

An average of 1.3 billion tons of soil per year is lost from agricultural lands in the United States because of erosion (McCauley and Jones 2005). Considering that soil formation rates are estimated to be only 10–25% of these erosion rates (Jenny 1980), loss and movement of soil by erosion is a major challenge for today's farmers and land managers. Soil erosion over decades can have detrimental effects on productivity and soil quality because the majority of soil nutrients and soil organic matter are stored in the topsoil, which is the soil layer most affected by erosion. For these reasons and more, sediment management for soil sustainability has numerous multiple benefits far exceeding the scope of the California Water Plan.

In the case of urban land management, use of low-impact development and other sediment management practices can reduce negative impacts of stormwater runoff, by maintaining the natural production of sediment and improving permeability of drainage areas. Land use goals for sediment may also improve flood management. By improving the flood system hydrology, sediment management results in improved safety and environmental and economic outcomes.

Coastal Sediment Management

Sediment in the coastal waterways can furnish material needed to replenish the beaches and marshes along the coastal areas. If the sediment is removed from navigation channels or harbors, the extracted material can be used for beach or marsh nourishment, construction purposes such as highway sub-base material, and flood control levees.

Widening the shoreline, either via beach nourishment or marsh restoration, improves storm surge and flood protection. The dollar value of this improved protection is nearly incalculable, not just for those who own coastal structures, but for the extraordinary number of infrastructure improvements that support the state, including power generation, major transportation assets, water systems, and the dollar value of the recreation and tourism industries that are large part of the state's economy. Restoring eroded coastlines also improves habitat for coastal biota and improves access safety to the shorelines.

Fisheries

In terms of water management, natural amounts of coarse-grained sediment (sand and gravel) in the stream and river system has many beneficial uses. It can serve in the inland waterways as a substrate for fish spawning areas. Enhancing the sustainability of the fishery benefits not only the state's fishing industry, but is also a water supply benefit as a declining fishery may lead to reductions of water exports or use of some water rights.

Beneficial Uses for Extracted Sediment

Extracted sediment is a manageable, valuable soil resource with beneficial uses of such importance that it should be incorporated into project plans and goals at the project's inception to the maximum extent possible. For example, extracted sediment can benefit:

- Habitat restoration/enhancement (wetland, source, island, and aquatic sites, including use by fish, wildlife, waterfowl, and other birds).
- Beach nourishment.
- Aquaculture.
- Parks and recreation (commercial and noncommercial).
- Agriculture, forestry, and horticulture.
- Strip mine reclamation and landfill cover for solid waste management.
- Shoreline stabilization and erosion control (fills, artificial reefs, submerged berms.).
- Construction and industrial use (including port development, airports, urban, and residential.
- Material transfer for fill, dikes, levees, parking lots, and roads.
- Multiple purposes (i.e., combinations of the above).
- Coastal Access.
- Storm Surge Protection.

The applicability of uses is subject to the demand for materials. An issue or barrier might be matching disposal to uses and the composition of the sediment (course grained versus fine-grained). A detailed discussion about various beneficial uses for extracted material can be found at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/beneficial_use.cfm.

System Capacity and Materials Use

Multiple benefits come from managing the sediment that accumulates at reservoirs and debris basins. If sediment that accumulates in reservoirs is not removed, storage capacity is reduced. If sediment is not removed or passed through, then the storage capacity for floodwater, water supply, or hydropower is reduced. If sediment is not removed from reservoirs and debris basins, the ability to provide flood risk management, water supply, or hydropower is diminished.

As an example, a pilot project in the Santa Ana River Watershed is being designed by the USACE and the Orange County Water District to manage sediment in the Santa Ana River. The Prado Basin Sediment Management Demonstration Project will remove 500,000 cubic yards of sediment behind Prado Dam and re-entrain the sediment in the river below the dam (see Box 26-6).

Potential Costs

Many agencies and organizations engage in sediment management activities. The cost of implementing sediment management to achieve water benefits varies widely depending on the sector and purpose of the management. When looking at the overall costs of sediment management, managers should consider and quantify the beneficial uses of the sediment and the ecosystem services, flood protection, storm surge protection, and water quality improvements associated with the benefits as a balance in comparison to the up-front financial investments. While the financial investment is often a one-time cost, the benefits are regularly long term, such as creating a wetland that provides habitat and water quality improvements in perpetuity.

A few sample investments in sediment management include:

Natural Resources Conservation Service (NRCS). From 2007 to 2012, the NRCS obligated more than $91 million in California for conservation practices to address soil erosion and sedimentation on agricultural land. These practices are recommended to reduce erosion, prevent the transport of sediment, or trap sediment before it leaves the farm or field.

U.S. Department of Agriculture Forest Service. Overall, the cost of watershed restoration projects on national forests is close to $2,000/acre, and most of these projects have the benefits of reducing erosion and sediment transport. Meadow restoration using the pond and plug approach is about $1,000/acre. Road decommissioning costs about $16/cubic yard of sediment (reduction in potential erosion).

Los Angeles County Flood Control District (LACFCD). Based on the alternatives included in the LACFCD's Draft Sediment Management Strategic Plan (April 2012), the cost to manage the Strategic Plan's 67.5-mcy planning quantity could be as much as $1.2 billion over the 20-year planning period, 2012 to 2032 (County of Los Angeles Department of Public Works 2012).

U.S. Bureau of Reclamation (USBR) and U.S. Bureau of Land Management (BLM). Gravels are added to Northern California rivers to aid in the anadromous salmon run each year. The amount of gravels added depends on the budget allocated each year. Such gravel additions are occurring in the upper Sacramento River area (i.e., Clear Creek), and in other rivers such as the American River, Yuba River, and Stanislaus River. The costs per ton of gravel added depends upon such factors as the method of placement, tonnage of gravel placed, and how the gravel is placed (e.g., dump trucks dumping gravel directly into river, lateral berms laid alongside the streambed at low water, or sluicing a mix of water and gravel directly into the river). Typical tonnages added may vary from 5,000 to 10,000 tons and more per application. In addition, the U.S. National Fisheries Service specifies the amount of cleaning (washing) that has to be done to the gravels prior to application, and the grain size distribution of the gravels, which adds to the cost.

Box 26-6 Case Study: Prado Basin Sediment Management Demonstration Project

The Santa Ana River watershed is the largest in coastal Southern California, covering 2,450 square miles. The Santa Ana River flows 75 miles from headwaters in the San Bernardino Mountains through Orange County to the Pacific Ocean. Upon the completion of Prado Dam in 1941, the sediment transport mechanics of the Santa Ana River watershed were altered dramatically. Ninety-two percent of the watershed drainage flows through the dam. As sediment-laden water enters Prado Basin, the water velocity decreases, sediment settles out of the water, and relatively sediment-free water is released through Prado Dam.

Disruption of natural sediment transport has numerous negative impacts upstream and downstream of the dam. Above the dam, sedimentation reduces the dam's storage and water conservation capacity, threatens infrastructure, and degrades valuable habitat in Prado Basin and along the river upstream of the basin. Downstream of the dam, a lack of sediment in the water released from the dam erodes the river bottom and banks; reduces the infiltration capacity of the river bottom; threatens infrastructure, such as bridges and flood control structures; and reduces sand replenishment at beaches.

The U.S. Army Corps of Engineers (USACE) is partnering with the Orange County Water District (OCWD) on a pilot project to remove up to 500,000 cubic yards of sediment behind the dam and re-entrain the sediment in a controlled manner back into the river downstream. One purpose of the Prado Basin Sediment Management Demonstration Project is to provide data, conclusions, and recommendations to design and implement a comprehensive, long-term sediment management program at Prado Basin, which may serve as a model for implementation of similar projects elsewhere. Key issues to be evaluated at a field scale in the project include sediment removal and conveyance measures, the rate at which sediment can be re-entrained into the river, and potential environmental impacts.

Removal of sediments would restore lost storage capacity behind Prado Dam and enhance water reuse and recharge capabilities. A cooperative agreement between the USACE and OCWD provides for the temporary storage of stormwater behind the dam to allow stored water to be released at rates that enable OCWD to divert stormwater to recharge basins for infiltration into the groundwater basin. Sediment accumulation reduces the volume of available storage. This project has the potential to significantly increase this important water supply for Orange County.

Re-entraining sediments removed from Prado Basin into the river below the dam will allow the sediments to migrate downstream and replenish eroded streambed sediments, provide sand to beaches, and encourage restoration and creation of habitat.

Special Situations

The battle to maintain Lake Tahoe as a pristine and visual jewel is an unusual sediment case study. The sediment of concern is very fine-grained sediment (less than 20 microns) that affects the clarity and people's aesthetic enjoyment of Lake Tahoe. In 2010, the Lahontan RWQCB developed TMDL allocations for sediment and nutrients to Lake Tahoe to control the impacts on lake clarity. To support the new requirements, the Lahontan RWQCB analyzed the costs of implementing controls in urban areas and stream channels and estimated the necessary capital investment at approximately $1.5 billion in 2007-2008 equivalent dollars.

In this case, the problem may be unique and the extensive costs of basin-wide improvements would not translate to other situations. Even so, there have been many new and innovative best practices for sediment management in the basin and these can translate to other programs.

Additionally the benefits of the investment have been equally evaluated and are considered to be of national interest.

Major Implementation Issues

The issues for implementing sediment management are similar to those experienced by related RMSs, including the following:

- The need to balance environmental impacts, social impacts, feasibility, and cost is important.
- Availability and affordability of land often play a role.
- Different stakeholders have different needs and different understandings of the need to manage sediment.
- Local managers sometimes implement site-specific solutions without considering the regional backdrop or how regional processes affect the local conditions.
- Stakeholders and regulators lack a complete understanding of the different natural regional sediment regimes and attempt to address issues on a statewide basis.
- Urbanization and other structural limitations may preclude introduction of natural regimes.
- Supply/demand is a factor with extracted sediment in terms of quantity and timing, sediment type, and use. Beneficial use is contingent upon recipients for managed sediment.
- Conflicting federal, State, and local regulations, coupled with conflicting agency missions, make it difficult for the agencies to view projects holistically from a regionwide perspective.
- Significant resistance has come from some local interests concerned with siting and transfer of impacts. There is a lack of advocacy to counter negative attitudes (e.g., “don’t see, don’t care”).
- Budget constraints weigh, including the need to find a funding source to pay for the incremental costs of RSM.

Sustainability issues facing the three management approaches — sediment source management, sediment transport management, and sediment deposition management — follow.

Sediment Source Management

Lack of Techniques for Coarse-Grained Sediments Management

Often there is a desire for the coarse-grained fraction of the natural supply of sediments (sand and gravel), but not the fine-grained sediments (silts and clays) from the watershed, to enter the streams and rivers so that they can replenish these sediments in fish spawning areas and also move toward the ocean, thereby replenishing the sand along the coastal beaches. Research is needed because so few techniques currently exist for implementing coarse-sediment bypassing in inland watersheds. Flood Control 2.2 — a joint project of the San Francisco Bay Estuary Partnership, San Francisco Estuary Institute, San Francisco Bay Joint Venture, Bay Area Flood Protection Association, and San Francisco Bay Conservation and Develop Commission, which is funded by the EPA Water Quality Improvement Fund grant program — is examining this question. The project, which began in September, 2012, and will extend until December, 2016, is examining the coarse-grain load in Bay Area flood channels, characterizing the channel configurations and constraints, and identifying ways to move coarse-grain sediment through the channels to the shoreline or to develop bypass areas where the sediment is diverted into habitat areas where it is much needed.

In particular, efforts must be made to keep coarse-grained sediments available and clean in fish spawning rivers and streams. Erosion in unstable watersheds brings fine-grained sediments into the channels which may settle and cover the coarse-grained sediments needed for spawning, thus eliminating them from use in the spawning process. This web site, published by Joseph M. Wheaton, describes these needs: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.

Barriers to Supplying Coarse-Grained Sediments to the Coastal Beaches

Many of the beaches along the coastline are receding because their natural supply of coarse-grained sediments from inland rivers has been stopped by dams, extracted for use, deposited on impermeable pavements, coastal armoring, in-stream sand and gravel mining, stormwater controls, changes to the ground surface contours, and other land use practices.

Instream sand and gravel mining removes a resource that downstream environments need. This situation is anticipated to become worse and accelerate with sea level rise. As noted above, the CSMW is working toward this effort, but challenges remain as agencies aim to work collaboratively, identify the necessary funding, and overcome the traditional jurisdictional conflicts that create misalignment of policy and regulation. Current USACE policy for placement of dredge materials is the lowest-cost alternative, which is not always where the material could best be used. Sediments can also be used to restore the template of flood protection and, in some cases, sand and gravel mining operations can be moved out of the stream or a mitigation fee can be imposed.

Along the coast, beach nourishment has usually been undertaken by combining the USACE's or other dredgers' maintenance dredging of sandy areas and pumping it or placing adjacent to or directly on the shoreline for distribution either via wave action or by mechanical means. This practice has been well received; however, funding remains minimal. Even with these successes, a challenge to beach replenishment occurs when material must be transported over land through beach neighborhoods in order to get to the beaches. In some California locations, sandy beaches, primarily used for recreation, are human-made and require continual replenishment, maintenance, and support.

Cost Allocation

The issue of whose budget pays is a major barrier to reuse of any kind. Often reuse is not only environmentally beneficial, but also presents the optimal use of society's funds. Even then, if the dredging budget will not pay for any increase in placement costs compared to disposal, and if the reuse site will not share some of the costs for receiving otherwise free material from the dredging project, the reuse does not occur. A USACE publication addresses this problem, which is available at http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/.

Additionally, current USACE policy for placement of dredged material, which requires the lowest cost alternative for the placement of dredged material, typically means transport to the location (e.g., beach) closest to the dredge area. Lack of broader policy discussion of this general issue is a lost opportunity to recommend to the Legislature that the body accomplish a number of things. For example, the Legislature should encourage congressional action to revise how the Harbor Maintenance Trust Fund is distributed and to continue support or even increase funding to entities, such as the California Coastal Conservancy, to share costs with USACE for dredging projects. A cost-benefit ratio for dredge disposal incremental determinations (the NED plan, or national economic development plan, per the USACE]) is needed.

Controlling Excessive Sediment from Causing or Entering Eutrophic Waterways

Eutrophic waterways typically have a lot of minerals and organic nutrients that are used by plants and algae. They often appear dark and have poor water quality. This occurs when certain nutrients, such as phosphorus, are absorbed on fine-grained sediments and carried into the waterways and lakes. These nutrients can cause algal blooms to go out of control in a lake, a condition that then creates a lack of oxygen resulting in fish kills. The sediments also result in a reduction of light and clarity in lakes, thereby harming the food chain and reducing the aesthetic quality of the lake. Controlling these conditions is challenging, and failing to do so is especially harmful to Lake Tahoe. Clear Lake struggles to manage sediment and resulting algal blooms (see Box 26-7).

Implementation of Regional Sediment Management

There are obstacles to the practical implementation of RSM. RSM requires a long-term, multi-year watershed view for planning. Yet, it may be difficult for stakeholders and regulatory agencies to adopt long-term views and without the necessary scale. Federal, State, and local regulations sometimes conflict with one another. Successful RSM requires compromises from everyone. Regulators often do not offer a compromise due to statutory requirements, not recognizing others' jurisdiction, and fear of exposure to third party lawsuits. Additional challenges for RSM are finding re-use projects/activities that occur at the same time that the sediment needs to be removed, long distances between potential users and the sediment source, and opposition from inhabitants/stakeholders. CSMWs Coastal SMP program aims to address many of these issues by providing a cogent, strategic methodology to address sediment imbalance issues within the specified region using RSM.

Limited Options Resulting from Other System Requirements

In some cases, the optimal sediment management approach may be precluded, owing to other system requirements or previously implemented decisions and goals.

As an example, a major shift in land use and population patterns may not be feasible. On a specific project level, large amounts of sediment already accumulated behind reservoirs prohibit the immediate implementation of a different approach to sediment management (e.g., a reservoir may need to be cleaned out to its original condition before a sediment flow-through approach can be implemented).

Box 26-7 Case Study: Clear Lake — Algae in Clear Lake

The Clear Lake Basin was shaped by a variety of processes over the last 1 to 2 million years. Scientists have recovered a nearly continuous sequence of lake sediments dating back 475,000 years. Other lake sediments in the region date back to the Early Pleistocene, approximately 1.6-1.8 million years ago.

Clear Lake is a naturally eutrophic lake. Eutrophic lakes are nutrient rich and very productive, supporting the growth of algae and aquatic plants (macrophytes). Factors contributing to the lake's eutrophication include a fairly large drainage basin to contribute mineral nutrients to the water, shallow and wind-mixed water, and no summertime cold water layer to trap the nutrients. Because of the lake's productivity, it also supports large populations of fish and wildlife. The algae in Clear Lake are part of the natural food chain and keep the lake fertile and healthy. Because of the lake's relative shallowness and warm summer temperatures, the algae serve another important purpose. They keep the sun's rays from reaching the bottom, thus reducing the growth of water weeds that would otherwise choke off the lake.

Along with Clear Lake's high productivity, algae in the lake can create a situation that can be perceived as a problem to humans. From more than 130 species of algae identified in Clear Lake, three species of blue-green algae can create problems under certain conditions. These problem blue-greens typically "bloom" twice a year, in spring and late summer. The intensity of the blooms varies from year to year and is unpredictable. The problem occurs when algae blooms are trapped at the surface and die. When this occurs, unsightly slicks and odors can be produced.

The advent of powered earthmoving equipment increased the amount of soil disturbance and facilitated large construction projects, such as the Tahoe-Ukiah Highway (State Highway 20), the reclamation of the Robinson Lake floodplain south of Upper Lake, stream channelization, and the filling of wetlands along the lake perimeter. To support the development, gravel mining increased within the streams, further increasing erosion and sediment delivery to Clear Lake. During this time period, mining techniques at the Sulphur Bank Mercury Mine changed from shaft mining to strip mining, resulting in the discharge of tens of thousands of yards of overburden directly into Clear Lake.

Starting in the summer of 1990, lake clarity improved significantly. This improved clarity has continued until the present. During the 1991-1994 time period, University of California researchers led by Drs. Peter Richerson and Thomas Suchanek analyzed lake water quality data collected for the previous 15 years, conducted experiments, and evaluated the Clear Lake system. Unfortunately, little data was available during the period of improved clarity since 1990. The "Clean Lakes Report" (http://www.co.lake.ca.us/Assets/WaterResources/Algae/Clean+Lakes+Report$!2c+1994.pdf) determined that excess phosphorus is a major cause; however, iron limits the growth of blue-green algae. The improved water clarity and reduced blue-green algal blooms continued into the new millennium. California Department of Water Resources data collected since the Clean Lakes Report was evaluated by Lake County staff in 2002. Surprisingly, phosphorus and total nitrogen concentrations in the lake did not change substantially when the lake clarity increased. Cursory review of the data did not provide evidence of chemical changes that led to the improved clarity and reduced blue-green algal blooms in Clear Lake.

Source: County of Lake 2010

Also important is the instream sand and gravel mining industry, which, according to some authors (e.g., Magoon) may represent the largest source of downstream loss, but is also providing important benefits to the local economy and source materials for multiple critical uses.

Sediment Transport Management

The discipline of sediment transport management is emerging. Much remains to be learned about the best ways to manage for instream sediment quality objectives to prevent aquatic organisms from being smothered by sediment while also providing sediment for downstream processes and needs.

Lack of Monitoring on Stable (Reference) Sediment Conditions in Watersheds

Altered channels have changed natural hydrogeomorphology and natural sediment processes. There is a benefit in achieving and maintaining watersheds in a stable condition as it relates to the generation and transport of sediments from the land surface to the surface streams. This requires understanding (assisted by geomorphic assessments on channels) and monitoring to determine when watersheds are stable or unstable. Management without these tools causes stream channels to degrade in their geomorphic form and they will not support the native aquatic biological habitat. This affects domestic water supplies (filtration). Unstable sediment conditions may also result in disruption of flood control structures.

Protecting Aquatic Life

The State Water Resources Control Board is establishing biological objectives, which will include those for suspended sediment and deposited sediments (California Environmental Protection Agency 2014). Excessive sediment in streams, as well as lack of natural sediment loads, can be detrimental to the aquatic life.

Sediment Deposition Management

Sediment impacts through turbidity, dredging, or burial are also of concern in the coastal environment. Dredging has the potential to destroy habitat and biota currently residing in that habitat, while placement of sands has the potential to bury biota at the placement area or downcast from it. Both of these activities have the potential to create turbid conditions that if not abated, could create adverse conditions for filter feeders, visual predators, and photosynthesis. The CSMW's Biological Impacts Analysis and Resource Protection Guidelines discusses these potential impacts in detail, as well as recommending methodologies to minimize such impacts.

Securing Disposal/Placement Locations

Finding disposal locations has become increasingly difficult and expensive due to development of nearby land, regulatory constraints/requirements, or opposition from those adjacent or along the haul routes to the deposition sites.

Another challenge to disposing of/reusing dredged sediment on dry land is dewatering the sediment. Due to the high content of water if the sediment is hydraulically dredged, the dewatering areas need to be quite large and a region may not have sufficient space available.

When dredged material is placed at an upland dewatering or stockpile site, often reuse options are not known until a particular reuse is proposed and the RWQCBs analyze the sediment quality data that was collected during dredging. This is because sediment that may be chemically suitable (considered to be “clean enough”) for one kind of reuse may not be suitable for other kinds of reuse. Often this results in delays for projects wanting to reuse the sediment, and can also constrain the emptying and use of the storage sites for future projects. Some have suggested it would help if the coastal RWQCBs had sediment screening criteria that dredgers could have access to before dredging activities.

Handling Contaminated Sediments

Management of contaminated sediments may be challenging. There are limited resources for cleaning of the sediments and disposal of containments taken from contaminated sediments. The USACE has a National Center of Expertise for handing contaminated sediments at http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

Contaminated Sediment Management

The potential for contamination is a consideration whenever dealing with sediments, whether these are in upper watersheds or in ports and harbors. When a project or a watershed has to contend with contaminated sediment, special considerations need to be applied. Even contaminated sediment can often be reused, but a more limited set of potential uses for that sediment may be available.

Reuse Challenges

Appropriate reuse is sometimes cost-prohibitive. Challenges to using sediment for beneficial uses include finding beneficial use projects that coincide with the timing of sediment removal, long distances between the sediment removal site and the beneficial use site, offloading equipment needs, encountering regulatory obstacles, and potentially steep disposal fees at the beneficial use site.

Regulatory Requirements

Regulatory and management frameworks involving sediment typically are designed to support specific uses. As a result, they involve multiple agencies and jurisdictions that are not necessarily accommodating of the complexities of managing all the aspects of sediment sources, transport, and deposition. As a result, sediment-related projects and/or multiple benefit projects may not be feasible due to timing, costs, and conflicts related to the desired deposition of the sediment. Regionally, the LTMS program previously described provides a cooperative framework for testing, permitting, and beneficial reuse projects. The Los Angeles Region Contaminated Sediments Task Force is a similar interagency regulatory group. Significant effort and energy is required to maintain such cooperative and collaborative efforts when dealing with dredging and beneficial reuse projects. CSMW also functions as a clearinghouse for member agencies to identify sediment-related activities of interest to other agencies.

Data Availability

A number of issues related to integrated management and better planning and coordination could be improved with better data availability. For example:

- Better planning and decision-making could occur with coordinated mapping efforts to allow agencies to more fully consider upstream and downstream impacts before making decisions.
- Ongoing monitoring would allow better adaptive management and an evaluation of management methods being used. Sediment monitoring should follow suitable quality assurance/quality control features, so that the data collected are scientifically defensible, are derived from field and laboratory methods acceptable to all users statewide, and are entered into a database accessible to all users. Improved forecasting and modeling would support long-term and strategic planning. Sediment transport modeling is becoming an increasingly important tool in watershed sediment considerations. The USACE and the EPA, as well as others, have been developing sediment transport models.
- Development of sand and sediment budgets would assist agencies in planning and reduce regulatory conflicts. The development of sand budgets is one of the most important aspects of regional sediment management.

Data challenges can be addressed. For example, CSMW maintains a Web site designed to make as much information as possible to costal sediment managers. In addition, there are many Web sites devoted to specific topics that CSMW has been involved with since 2003. These range from a topical library containing links to relevant reports to a searchable database of references. A spatial database containing numerous data layers can be found at http://www.dbw.ca.gov/CSMW/default.aspx.

Sediment and Climate Change

Climate change is already occurring and is projected to continue altering temperature and hydrology patterns in the state. Climate change studies project an increased frequency of extreme weather, higher temperatures, larger and more frequent wildfires, longer droughts, and more precipitation falling in the form of rain than snow. These changes will bring shifts in vegetative species, heighten soil exposure, and will cause flooding to already vulnerable lands and coastlines, adding a heavy mix of sediment and debris to stormwaters. Coupled with sea level rise and surge, which increases coastal erosion, beach erosion, and coastal flooding, climate change will amplify the already difficult task of sediment management. Drought and climate change alter permeability and other physical characteristics of sediment, and increased carbon dioxide (CO_2) levels may influence soil chemistry.

Adaptation

Adaptation will necessitate projecting where excessive sediments will source and accumulate as a result of flooding. Effective management of those sediments for habitat, floodplains, and shoreline stability will improve resiliency.

With climate change expected to bring wetter winters and drier summers, erosion will become an even greater threat to California lands and sediment management. Several adaptation strategies may provide benefits in light of climate change.

Where floodplain restoration is feasible, this will allow for natural deposits of sediment and serve dual purposes of managing sediment and replenishing soil. Excess, clean sediment can be used beneficially on eroding beaches, marshes, and agricultural lands, augmenting natural processes. As an example, State and federal agencies, including the California Coastal Conservancy, have provided funding for the Hamilton/Bel Marin Keys Wetlands Restoration near Novato, California. In this project, dredged excess sediment was used to create habitat that will aid in storm surge protection.

Warmer temperatures and higher levels of CO_2 may, in some cases, lead to increased vegetation. Vegetation can minimize runoff and lessen erosion, preventing sediments from entering waterways. Effective management of landscapes, including planting heat- and drought-tolerant native vegetation around waterways, can minimize sediment loads. In other cases, where there is high fuel loading in an extreme fire hazard zone, excess vegetation could increase damage caused by fire, leading to post-fire erosion and excess sediment loading. Management for vegetation should be considered on a case-by-case basis.

Mitigation

Removing sediment for navigation, flood control, and reservoirs, among other uses, is a continuous process that can result in high greenhouse gas (GHG) emissions from fossil fuel-powered equipment.

There is a growing opportunity for GHG offsets through the use of renewable energy in sediment management operations, such as harbor maintenance dredging. Potential may also exist for sequestration in the reuse of dredged sediment in wetland and vegetated habit restoration, but more research is needed before this can be determined.

Recommendations to Facilitate Sediment Management

New recommendations for sediment management may increase costs and/or the amount of time needed to obtain permits. All new sediment recommendations should be strongly evaluated to determine to what extent they could inhibit important water/flood projects and activities. If impacts may occur, some form of mitigation for these effects should be included when implementing any given recommendation.

Policy and Regulatory Reconciliation

1. The State and USACE should convene a stakeholder working group that includes flood protection and water supply entities to recommend methods to overcome sediment management regulatory conflict and encourage long-term thinking, including the issuing of permits that match the time horizon for any established sediment management plan. The stakeholder working group should consult and build upon the successes of the CSMW. The stakeholder group should also developed recommendations for consideration by the State Legislature and Congress to address conflicting statutory requirements and facilitate flexibility among the agencies to develop sediment management approaches to meet regional needs.

2. The USACE, Natural Resources Agency, California Environmental Protection Agency, Department of Finance, Governor's Office of Planning and Research, and the California Water Commission should convene a task force or stakeholder working group to recommend methods for sediment management cost allocation. Often reuse is not only environmentally beneficial, but also presents the optimal use of funds.
    A. The stakeholder group should also evaluate needs for outreach and education on sediment management and offer recommendations for next steps to address those needs.
    B. Specific focus should be given to cover the incremental costs of RSM.

Sediment Source Management

3. The Governor's Office of Planning and Research should develop model general plan guidelines that support optimal sediment source management.
4. Federal, tribal, State, regional, and local agencies and stakeholders should support and participate in RSM for those sediments that must be dredged to keep the waterways and other facilities open for navigation or to support flood control efforts. In addition, there should be support of those efforts to use that sediment beneficially within regions. One possible use of the sediment is levee construction that can direct the floodwater to the most desirable location.
5. The State Lands Commission and other responsible agencies should scrutinize instream and beach Sediment Mining Permits. The Commission should evaluate impacts of sediment-mining permits on a case-by-case basis, which allow the removal of coarse-grained material directly from streambeds or from coastal beaches. While such permits may be satisfactory in some instances, in other instances such permits reduce the sediment needed for fish spawning beds and for beach replenishment.
6. The State should implement the requirements recommended by the California Association of Storm Water Quality Agencies for stormwater discharge control programs associated with sediment management, which
    A. Are technically and economically feasible.
    B. Provide significant environmental benefits and protect the water resources.
    C. Promote the advancement of stormwater management technology.
    D. Are compliant with State and federal laws, regulations, and policies. Reducing or controlling stormwater discharges keeps watershed and industrial pollutants from running into the waterways, thereby improving water quality.
7. The Regional Water Quality Control Boards should work with stakeholders to secure broader support of sediment water quality requirement efforts and promote development of stakeholder- based implementation plans to address excessive sediment problems.

Sediment Transport Management

8. The State should support research and design of fine-grained and coarse-grained sediment bypass structures. This will allow the coarse-grained sediment to be separated and either enter the streams and serve its many beneficial uses there, such as for fish spawning grounds and the restoration of coastal beaches, or be trapped in detention ponds where it can be excavated and used beneficially. The fine-grained sediment will be separated and can be used for wetland establishment or other uses. The separation and removal of fine-grained sediment with their attached nutrients can help improve the water quality in lakes having excessive eutrophication. This work will need to account for water quality requirements and other interests, such as fishing and recreation.

9. The State should encourage the use of remote sensing as a tool for sediment transport management, which can track sediment from source to transport in the streams. Such models (such as SWAT, HEC-HMS, and HSPF) need adequate calibration and validation, but once calibration is done, these models can help to manage the sediments throughout the watershed. The watershed model can also predict the concentrations of other water quality substances in the water.

10. The Natural Resources Agency and California Environmental Protection Agency should implement, as much as possible, an integrated approach to achieve the maintenance of stable watersheds. A stable watershed is one where sediment yield mimics the natural sediment production that would occur in the absence of anthropogenic conditions. If the watershed is not stable, assist in efforts to make it so.

Sediment Deposition Management

11. Where feasible, the State in cooperation with the local sediment management agencies should determine the Sediment Yields of Watersheds when downstream sediment problems are becoming an issue. This type of monitoring may not be feasible in undeveloped, highly erosive mountain areas. These yields (such as in tons/square mile/year) can be determined at monitoring sites, which have matching pairs of suspended sediment concentrations and instantaneous flow rate measurements. Knowing the sediment yields will help to manage extraction and dredging budgets for the navigation channels and other non-navigation facilities.

12. The Regional Water Quality Control Boards in cooperation with the local sediment management agencies should expand use of regionally-based sediment screening criteria so that agencies could know sooner what the use of the dredged material could be and plan accordingly. Establish potential uses of dredged material, depending upon its quality, in advance. The upland sites receiving dredged material can then be emptied sooner and become available for additional dredged material. This will assist in maintaining the shipping channel in operational condition.

13. The State Lands Commission and DWR should prepare sand budgets for each watershed when downstream sand availability issues are occurring. Comparing these sand budgets for each watershed over time will reveal the efficacy of source BMPs' effect on sand transport, be of use in determining how well sand is moving toward the coastal beaches, allow comparison of sand generation in the watershed to that removed by instream sand removal permits, and show which watersheds are best generating sand. These sand budgets should

include the sand budgets developed for coastal areas, including the regional sediment budget studies conducted by UC Santa Cruz for CSMW.

14. All affected jurisdictions should work with or through the CSMW, because it is preparing coastal RSM plans for most of the littoral cells along the coast.
15. The State should support and provide incentives for expanding successful interagency models to cover dredging projects throughout the state. Identifying beneficial reuse opportunities that support RSM goals should be a key objective of the State's involvement.
16. The State should develop a funding source to encourage and support beneficial reuse projects, specifically those that enhance, restore, or support habitat including beach nourishment and wetland restoration projects. State funding can be partnered with federal and private funds to support these efforts.
17. The State may also consider ways to encourage beneficial reuse of sediment without State funding. Specific ideas include providing a tax credit or widely and flexibly applied mitigation credit when sediment is reused beneficially rather than treated as a waste product.
18. The State should enable funding for special districts and local governments to undertake sediment management actions. This could include the ability to levy taxes for sediment management, similar to infrastructure districts.
19. For sediment removal projects from facilities that capture sediment from undeveloped watersheds (e.g., some dams and debris basins), State agencies should allow pre-testing to facilitate deposition of sediment at solid waste landfills, inert landfills, and other potential deposition sites, which otherwise may require testing and affect beneficial use of sediment, especially in emergency situations.

Data Acquisition and Management

20. Federal and State governments should allow for the installation of data collection and transmitting equipment and stations in all State- and federally-owned lands, even in designated wilderness and Wild and Scenic rivers, when the collection of data on such lands is necessary to provide a complete and accurate geomorphic assessment of streams and watershed stability. State and federal governments should also encourage the development of data collection and transmitting equipment that can be installed and operated with minimal impacts on habitat.
21. Federal and State governments should support development of guidelines to identify when geomorphic assessments of streams for watershed stability are appropriate to prevent undue delays in processing permits and ensure that studies are scaled to project size.
22. Federal and State governments should support sediment and flow monitoring programs of others if needed to determine the sediment yields from a watershed and sediment budgets for downstream areas. They should also establish monitoring protocols that produce scientifically defensible data of comparable quality throughout the state. Such monitoring will add to the water quality database of the waterway.
23. Federal and State governments should support modeling and monitoring for sediment dynamics in estuarine and near-shore (littoral cell) environments when understanding

estuarine and near-shore sediment transport issues is key to adaptive management, infrastructure protection, and habitat restoration.

24. The State should expand efforts for a sediment data exchange and cooperate with others who may be obtaining sediment data in a watershed so that a common database is used that is accessible to all users. Stakeholders should be convened to establish data needs and requirements. CSMW has developed a GIS database and associated web viewer, and is working with the Ocean Protection Council to incorporate their spatial data into the State Geoportal, currently under development. The State Geoportal is envisioned as a one-stop location for most of California agencies' geospatial database.

25. All responsible agencies should utilize a common GIS mapping framework and use GIS to overlay maps relating sources of excessive sediment production in watersheds with areas having sediment problems in the stream in those watersheds.

References

References Cited

California Department of Boating and Waterways and State Coastal Conservancy. 2002. C*alifornia Beach Restoration Study*. Sacramento (CA): Viewed online at: http://www.dbw.ca.gov/PDF/Reports/BeachReport/FUll.pdf.

California Environmental Protection Agency. 2014. "Proposed Policy for Biological Objectives for (Perennial Streams & Rivers of) the State of California." Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml.

Central Valley Regional Water Quality Control Board. 2011. *The State of the Central Valley Region Address: A Five-Year Review Reflection and Projection.* Viewed online at: http://www.waterboards.ca.gov/centralvalley/board_info/exec_officer_reports/state_of_cvrwqcb_dec_2011.pdf.

Coastal Sediment Management Workgroup. 2014. "Sediment Master Plan." California Department of Boating and Waterways. [Web site.] Viewed online at: http://www.dbw.ca.gov/csmw/smp.aspx.

County of Los Angeles Department of Public Works. 2012. "Sediment Management Strategic Plan." [Web site.] Viewed online at: http://dpw.lacounty.gov/lacfcd/sediment/stplan.aspx.

McCauley A and Jones C. 2005. *Managing for Soil Erosion*. Bozeman (MT): Montana State University Extension Service. Soil and Water Management Module 3. 12 pp. Viewed online at: http://landresources.montana.edu/SWM/PDF/Final_proof_SW3.pdf.

San Francisco Bay Conservation and Development Commission. 2001. *Chapter 3.0, Authorization Process for Dredging and Dredged Material Disposal Projects.* Viewed online at: http://www.bcdc.ca.gov/pdf/Dredging/LTMS/Mgt_Plan/chpt3.pdf.

Theodoratus D and McBride K. 2009. "California Tribal Environmental Justice Collaborative Grant Project. Report for California Tribal Environmental Justice Collaborative Grant Project." [Web site.] Viewed online at: http://www.catribalej.com/reporting.html. Accessed: June 6, 2010.

United Nations Educational Scientific and Cultural Organization. 2011. *Sediment Issues & Sediment Management in Large River Basins Interim Case Study Synthesis Report.* International Sediment Initiative, Technical Documents in Hydrology. Viewed online at: http://unesdoc.unesco.org/images/0021/002128/212891e.pdf.

U.S. Environmental Protection Agency. 2009. *National Water Quality Inventory: Report to Congress, 2004 Reporting Cycle*. Washington (DC): Viewed online at: http://water.epa.gov/lawsregs/guidance/cwa/305b/upload/2009_01_22_305b_2004report_2004_305Breport.pdf.

Additional References

American Society of Civil Engineers. 1997. *Guidelines for Retirement of Dams and Hydroelectric Facilities.* ASCE Publications. [Book.]

———. 2014. "Policy Statement 522— Regional Sediment Management." ASCE American Society of Civil Engineers. [Web site.] Viewed online at: http://www.asce.org/Content.aspx?id=8638.

Bridges TS. 1999. "Center for Contaminated Sediments." U.S. Army Corps of Engineers. [Web site.] Viewed online at: http://el.erdc.usace.army.mil/dots/ccs/ccs.html.

California Regional Water Quality Control Board Central Valley Region. 2009. Cleanup and Abatement Order No. R5-2009-0030 for El Dorado County and the United States Department of Agriculture, Forest Service, Eldorado National Forest, Rubicon Trail, El Dorado County. Viewed online at: http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/el_dorado/r5-2009-0030_enf.pdf.

———. 2012. Cleanup and Abatement Order No. R5-2012-0700 for California Department of Parks and Recreation Carnegie State Vehicle Recreation Area, Alameda and San Joaquin Counties. Viewed online at: http://www.waterboards.ca.gov/centralvalley/board_decisions/adopted_orders/alameda/r5-2012-0700_enf.pdf.

California Stormwater Quality Association. 2014. "California Stormwater Quality Association." [Web site.] Viewed online at: http://www.casqa.org/.

Coastal Sediment Management Workgroup. 2014. "Coastal Sediment Management Workgroup." California Department of Boating and Waterways. [Web site.] Viewed online at: http://www.dbw.ca.gov/CSMW/default.aspx.

County of Lake State of California. 2010. "Algae in Clear Lake." [Web site.] Viewed online at: http://www.co.lake.ca.us/Government/Directory/Water_Resources/Algae_in_Clear_Lake.htm.

Dredging News Online. 2010. "California American Water Files Application for Removal of Silted-up Dam — Dredging Not Feasible." [Web site.] Viewed online at: http://www.sandandgravel.com/news/article.asp?v1=13621.

Gordon M and Zamist R. 2006. *Municipal Best Management Practices for Controlling Trash and Debris in Stormwater and Urban Runoff.* California Coastal Commission and Algalita Marine Research Foundation. Viewed online at: http://www.plasticdebris.org/Trash_BMPs_for_Munis.pdf.

Houston J. 1970. *Hydraulic Dredging Theoretical and Applied.* 1st Edition. Cambridge (MD): Curnell Montime Press. 318 pp. [Book.]

Jenny H. 1980. *The Soil Resource: Origin and Behavior*. New York (NY): Springer-Verlag. 377 pp. [Book.]

Kuhnle RA and Simon A. 2000. *Evaluation of Sediment Transport Data for Clean Sediment TMDLs.* NSL Report No. 17. Oxford (MS). [Web site.] Viewed online at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/NSLReport17.pdf.

Martin LR. 2002. *Regional Sediment Management: Background and Overview of Initial Implementation.* Prepared for: U.S. Army Corps of Engineers Institute for Water Resources Policy Studies Program. Viewed online at: http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/02ps2sed_man.pdf.

Murphy K, Rich T, and Sexton T. 2007. *An Assessment of Fuel Treatment Effects on Fire Behavior, Suppression Effectiveness, and Structure Ignition on the Angora Fires*. United States Department of Agriculture. Viewed online at: http://www.cnpssd.org/fire/angorafireusfsfullreport.pdf.

New England Environmental Finance Center. n.d. *Promoting Low Impact Development in Your Community*. Viewed online at: http://efc.muskie.usm.maine.edu/docs/lid_fact_sheet.pdf.

Prince George's County, Maryland, Department of Environmental Resources and Programs, and Planning Division. 1999. *An Integrated Design Approach: Low-Impact Development Design Strategies*. Viewed online at: http://www.epa.gov/owow/NPS/lidnatl.pdf.

San Francisco Bay Conservation and Development Commission. 1998. *Chapter 3.0, Dredging and Dredged Material Characteristics — An Overview*. Final Environmental Impact Statement/Environmental Impact Report. Viewed online at: http://www.bcdc.ca.gov/pdf/Dredging/EIS_EIR/chpt3.pdf.

Science Applications International Corporation. 2012. *Review of Sediment Management Impacts and Issues Relevant to Protection of California Coastal Biota*. Volume 2. User's Guide and Resource Protection Guidelines. Viewed online at: http://dbw.ca.gov/csmw/pdf/BIA_Vol_2_SAIC_Nov2012.pdf.

Smart Growth/Smart Energy Toolkit. 2007. *Model Low Impact Development (LID) Bylaw*. Viewed online at: http://www.mass.gov/envir/smart_growth_toolkit/bylaws/LID-Bylaw-reg.pdf.

The Heinz Center. 2002. *Dam Removal: Science and Decision Making*. Washington (DC): Viewed online at: http://water.epa.gov/polwaste/nps/upload/Dam_removal_full_report.pdf.

Trippsmith K. 2010. *Tribal Water Stories*. California Tribal Water Summit Planning Team. Viewed online at: http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.

Turner TM. 1984. *Fundamentals of Hydraulic Dredging*. 1st Edition. Centreville (MD): Cornell Maritime Press. 214 pp. [Book.]

U.S. Army Corps of Engineers. 1983. *Engineering and Design Dredging and Dredged Material Disposal*. Engineer Manual No. 1110-2-5025. Washington (DC): Viewed online at: http://140.194.76.129/publications/eng-manuals/EM_1110-2-5025/EM_1110-2-5025.pdf.

———. 1987. *Engineering and Design: Confined Disposal of Dredged Material*. Engineer Manual No. 1110-2-5027. Washington (DC): Viewed online at: http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-5027.pdf.

———. 2004. *Regional Sediment Management*. Division of Boating and Waterways. Washington (DC): Viewed online at: http://dbw.ca.gov/csmw/pdf/rsmprimer.pdf.

U.S. Commission on Ocean Policy. 2004. *Chapter 12, Managing Sediment and Shorelines*. *An Ocean Blueprint for the 21st Century.* Final Report. Washington (DC): Viewed online at: http://govinfo.library.unt.edu/oceancommission/documents/full_color_rpt/12_chapter12.pdf.

U.S. Department of Housing and Urban Development. 2003. *The Practice of Low Impact Development*. Upper Marlboro (MD): NAHB Research Center, Inc. Viewed online at: http://www.huduser.org/publications/pdf/practlowimpctdevel.pdf.

U.S. Department of the Interior and Bureau of Reclamation. 2006. *Dam Decommissioning and Sediment Management. Erosion and Sedimentation Manual*. Denver (CO): Viewed online at: http://www.usbr.gov/pmts/sediment/kb/ErosionAndSedimentation/chapters/Chapter8.pdf.

U.S. Environmental Protection Agency. 1991. "Proposed for Ocean Disposal (Testing Manual). Water: Dredged Material Management." [Web site.] Viewed online at: http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/gbook_index.cfm.

———. 2009. "Managing Stormwater with Low Impact Development Practices: Addressing Barriers to LID." New England. Viewed online at: http://www.epa.gov/region1/npdes/stormwater/assets/pdfs/AddressingBarrier2LID.pdf.

———. 2013. "Beneficial Use of Dredged Material." [Web site]. Viewed online at: http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/beneficial_use.cfm.

———. 2013. "National Dredging Team (NDT)." [Web site.] Viewed online at: http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/.

U.S. Environmental Protection Agency and Hardrock Mining. 2003. *Appendix H. Erosion and Sedimentation*. *EPA and Hardrock Mining: A Source Book for Industry in the Northwest and Alaska.* Viewed online at: http://yosemite.epa.gov/R10/WATER.NSF/840a5de5d0a8d1418825650f00715a27/e4ba15715e97ef2188256d2c00783a8e/$FILE/ATTU303P/appendix%20h.pdf.

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 1998. *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. – Testing Manual*. Viewed online at: http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/2009_10_09_oceans_regulatory_dumpdredged_itm_feb1998.pdf.

———. 2007. "Identifying, Planning, and Financing Beneficial Use Projects Using Dredged Material: Beneficial Use Planning Manual." Washington (DC): Viewed online at: http://water.epa.gov/type/oceb/oceandumping/dredgedmaterial/upload/Identifying-Planning-and-Financing-Beneficial-Use-Projects-Using-Dredged-material-pdf.pdf.

U.S. Fish and Wildlife Service, National Marine Fisheries Service, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency. 2006. *Sediment Removal from Active Stream Channels in Oregon: Considerations for Federal Agencies for the Evaluation of Sediment Removal Actions from Oregon Streams*. Version 1.0. Viewed online at: http://www.fws.gov/oregonfwo/ExternalAffairs/Topics/Documents/GravelMining-SedimentRemovalFromActiveStreamChannels.pdf.

U.S. Navy. 1990. *Final Environmental Impact Statement for Proposed New Dredging*. Draft Environmental Impact Statement for Proposed New Dredging: U.S. Navy Military Construction Projects ; P-202 Naval Air Station, Alameda, P-082 Naval Supply Center, Oakland, San Francisco Bay, California. [Book.]

UNESCO and IRTCES. 2011. *Sediment Issues & Sediment Management in Large River Basins*. Interim Case Study Synthesis Report. UNESCO (Beijing): Prepared by the International Sediment Initiative. Technical Documents in Hydrology. Viewed online at: http://www.irtces.org/isi/isi_document/2011/ISI_Synthesis_Report2011.pdf.

Wheaton JM. 2013. "Spawning Habitat Integrated Rehabilitation Approach (SHIRA)." Joseph M. Wheaton Research Linking Fluvial Geomorphology & Ecohydraulics. Logan (UT): [Web site.] Viewed online at: http://www.joewheaton.org/Home/research/projects-1/past-projects/spawning-habitat-integrated-rehabilitation-approach-shira-.

VOLUME 1 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 27

Watershed Management

Plumas National Forest. Various meadow restoration projects, particularly those related to the Moonlight Fire of 2007, have delivered excellent results in the areas surrounding Antelope Lake, a small, remote lake popular with recreationists in the northeastern portion of the Mt. Hough Ranger District.

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Chapter 27. Watershed Management

Watershed management is the process of creating and implementing plans, programs, projects, and activities to restore, sustain, and enhance watershed functions. These functions provide the goods, services, and values desired by the human community that are affected by conditions within a watershed. The practice of community-based watershed management, which is practiced in hundreds of watersheds throughout the state, has evolved as an effective approach to natural resource management. These community-based efforts are carried out with the active support, assistance, and participation of several State agencies and programs.

Managing at a watershed level has proven to be an appropriate organizing landscape unit for the coordination and integrated management of the numerous physical, chemical, and biological processes that make up a river basin ecosystem (Box 27-1). A watershed serves well as a common reference unit for the many different policies, actions, and processes that affect the system, and it also provides a basis for greater integration and collaboration among those policies and actions.

Watershed Management in California

A primary objective of watershed management is to increase and sustain a watershed's ability to provide for the diverse needs of the communities that depend on it including local, regional, State, federal, and tribal stakeholders. Significant efforts to manage natural resources better using a watershed approach are occurring in several hundred structured efforts in all regions of California involving organizations, local governments, landowners/users, and stewardship groups along with State and federal agencies.

Many of these efforts are working to blend community goals and interests with the broader goals of the State as a whole in a manner consistent with improving environmental, social, institutional, and economic conditions within the watershed. The need to address environmental justice and social equity has been recognized and addressed, along with more traditional project management approaches.

In many communities, these organized efforts serve as forums to bring about collaborative management involving the public and private sector; the academic community; and people working at the local, regional, State, and national levels, all benefitting from the inherent capabilities of each group. The benefits of watershed-based management are being realized in such diverse locations as the upper Feather River, the Los Angeles River basin, and the Napa River.

In addition to these local efforts, a number of regional, statewide, and national initiatives have been carried out to help improve the overall ability to practice watershed management. A chronology of some notable initiatives in California can be found in *California Water Plan Update 2009*, Volume 2, Chapter 27, available online at http://www.waterplan.water.ca.gov/cwpu2009/index.cfm (California Department of Water Resources 2009).

Bond measures have brought significant funding for the maintenance and restoration work that is needed in many of California's watersheds. Proposition 50 (2002) and Proposition 84 (2006)

Box 27-1 Watershed Defined

What is a Watershed?

In its historical definition, a watershed is the divide between two drainage streams or rivers separating rainfall runoff into one or the other of the basins. In recent years, the term has been applied to mean the entirety of each of the basins, instead of just the divide between them. The Continental Divide is a watershed according to the earlier definition, where rainfall runoff is directed toward the Gulf of Mexico or toward the Pacific Ocean. The Mississippi River basin and the Colorado River basin are watersheds under the new definition. Other parts of the world use the terms catchment, or river basin, to describe the drainage area between (historical) watersheds. The phrase "watershed event," an occurrence that changes the pattern of all that follows, moving the flow of events toward a different outcome, is derived from the earlier definition of watershed.

A watershed includes all natural and artificial (human-made) features, including its surface and subsurface features, climate and weather patterns, geologic and topographic history, soils and vegetation characteristics, and land use. A watershed may be a small area or as large as the Sacramento, San Joaquin, or Klamath River basins.

Using watersheds as organizing units for planning and implementation of natural resource management means that:

- Large regions can be divided along topographic lines that describe a natural system more accurately than typical jurisdictional lines.
- Condition and trends analysis can be done on the basis of the entire natural system, in concert with economic and social conditions.
- Communities, including resource management and regulatory agencies, within, and outside a particular watershed can better track and understand the cumulative impacts of management activities on the watershed system.
- Managers within each watershed can adjust their measures and policies to meet management goals more effectively across scales, including regional and statewide goals.
- Multi-objective planning is facilitated by inclusion in, and reference to, a whole-system context.

Effective management recognizes the mutually dependent interaction of various basic elements of a watershed system including the hydrologic cycle, nutrient and carbon cycling, energy flows and transfer, soil and geologic characteristics, plant and animal ecology and the role of flood, fire, and other large scale disturbance.

Each must be considered in context with the others, because change in one spurs changes in the others, creating a different system outcome.

stressed the need for integrated planning that includes objectives at the watershed and regional scales, and provide incentives to carry out work consistent with these plans.

Potential Benefits

Managing people's interactions with and impacts on natural ecosystems using a watershed approach that emphasizes maintaining, restoring, or enhancing the many functions associated with these natural systems produces a number of significant benefits. Many of the benefits (e.g., reliable quantities of clean water, agricultural and forest products, biofuels) and avoided costs (e.g., reduced flood or fire damages) can be described using traditional economic terms, such as products, goods, or services, and are readily quantified and valued in the traditional marketplace. Other values associated with natural systems such as biological diversity, disease suppression, and climate moderation are more difficult to quantify monetarily because these values are not routinely traded in the marketplace. As a result, the term "ecosystem services" is often used to better describe and equate the monetary and non-monetary values or benefits provided to society by healthy watersheds. Some typical watershed products, goods, and services are listed in Table 27-1.

Potential Costs

Costs associated with watershed management depend on many factors, such as the size of the watershed; the land and water use activities occurring in the watershed; the condition and trends of the watershed; and the values, goods, and services demanded from the watershed. Much of the cost of watershed management in California is associated with the specific land or water use activities occurring within the watershed on a recurring basis and is directly related to these uses. The additional or external costs of watershed management that are discussed in this chapter tend to be associated with interventions designed to influence management or improve the results of management, to offer specific protection for certain functions and values, or to restore the functional conditions and associated uses of a watershed. These interventions may come from various levels of government or interests either within or outside the watershed. A methodological approach is used for estimating costs associated with specific watershed-scale resource management efforts. Using this approach, the potential costs associated with these interventions are estimated by:

- Extrapolating costs based on available estimates of other program expenditures (see Table 27-2, used in *California Water Plan Update 2005* and *California Water Plan Update 2009*, in resource management strategy chapters on watershed management). Estimates are based on CALFED watershed management estimates scaled up for statewide coverage.
- Applying a "willingness to pay" approach based on existing examples (using CALFED Watershed Program analysis as part of program finance plan development).
- In addition to the more easily quantified benefits of well-functioning watersheds, effective watershed management can also result in significant avoided costs, such as lessened fire and flood damage, erosion and sediment loss reduction, water quality maintenance, reduced illnesses and treatment costs, and control of agricultural pests. An example is shown in Box 27-2, "Watershed Degradation and Water Treatment Costs."

Willingness to Pay

To estimate the approximate external costs to fully implement the watershed management strategy, an analysis developed by the CALFED Watershed Program was used, which examined areas where communities have chosen to provide quantifiable financial support for watershed management, thus demonstrating "a willingness to pay" for the services provided by a well-managed watershed. This analysis, developed using methods described by the U.S. Department of Energy (Ulibarri and Wellman 1997) and the U.S. Congressional Research Service (Breedlove 1999), is an attempt to assign a monetary value to effective watershed management.

Napa County was used as a basis for this comparison for several reasons. First, it has a demographic similarity to the demographic makeup of the state as a whole. Second, taxes are

Table 27-1 Typical List of Watershed Products, Goods, and Services

Typical Watershed Products, Goods, and Services (also described as ecosystem services)	Benefit of Service
Provision of water supplies	Agriculture, municipal, industrial, and other beneficial uses.
Provision of food, fiber, fuel	Sustainable production of agricultural and forest products that are dependent on healthy productive soils, favorable climate and water conditions, and the availability of pollinators.
Water purification/waste treatment	Well managed watersheds produce clean, cool water generally useful for a broad range of beneficial uses. Virtually all fresh water used in California originates as precipitation that is intercepted, captured, routed, and released from watersheds in California and the Colorado River basin.
Flood mitigation	Healthy watersheds with adequate distributed wetlands and functional floodplains moderate the volume and timing of surface runoff reducing flood damage.
Drought mitigation/flow attenuation	A healthy watershed works like a sponge to store and release water to both streams and groundwater. Healthy watersheds in California increase the residence time of water, and tend to store and release water longer into the dry season.
Provision of aquatic and terrestrial habitat	Uplands, rivers, streams, floodplains, and wetlands provide necessary habitats for fish, birds, mammals, and countless other species, and generally sustain a strong level of biological diversity that provides wide benefits to society.
Soil fertility, health, productivity	Soil health and fertility is an essential component of primary ecosystem production, and is critical for maintenance of important terrestrial, floodplain, riparian, and wetland components and processes.
Nutrient, mineral cycling and delivery, carbon sequestration	Cycling of nutrients is necessary to maintain healthy, diverse biological systems, to sustain biological diversity that mediates disease, and to sustain populations of native species.
Biodiversity maintenance	Diverse assemblages of species work to provide the services (including all those listed in this table) upon which societies depend. Conserving genetic diversity preserves options for the future and increases the resilience of ecosystems in the face of the impacts of a changing climate.
Recreational opportunities	Swimming, fishing, hunting, boating, wildlife viewing, hiking, and skiing are all delivered or enhanced in healthy watersheds, often resulting in concurrent economic improvements in local communities reliant on recreation as a source of economic sustenance or growth.
Climate moderation/buffering	Generally, a diversified watershed ecological system is more robust and resilient to rapid climate changes or other types of disturbance. Maintaining a resilient watershed ecosystem will be of critical importance in the face of a changing climate. That adaptation will better ensure that watershed ecosystem functions will continue to provide the goods, services, and values of the systems experienced today.
Aesthetics	Quality of life is a major, but difficult to quantify, benefit of watershed conditions. Pleasant surroundings with clean air, clean water, and adequate recreational opportunities have been shown to be beneficial across a broad spectrum of social structures.
Managing salinity gradients	Freshwater flow regimes can determine salinity gradients in deltas, coastal estuaries, and near-shore marine environments, a key to biological richness and complexity.

Source: Table content adapted from *Rivers for Life: Managing Water for People and Nature* (2003) by Sandra Postel and Brian Richter.

Table 27-2 Estimates of Watershed Management Costs to Year 2030, from *California Water Plan Update 2005* and CALFED Program Estimates

Period (years)	Assessment-Planning[a] ($ millions)	Public Process[b] ($ millions)	Projects[c] ($ millions)	Total for Period ($ millions)
2004-2009	$10-$37.5	$8-$16	$14-$80	$160-$667
2010-2015	$10-$30	$8-$16	$14-$88	$160-$804
2016-2030	$10-$25	$8-$16	$14-$100	$160-$2,115
Total				$480-$3,586

Source: *California Water Plan Update 2005*, Volume 2, *Resource Management Strategies*, Chapter 25, "Watershed Management."

Notes:

The CALFED service area is defined as the Sacramento and San Joaquin River basins, the Tulare Lake basin, the Delta and San Francisco Bay Area, and the portion of Central and Southern California serviced by the State Water Project.

[a] CALFED service area is estimated as 40 percent of statewide need. Therefore, statewide assessment and planning = 2.5 x CALFED values from draft CALFED Finance Plan (2004).

[b] The service area for public process is estimated as 25 percent of the statewide need. Therefore, statewide public process = 4x CALFED values.

[c] For projects, CALFED service area is estimated to be 25 percent of the statewide need. Therefore, statewide projects = 4x CALFED values.

collected that are directly tied to implementation of community-generated watershed management plans; these tax levies also demonstrate strong local support among voters and elected officials for the values inherent in improved watershed management. Finally, these funds are generated and dispersed locally, by locally responsive government entities.

Valuations from three different Napa County tax measures were investigated:

- A half-cent sales tax passed by 68 percent of voters in the late 1990s that generates approximately $10 million in revenue per year specifically for watershed management (the "Living River" program).
- A parcel tax of $12.70 per parcel that is supported and levied within the City of Napa for watershed management.
- An additional parcel tax of $12 per year specifically for stormwater runoff management inside the city's watersheds.

These assessments generate funds (based on 2009 estimates) that range from nearly $14,000 per square mile for the sales tax revenue, to just less than $1,600 per square mile for the parcel tax. For the purposes of this value estimate, a lower amount of $1,572 per square mile is used, which in turn, is adjusted to account for the slight difference in demographic statistics between Napa and California at large. These value estimates (Table 27-3) represent the annual external cost of fully implementing the watershed management strategy over approximately half the surface area of California, including all or part of the Sacramento River, San Joaquin River, Tulare Lake, San Francisco Bay, South Coast, and South Lahontan hydrologic regions.

Box 27-2 Watershed Degradation and Water Treatment Costs

The development of watershed and aquifer recharge lands results in increased contamination of drinking water. With increased contamination comes increased treatment costs. The costs can be prevented with a greater emphasis on source protection. A study of 27 water suppliers conducted by the Trust for Public Land and the American Water Works Association in 2002 found that the more forest cover in a watershed, the lower the treatment costs. According to the study, "Approximately 50 to 55 percent of the variation in treatment costs can be explained by the percent of forest cover in the source area. For every 10 percent increase in forest cover in the source area, treatment and chemical costs decreased approximately 20 percent, up to about 60 percent forest cover."

The study did not gather enough data on suppliers with more than 65 percent forest cover to draw conclusions. However, it is suspected that treatment costs level out when forest cover is between 70 and 100 percent. The 50 percent variation in treatment costs that cannot be explained by the percent forest cover in the watershed is likely explained by varying treatment practices, the size of the facility (larger facilities realize economies of scale), the location and intensity of development and row crops in the watershed, and agricultural, urban, and forestry management practices. The table shows the change in treatment costs predicted by this analysis, and the average daily and annual cost of treatment if a supplier treats 22 million gallons per day.

Table A Change in Water Treatment Costs for Each 10 Percent of Forest Cover in Source Watershed

Percent of Watershed Forested	Treatment and Chemical Costs per Million Gallons	Change in Costs	Average Treatment Costs Daily	Average Treatment Costs Per Year
10%	$115	19%	$2,530	$923,450
20%	$93	20%	$2,046	$746,790
30%	$73	21%	$1,606	$586,190
40%	$58	21%	$1,276	$465,740
50%	$46	21%	$1,012	$369,380
60%	$37	19%	$814	$297,110

Source: Extracted from Land Conservation and the Future of America's Drinking Water - Protecting the Source (2004). Published by the Trust for Public Lands and the American Water Works Association.

Simple extrapolation of this value to the entire land area of the state would result in an estimated annual cost of $221 million to fully implement the strategy. For this example, "fully implement" suggests extensive application within the regions of the policy-level and strategic practice recommendations in this chapter. It should be noted here that an as-yet-undetermined, but likely significant, portion of that cost is not an added cost, but existing expenditures applied differently. For instance, permits and stream alteration agreements issued by watershed boundary instead of jurisdictional boundary could result in considerable added benefit and positive effect without adding to the real cost of implementation. Also, land use planning done on the basis of watershed impact may yield higher beneficial results without increasing costs.

Table 27-3 Cost Estimate to Fully Implement the Strategy — Willingness to Pay

Napa County	Less 10%	Bay-Delta Watershed Area (mi²)	Southern California Area (mi²)	Total Value Estimated
$1,572 per mi²	$1,414 per mi²	48,050		$67,942,700
			30,000	$42,420,000
Total Valuation:	$110,362,700			

Source: California Department of Water Resources, 2011

Major Implementation Issues

Managing land and water resources for selected products, services, and values has altered the conditions and functions of many watersheds in California. These management activities have produced some negative effects that need to be addressed to continue to effectively manage and utilize watershed services.

Altered Hydrologic Cycles

The hydrologic cycle includes precipitation, flow of water over the land and underground, and evaporation into the atmosphere. How land is managed can reduce rainwater infiltration and the timing and volume of runoff. Storms are increasingly characterized by high-intensity runoff over short periods, especially in urban areas but also in some rural areas, and that runoff creates a risk of flooding and reduces the ability of the water supply infrastructure to capture water for use during dry times. This compression of runoffs robs the streams and landscape of groundwater, leading to dry land, a shift in vegetation types, lower and warmer streams, and deterioration of stream channels, all of which lead to shifts in the plants and wildlife that can be supported. In some areas, diversion of water from streams in the watershed to other regions outside the watershed, or application of water imported from outside the watershed, has dramatically changed ecological functions or altered the flow of water through the watershed.

In particular, high-elevation runoff is expected to result in higher flows over shorter durations, thereby causing earlier and greater spring flooding followed by longer, drier summers. Those conditions could have an impact on plants and wildlife, especially in sensitive environments. One innovative strategy involves placing snow fencing in small openings (in clear-cut tree harvest areas or high-elevation meadows) of 1.25 acres or less, which could reduce spring runoff and pollution from roadways, support local flood control, accelerate ecosystem restoration, and improve habitat. For more information on the application and benefits of snow fences, refer to Volume 3, Chapter 32, “Other Resource Management Strategies.”

Altered Nutrient Cycles

As watersheds are developed, the amount of dissolved nutrients in streams within the watershed is increased, often from inappropriate use or excessive application rates of fertilizers or biosolids, which can trigger dramatic changes in water bodies, vegetation, and wildlife communities.

Nutrients generated by human activity are frequently exported from the location where they are generated or applied by humans to a downstream or downslope water body, where they can support algae or other plant growth that impairs the usability and ecological quality of water bodies. In addition to direct effects on surface waters and groundwater, increased nutrients can lead to the establishment of non-native invasive plant species at the expense of native vegetation. Many native plants evolved under relatively low-nutrient conditions, whereas increased nutrient availability typically creates conditions that favor non-native invasive plant species. The invasive species often outcompete the native vegetation and form single-species stands with little or no biological diversity; little habitat value for wildlife; and altered soil conditions, such as reduced infiltration capacity.

By government regulation, biosolids must only be applied in an agricultural operation at a rate that just satisfies the agronomic need of the crop to be grown, and with location restrictions that avoid waterways as a means of eliminating or severely restricting nutrient runoff. Under appropriate application protocols, nutrient concentration increases are minimized and invasive species are less likely to become established.

Life Cycles and Migration Patterns of Wildlife

Many projects built in the past, prior to modern environmental laws such as the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), have disrupted wildlife migration corridors or destroyed or degraded habitat that is critical for certain animal life stages. Some examples of the effects of watershed alteration on wildlife ecology are found in the changes in freshwater inflows to coastal wetlands caused by changed watershed conditions, which directly affect many estuarine and ocean species that breed and rear in these communities; blocked access to spawning and rearing habitats for anadromous fish by the dams that impound water on most significant California waterways; and reduction in extent of the riparian forests that support migration of Pacific Flyway bird species.

Fire and Water

Active suppression of wildland fires since the 1920s has created an increased risk of larger, more intense wildfires that do much more damage to watersheds than fires of historical intensities. Modern watersheds have limited capabilities of rapidly recovering from these fires, and accelerated soil erosion, diminished productivity and diversity of plant communities, displaced wildlife, significant alterations of natural biological cycles, and limited subsequent human use of the lands are typical aftereffects. Catastrophic fires also have large effects on hydrology and water quality within a watershed, causing increased surface runoff and reduced infiltration, creating more frequent and severe downstream flood events, exacerbating water quality problems, increasing operation and maintenance costs for reservoirs and canal systems, and producing large economic losses to local communities.

Climate Change

Watershed integrity is vulnerable to the changes in temperature, precipitation, and water flows that are likely under currently projected scenarios of climate change. As indicated in Box 27-1, each element of a watershed system must be considered in context with the others because changes in one element (e.g., the hydrologic cycle) spur changes in the others (e.g., the roles of flood and fire), creating a different system outcome. Watersheds within regions where precipitation decreases can become more susceptible to pests, fires, and pollutants. Projected increases in storm intensity could increase inland and coastal flooding, increasing the likelihood of downstream property damage and loss of life. Runoff from high-intensity storms would cause increased rates of soil erosion and soil loss, particularly in watersheds recovering from recent droughts or fires, because soils in those areas would lack vegetation cover that stabilizes soils.

Adaptation

As indicated in Table 27-1, a diverse watershed ecosystem can be resilient to changes in climate, so maintaining healthy watershed ecosystems will be critically important in the face of a changing climate by ensuring that ecosystem functions within a watershed will continue to provide the goods, services, and values of the systems Californians rely on today. How land is managed affects the way watersheds can adapt to the effects of climate change, and an effective watershed management strategy provides multiple benefits to human society, such as producing water, food, fiber, and fuel; mitigating floods and droughts; providing aquatic and terrestrial habitats and recreational opportunities; moderating local climates; and maintaining biodiversity and healthy soils. Managing interactions with natural watershed systems to maintain, restore, and enhance the many functions within a watershed allows Californians to have reliable quantities of clean water, as well as agricultural and forest products. An effective watershed management strategy also helps to reduce the cost of flood and fire damages, suppress disease, and increase biodiversity.

Mitigation

California's forested watershed ecosystems have relatively high carbon sequestration potential, and appropriate vegetation management can significantly increase rates of carbon sequestration as well as reduce rates of natural greenhouse gas (GHG) emissions. Improved watershed management for water reuse, pollution control, and other ecosystem services could provide multiple opportunities to reduce the energy use and emissions of GHGs. Tracking and reporting changes in California's major watersheds could help to assess and evaluate water quality and watershed conditions for controlling pollution and saving related energy.

Supporting adaptive management programs could provide opportunities to control energy use and GHG emissions by avoiding negative impacts on ecological conditions, water quality, and watershed functions, as well as by adjusting the operations or redesigning existing projects to create benefits for climate change mitigation. Providing technical information and watershed education and outreach in the decision-making process could have long-term benefits for climate change mitigation related to the maintenance and improvement of watershed functions, water conservation, water reuse, and water pollution prevention.

Other opportunities within this strategy to mitigate for energy use and GHG emissions include management actions to maintain and improve watershed function, such as designing and selecting projects to avoid negative impacts on ecological conditions, water quality, and watershed functions, and controlling stormwater, reducing surface runoff, and retaining intact floodplains and wetlands to maintain and improve watershed function and control water pollution.

Water-use efficiency practices in watersheds could have benefits for reducing energy use and GHG emissions. Those practices include decreasing the amount of irrigated landscaping in the watershed and increasing the use of native vegetation in landscaping and agricultural buffer lands, as well as installing and maintaining stream flow gauges to measure water use. Improving watershed ecosystem functions by restoring and preserving stream channel morphology and creating habitats around stream and river corridors could provide carbon sequestration potential for GHG reduction. However, energy use efficiency and clean energy standards should be used to offset related GHG emissions during restoration.

Links to other Resource Management Strategies

Watershed management is linked to the following resource management strategy chapters within this volume:

- Chapter 4, “Flood Management.”
- Chapter 15, “Drinking Water Treatment and Distribution.”
- Chapter 18, “Pollution Prevention.”
- Chapter 19, “Salt and Salinity Management.”
- Chapter 20, “Urban Stormwater Runoff Management.”
- Chapter 21, “Agricultural Land Stewardship.”
- Chapter 22, “Ecosystem Restoration.”
- Chapter 23, “Forest Management.”
- Chapter 24, “Land Use Planning and Management.”
- Chapter 25, “Recharge Area Protection
- Chapter 29, “Outreach and Engagement.”

Recommendations

Policy-Level Recommendations

1. Establish a scientifically valid means of tracking and reporting changes in the state’s major watersheds that provide reliable, current information to local communities, State and federal agencies, and others, regarding the net effects of management against the background of external change.

2. Support adaptive management programs that regularly assess the performance and condition of projects and programs to determine if they are satisfying ecological and community needs compatibly. Adjust the operations or redesign existing projects or programs as needed.

3. Clearly define expected products, goods, and services at the State level, to provide a large-scale basis from which to apply local variations and additions.

4. As appropriate and feasible, coordinate State funding and support within watersheds and between programs to generate more focused, measurable results.

5. Align agency goals and methods more effectively to reflect coordinated approaches to resource management using watersheds as the unit of implementation and effectiveness measurement.

6. Provide easy access to technical information such as geographic information system layers, monitoring data, planning models and templates, and assessment techniques from multiple sources, which are useful at multiple levels of decision-making.

7. Conduct management activities in a manner, and within a context, that is consistent with watershed dynamics and characteristics.

8. Provide local land-use decision-makers with watershed education and information access to promote maintenance and improvement of watershed functions in local decision-making.

9. Develop and implement a process to streamline and fast track projects which meet the goals of the following Strategic Practice Recommendations.

10. Establish basis and means of assigning monetary values to the benefits gained as a result of implementing projects that meet the goals of the following Strategic Practice Recommendations.

Strategic Practice Recommendations

11. Use a watershed approach to coordinate forest management, land use, agricultural land stewardship, integrated resources planning, and other appropriate resource strategies and actions.

12. Design and select projects with ecological processes in mind and with a goal of making the projects as representative of the local ecology as possible.

13. Increase precipitation infiltration into the soil to reduce surface runoff to a level that is typical of natural runoff retention patterns. This goal is often achieved by reducing impervious surfaces within a watershed. Retain intact floodplain and other wetlands, to the extent possible, to maintain or increase residence time of water in the watershed.

14. Place snow fencing strategically in small openings (e.g., in clear-cut tree harvest areas or high-elevation meadows) of 1.25 acres or less, to strengthen forest and watershed management and to facilitate slower snow melt and thus extend runoff into the summer, among other benefits. Particularly when positioned atop ridgelines adjacent to cliffs and ravines, snow fencing could enhance snow mass accumulation. (For more information on the application and benefits of snow fences, refer to Volume 3, Chapter 32, "Other Resource Management Strategies.")

15. Decrease the amount of irrigated landscaping in the watershed and increase the use of native vegetation in landscaping and agricultural buffer lands.

16. Design appropriate wildlife migration corridors and biological diversity support patches within watersheds when planning fire-safe vegetation alteration.

17. Promote the installation and maintenance of stream flow gauges in major drainages.

18. Maintain and create habitat around stream and river corridors that is compatible with stream and river functions. Provide as much upslope compatibility with these corridors as possible.

19. Where practical, design drainage and stormwater runoff controls and treatment to maximize infiltration into local aquifers, and minimize immediate downstream discharges during runoff.

20. Regional water quality control boards and stormwater agencies should set a high priority on protection and improvement of water quality in domestic water supply reservoirs, especially in watersheds where geology precludes infiltration of stormwater.

21. Provide regionally appropriate, regular, and dependable educational materials to encourage water conservation, water reuse, and water pollution prevention.

22. Restore and preserve stream channel morphology to provide floodwaters access to the floodplain and to encourage stable banks and channel form.

23. Restore the characteristics and functions of native grasslands, woodlands, forests, and other wildlands.

24. Remove or control invasive weeds as a part of overall resource management efforts.

25. Protect soil resources and restore the functions of drastically disturbed soils, to slow runoff and increase rainfall infiltration.

26. Proactively address the recovery of special-status species, at both watershed and population scales, and incorporate measures to avoid future listing of other at-risk species.

References

References Cited

Breedlove J. 1999. *Natural Resources: Assessing Nonmarket Values through Contingent Valuation*. Washington (DC): Congressional Research Service. [Report to Congress.] CRS Report No. RL30242. Viewed online at: http://www.cnie.org/nle/crsreports/natural/nrgen-24.cfm. Accessed: March 14, 2013.

California Department of Water Resources. 2009. *California Water Plan Update 2009*. Bulletin 160-09. Sacramento (CA): California Department of Water Resources. Viewed online at: http://www.waterplan.water.ca.gov/cwpu2009/index.cfm. Accessed: March 14, 2013.

Ulibarri CA, Wellman KF. 1997. *Natural Resource Valuation: A Primer on Concepts and Techniques*. Prepared for: the U.S. Department of Energy under Contract DE-AC06-76RLO 1830. 70 pp.

Additional References

Natural Resources Agency and State Water Resources Control Board. 2002. *Addressing the Need to Protect California's Watersheds: Working with Local Partnerships*. Sacramento (CA): Natural Resources Agency and State Water Resources Control Board. [Report to the Legislature required by Assembly Bill 2117, Chapter 735, Statutes of 2000.] 79 pp.

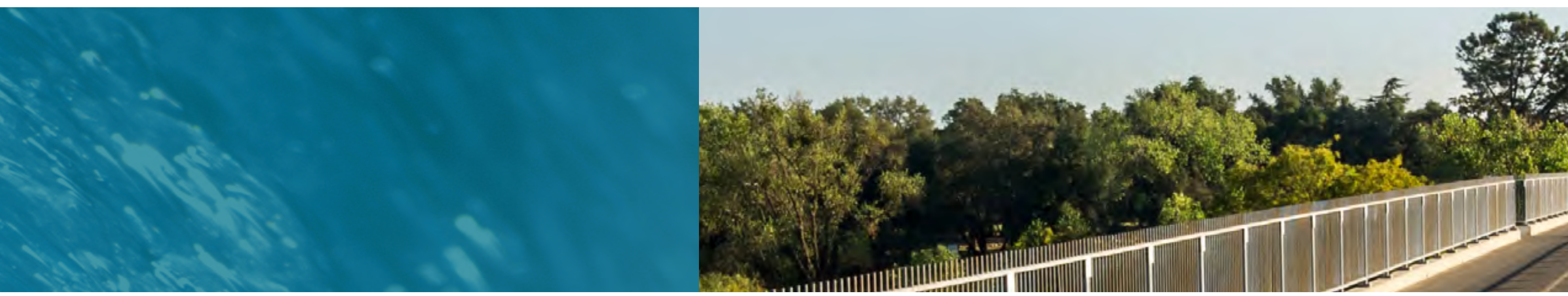
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy.

Postel S, Richter B. 2003. *Rivers for Life: Managing Water for People and Nature*. Washington (DC): Island Press. 220 pp.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 28

Economic Incentives — Loans, Grants, and Water Pricing



Sacramento County. State incentives were leveraged by local cost-sharing partners to develop the American River Bike Trail, which was completed with the construction of the Jedediah Smith Memorial Bridge (shown here) in the William B. Pond Recreation Area of the American River Parkway.

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Chapter 28. Economic Incentives — Loans, Grants, and Water Pricing

Loans, Grants, Water Pricing, Technology Adoption, and Water Market Policies

Economic incentives include financial assistance, water pricing, and water market policies intended to influence water management. Economic incentives can influence the amount and time of water use, wastewater volume, and source of water supply.

Examples of economic incentives include low interest loans, grants, and water rates and rate structures. Free services, rebates, and the use of tax revenues to partially fund water services also have a direct effect on the prices paid by water users. Government financial assistance can provide incentives for integrated resource plans by regional and local agencies. Also, government financial assistance can help water suppliers make incentives available to their water users for a specific purpose. Assistance programs can also help align the economic and financial drivers affecting local, regional, and statewide water management decisions to minimize unintended consequences and maximize the benefits of working cooperatively with consistent goals and objectives. As opposed to incentives, penalties are a type of economic disincentive that can be used to discourage undesirable water use behavior.

Incentives can be created or enhanced by facilitating water market transfers, by creating market opportunities where they did not exist, by expanding opportunities where they currently exist, or by reducing market transaction costs. In each case, new or enhanced market opportunities can influence water management decisions.

Economic Incentives in California

Water Rate Incentives

The most prevalent water rate policy is for water suppliers to price the water they supply to recover costs for such things as planning, operation, maintenance, capital, and administration. Water rates are also commonly used to contribute to water agency capital investment accounts for funding anticipated infrastructure projects. Water rates can be used to recover costs for compensating third parties such as agricultural services businesses that are adversely affected by water market transfers. Other means available to recover costs include ad valorem taxes and revenues from bonds not repaid from water rates.

Some agencies are not required to recover the full cost of development and maintenance. For example, Congress has not required the U.S. Bureau of Reclamation (USBR) to recover all of the costs of providing supplies to Central Valley Project agricultural contractors that meet specific acreage limitation criteria. This is an example of an incentive that was designed in 1902 to achieve a social goal of agricultural development in the West. Rates charged for urban wastewater treatment also traditionally have not been required to recover the full cost of projects because of substantial federal grant funding through the Clean Water Act.

Water rate incentives can take several forms. Water rate structures designed to recover costs can be fixed, uniform, or tiered rates (Box 28-1). Both uniform and tiered rates can have a fixed component. Where water use is unmetered, fixed assessments might be necessary. For example, water rates can be based on connection size (of the pipe entering the residence) for urban users or irrigated acreage for agricultural users.

Marginal cost pricing is one strategy to help promote more efficient water use. With marginal cost pricing, instead of being based on average unit costs, the volumetric rates to all customers would be based on the unit cost to the water purveyor of the last and probably most expensive, source of supply. In a much milder form, marginal-cost pricing for new customers (e.g., residents of new subdivisions) might reflect the average cost after factoring in the cost of the additional supply needed for those customers. This price would be higher than that for customers who are served by the existing delivery infrastructure.

Most urban water suppliers in California are moving away from fixed and uniform rates and toward rate structures based on the amount of water used. Many urban suppliers have already adopted tiered rate structures where the unit water charge increases as water use increases; the more units of water used, the higher the charge for each subsequent unit (increasing tiered rates). Some tiered water rate structures may have higher season rates. In 1999, a survey of the California urban water purveyors found that about 43 percent had increasing tiered rates, 45 percent had uniform rates, 10 percent had fixed or other type rates, and 2 percent had declining tiered rates. By 2003, about 41 percent had increasing tiered water rates, 49 percent had uniform rates, 9 percent had fixed or other type rates, and 1 percent had declining tiered rates. A 2007 survey of the suppliers reporting their rate structures reported that 58 percent had increasing tiered rates, 36 percent had uniform rates, 2 percent had declining tiered rates, and 4 percent had other types of rates. In 2011, the agencies responding to the survey indicated that 67 percent had increasing tiered rates, 23 percent had uniform rates, 1 percent had declining tiered rates, and 9 percent had other types of rates.

Most apartment building owners do not individually meter their tenants, removing the effect of volumetric pricing on the tenant’s water use. Although most residential wastewater treatment is currently charged a fixed rate, commercial and industrial users are more likely to be charged by wastewater volume and in some cases, by the types of constituents in their wastewater. Some agricultural agencies have adopted tiered rate structures.

A recent influence on water rates is the cap and trade program which was adopted by the Air Resources Board in 2011 as part of AB 32. Under cap and trade, the water sector will be treated same as any other non-exempt industry. The cost of purchased electricity from fossil fuel sources will increase due to the premium placed on electricity by the allowance requirement under cap and trade, and those costs will be passed on to users such as water districts. Electricity from hydropower generation or renewable energy sources will avoid that premium. However, renewable energy is more expensive than fossil fuel based electricity. Water districts purchasing electricity from wholesale, market-based fossil fuel sources will experience an increase in the cost of electricity either due to an increase in market prices as private generators include the cost of cap and trade allowances in their sales price, or, for imported electricity, the water district

Box 28-1 Water Rate Structures to Recover Costs

Fixed rate. The water user pays the same amount for water each month regardless of the amount of water use. This is common where water is unmeasured (also known as a flat rate). Example: $20 water bill each month.

Uniform (or constant) rate. The water user pays the same for each unit of water. This requires measurement of water. Example: $100 for each acre-foot of water.

Tiered water rate. As use exceeds predetermined amounts, the water user pays a higher or lower rate for each unit of water. This requires measurement of water. Example of a tiered rate with increasing unit costs (also known as an increasing block rate): $1 for the first 100 cubic feet, $1.50 for the second 100 cubic feet, $2 for the third 100 cubic feet, etc

itself will need to acquire allowances. The increase in electricity will create an added cost for water districts which rely on electricity for activities such as pumping water and running water treatment plants. Water districts using more energy, such as for conveying water greater distances, may expect to see larger cost increases. Potentially mitigating some of these effects is one of the recommended investment priorities for proceeds from the cap-and-trade auctions, which are energy efficiency and clean energy. Projects to increase water system and use efficiency as well as energy efficiency funded under this investment priority have the potential to reduce water utility costs.

Water users who use electricity provided by IOU's or municipal utilities should expect to see some rate relief in their electricity bills due to the free allowances allocated to those utilities in the cap and trade program. The rate relief program is currently under development by the California Public Utilities Commission (CPUC) and by individual municipal utilities, and it is uncertain how the rate relief will affect retail electricity customers, and whether the class of affected customers will include water districts.

Financial Assistance Incentives

The California Department of Water Resources (DWR), the State Water Resources Control Board (SWRCB), and the California Department of Public Health (CDPH) have run multimillion dollar bond-funded programs, which have provided grant and low interest rate loan money to many local agencies for integrated regional water management, water conservation, water recycling, distribution system rehabilitation, groundwater storage, water quality improvement, conjunctive use projects, and drinking water treatment. These programs are intended to encourage local agencies to adopt water management practices which have a statewide as well as a local benefit. More than $18.4 billion in grants and low interest loans have been authorized via State-issued bond programs since 1996.

DWR is currently managing the Integrated Regional Water Management Grant Program (IRWM grant program), using funding authorized from the passage of Propositions 84 and 1E. In August 2010, DWR issued program guidelines for the IRWM grant program. Those guidelines described the solicitation and evaluation processes for the award of funds to regional water management groups (RWMGs). The program guidelines include requirements that integrated regional water management plans address the causes and effects of climate change on water management. Specifically, to receive funding, the 2010 climate change standard required that a

RWMG (1) evaluate the adaptability of their water management infrastructure to the anticipated effects of climate change, and (2) consider the effect on greenhouse gas emissions (and thus on climate change) from the construction and operation of its new water infrastructure and programs. Updated program guidelines issued in November 2012 also require that plans include a prioritized list of climate change vulnerabilities and a plan, program or methodology for further data gathering and analysis of them.

At the wholesale agency level, the Metropolitan Water District of Southern California (MWD) has developed plans to expand its Local Resources Program, which provides an incentive of up to $250 per acre-foot to its member agencies for water recycling, groundwater recovery, and seawater desalination. MWD's water rate structure includes a "water stewardship charge" to collect revenue to help individual retail suppliers develop projects and programs that benefit the region. Incentives can include rebate programs for low-flush toilet installation, water audits for residential landscapes, and mobile lab services for increasing on-farm water use efficiency at no charge to customers, or other innovative programs.

Water Market Policies

California Water Code (CWC) Sections 1725 through 1732 were adopted to facilitate short-term water transfers. Prospective buyers benefited from the reduced cost of obtaining SWRCB approval, length of time for approval, and risk of denial of approval. These buyer benefits translated into increased opportunity costs to prospective sellers by encouraging those buyers to participate in the market and giving them the ability to offer higher payments. DWR and the SWRCB have taken actions to both facilitate and encourage water transfers. USBR ran water banking operations during the 1976-77 drought. In 1992, DWR operated the Drought Water Bank and currently operates the Dry Year Water Purchase Program on behalf of the State Water Project contractors. DWR has also developed procedures to wheel water market purchases through the California Aqueduct for both its contractors and other parties. In 2009, DWR operated a water bank to coordinate water transfers between willing sellers and willing buyers in response to drought conditions.

Potential Benefits

A major purpose of economic incentives is to promote water management practices that meet federal, State, regional, and local policy goals. Incentives may produce environmental or social benefits, or avoid or delay construction of new water supply projects by promoting water use efficiency. When water costs increase, for example, customers have a choice to either pay the higher water bill or find ways to use less water, such as using a broom or blower to clean sidewalks instead of a hose. Residential customers might install smart irrigation controllers or change to drought-tolerant landscaping. Industrial users may adopt process technologies that use less water or move to on-site recycling. Agricultural users may shift crop types, change their irrigation technology, or reduce the acreage they irrigate. Water efficiency gains may require higher expenditures for businesses and residential users and/or lower incomes to businesses, depending on the ability of users to adjust their water use.

Water use efficiency is a policy goal that can be facilitated by economic incentives. A water management system becomes more efficient when users act as if the cost of the last increment of water they use (i.e., the marginal cost of water) is equal to its opportunity cost (i.e., the amount of economic value that water would generate in its next best alternative use). If more water is available, users should act as if the cost were equal to the opportunity cost of the resources needed to make it available (e.g., the land, labor, and materials needed to construct a recycling plant, a reservoir, or to institute a conservation measure). The quantification, to the extent practicable, of environmental and social values which could be realized for the alternative uses of the water should also be considered when determining opportunity costs.

If water suppliers make management decisions as if their customers faced these costs, including the decision to invest in new supplies, then water use efficiency more likely will be improved, even if the prices actually seen by their customers do not fully reflect those costs. This strategy applies to decisions by State and federal agencies to provide financial incentives to local water suppliers and to decisions to develop statewide water supplies.

Economic incentives, such as water pricing, can also promote social (e.g., preservation of agricultural production in disadvantaged areas dependent on agriculture for food security and economic health) and environmental well-being (e.g., preservation of wetland habitat and streamflows for fish). These benefits should also be evaluated whenever possible to facilitate informed decision-making by policy makers, including the public.

It should also be made clear that improving water use efficiency may not necessarily result in reduced use because of the increased productivity of water (i.e., the added efficiency increases its marginal value). For example, if water cost or availability was a constraint and depending on the demand for the product, production could increase and water use could approach, if not equal or even exceed, the previous amount of use. In any case, efficiency improvements can allow the same or greater value to be created with reduced water use.

Economic incentives that produce more efficient water management practices, such as lining canals, can result in unintended costs to the environment by reducing supplies to wetlands dependent on subsurface flows. Conversely, water rate policies that lower the cost of surface water during wet cycles, apparently promoting inefficiency, can encourage recharge of groundwater basins, thus promoting conjunctive use and greater overall efficiency. Water quality improvements resulting from economic incentives can, in addition to benefiting the environment, help farmers meet drainage water goals as well as lower treatment costs or provide health benefits to urban users.

It is difficult to quantify secondary (or indirect) benefits provided by economic incentives since the incentives influence decisions on other management strategies that produce their own benefits. Economic incentives can be used to influence development of water supply augmentation or demand reduction programs that promote regional self-reliance. For example, grant funds from a State agency can help promote recycling by reducing its cost to local suppliers. Similarly, a wholesale water agency might make financial assistance available to retail water purveyors to encourage implementation of projects or programs that would benefit the region. Financial assistance can also be used to achieve beneficial changes in water system storage, conveyance, and treatment operations. The willingness of a water agency to participate in water marketing can also be influenced by economic incentives.

Water market policies that promote willing buyer/willing seller water transfers by increasing opportunity costs to potential sellers tend to move water from areas and activities where it produces less economic value to areas and activities where it produces higher economic value.

This can occur on a short-term (e.g., drought emergency) or long-term basis. With appropriate compensation and mitigation for adverse impacts, the overall economic well-being of the state can be increased without additional water development and without imposing undue hardship.

Potential Costs

One financial cost of an incentive program to a water purveyor or government agency is the cost of its creation and administration, including the costs of arranging bond funding or low interest rate financing. Grant programs include the cost to the taxpayers of obtaining and repaying grant funds. Other costs would be associated with the adoption of water management strategies or water use behaviors — including forgoing some water use — that may result. The costs of the economic incentives will depend on how the incentives are integrated with other management strategies. As with other management strategies, economic incentives must be specific to the circumstances and water management goals of each individual water supplier.

If incentive programs result in the adoption of programs or the construction of projects that would not otherwise be adopted or created, then the associated economic, social, and environmental costs of those projects and programs would have to be compared to the costs of programs and projects that would have been adopted or created in the absence of the incentives to determine if, on balance, the incentive programs resulted in greater costs than were avoided through their use.

Another type of cost can arise from the possibility that an incentive will result in actions not aligned with policy goals or that incentives will operate at cross purposes (i.e., have unintended consequences). To the extent that resources are misallocated, a loss in economic, social, and/or environmental well-being will be incurred compared with fewer losses, if any, from a better allocation of resources.

Major Implementation Issues

Selecting Appropriate Water Rates

A major consideration is determining what rates to charge customers while ensuring that costs of providing the water (including conveyance, treatment, and distribution) and treating and disposing of the wastewater are recovered. Also, managing water rate changes during water shortages can be challenging since incremental costs of supply can both increase dramatically and change rapidly, making it more difficult to recover costs.

If regulations against collecting revenues in excess of costs remain in effect, some suppliers would have to reduce their lower tier prices in order to charge higher costs at the higher tiers. While achieving overall reductions in total water usage, lowering the first tier rate would tend to increase use by the lower tier customers, a potentially undesirable result from a water use management standpoint, which seeks to encompass all customers and customer segments.

Those water utilities regulated by the CPUC which have implemented tiered rates and revenue decoupling mechanisms are not permitted to collect revenues in excess of authorized costs. Any excess revenues are refunded to customers and any revenue shortfalls are recovered through a surcharge.

AB 2882 (2008) facilitates allocation-based conservation water pricing by amending the CWC to add new requirements for implementing tiered water rates. The added requirements, if followed, allow suppliers to adopt rates which discourage the waste and unreasonable use of water while ensuring that water service fees are proportionate to the cost of providing water service in accordance with the requirements of Proposition 218 (1996).

If surface water rates are set too high, and the option is available, agricultural users or urban water users may choose to pump groundwater instead. This could have undesirable consequences for groundwater management.

Funding for Loans and Grants

The availability of State funding can be intermittent. Funding methods that require direct legislative appropriation or approval of new water bonds could require years of lead time before funds are available.

State Funding for Investor-Owned Water Utilities Regulated by the California Public Utilities Commission

With relatively few exceptions, State bond-funded grants and loans have historically been limited to public agencies and nonprofit organizations. While public water agencies serve the majority of Californians, approximately six million of the state's residents are served by investor-owned water companies under the jurisdiction of the CPUC. Some of these investor-owned water companies and districts serve disadvantaged communities where customers may be faced with unaffordable rate increases to make necessary improvements to meet water quality and safety standards. In addition, all Californians pay for these bonds through taxes, including the customers of CPUC-regulated water utilities. The CDPH has determined that, for its programs, the benefits of State funded grants and loans should accrue to all customers, regardless of whether they receive water from a publicly-owned or investor-owned water company, unless specifically stated otherwise in the authorizing legislation. This determination could also be made by other State agencies for their grants and loans programs.

To ensure that savings accruing from State funding are passed on to customers, the CPUC instituted rules to protect the public interest integrity of the bond funds in early 2006. In recent years, bonds have addressed the eligibility of investor-owned water companies for the bond or grant programs (e.g., the Proposition 84 implementation legislation and the water bond legislation proposed in both 2008 and 2009). The investor-owned water utilities continue to work with the Legislature to ensure that future bond measures explicitly include eligibility for all water suppliers, thus ensuring that all Californians can benefit from available State funding.

Criteria for Loans and Grants Funding Approval

Historically, requests for loans and grants have exceeded available funding. Deciding which strategies and which suppliers receive loans and grants requires setting of priorities for funding. Financial and economic criteria for determining funding eligibility may leave out communities that cannot support needed infrastructure without financial assistance. Setting aside funds for those types of communities as well as lowered eligibility requirements may be required.

Incidence of Costs of Incentives

Economic incentives can affect social equity when those incurring the costs of providing incentives, through higher taxes or fees, do not receive a fair share of the benefits that the incentives are expected to generate. As an example, increasing the costs for agricultural water supplies increases the efficiency of on-farm water use, but can also induce changes in crop patterns that result in lower farm employment. Communities dependent on farm production may be disproportionately affected. In the urban sector, if water rate changes reduce the use of ornamental landscaping, jobs that depend on establishing and maintaining that landscaping could be lost.

Incentives for water transfers can result in more water moving out of agricultural production and into other uses on a temporary or permanent basis. Communities supplying inputs to farm production through farm labor; farm equipment sales and repair; crop harvesting, hauling, and storage services, banking, legal, and farm management services may be adversely affected. This is a bigger issue in communities more heavily dependent on supplying these inputs.

Environmental Justice

Pricing policies that are designed to promote efficiency may affect the ability of disadvantaged populations to purchase sufficient water to maintain a minimal lifestyle. Some type of lifeline rate may be desirable in these cases. Also, obligations placed on the General Fund through bond measures adopted to provide financial incentives creates repayment burdens that jeopardize funding capacity available for social programs that benefit the disadvantaged.

Regulations

Some water agencies have regulations that prevent the use of water metering necessary for measuring and pricing volumes of water. Typically, loans and grants are constrained by bond language to strategies that lead to capital expenditures. Most loans and grants may not be used for developing non-capital strategies such as water rate changes, yet such rate design changes can be as cost-effective or more at achieving demand reduction than non-price conservation programs.

Development of Water Markets

See Chapter 8, “Water Transfers,” for a discussion of the development of water markets.

Self-Served Water Users

Self-served water users are not subject to water supplier rate policies and are, therefore, unaffected by rates that are intended to increase efficiency.

Economic Modeling Tools

Responding appropriately to economic incentives requires decisions based on information from system modeling tools that correctly account for all the costs and benefits of water management strategies. Systems analysis tools are needed because of the interactions between water management alternatives and carryover storage and reuse, for example, and the implications of these interactions for system reliability. These types of tools can be very expensive to develop and maintain, particularly for water systems of any complexity. The cost of obtaining data, continually updating the data, and availability of that data are concerns. In addition, the technical knowledge to do this work, including implementing the models, may not be available in-house.

Recommendations to Help Promote Economic Incentives

The State and water agencies should consider and evaluate economic incentives as an integral part of their package of management strategies. The following recommendations recognize that economic incentives will vary widely throughout California due to differences in local conditions:

1. Institute water rates that support better water management based on the unique conditions in each water district.
   - A. Use volumetric pricing wherever practicable and economically efficient.
   - B. Use tiered pricing to the extent that it improves water management, including consideration of higher prices for water in excess of agricultural and urban vegetation management requirements.
   - C. Recover more costs from variable charges and fewer costs from taxes and fixed water charges as is financially prudent.
   - D. Agencies adopting new water rates should clearly identify what they mean to water users and provide education, training, and technical assistance to water users to maximize the desired outcome of those policies.
2. Institute loans and grants that support better regional and statewide water management based on the conditions in each region.
   - A. The State should develop guidelines and ranking criteria for grant and loan awards to water agencies that consider cost-effective water management, environmental costs and benefits, and environmental justice and equity objectives.
   - B. The grant and loan process should account for the fact that some water agencies have limited funds and staff to prepare applications.
   - C. Agencies receiving grants and loans should make information on the success of the programs/projects that they implement available so that the experience can be used to design better incentive plans.
   - D. Investor-owned water utilities should continue to work with the Legislature to ensure that future bond measures explicitly include eligibility for all water suppliers, as appropriate.
3. The State should provide technical assistance to local agencies in developing equitable and effective economic incentives to achieve local and statewide water management goals and objectives.
4. The State should explore innovative and equitable ways to provide financial incentives to private for-profit water purveyors that avoid or minimize the perception of shareholders

unfairly benefiting from public funds and without risking the tax-exempt status of bond funding for these incentives.

5. The State should assist local agencies in using planning methods and adopting policies that promote long-run water use efficiency on a regional and statewide basis while accounting for policies on environmental and social well-being.

6. The State should provide technical expertise and funding to help local agencies develop and use water management system modeling tools that allow comprehensive economic analyses to be conducted and the model results to correctly reflect economic incentives.

Refer to Chapter 8, "Water Transfers," for recommendations on promoting water transfers.

References

References Cited

None.

Additional References

Best Best & Krieger LLP. 2008. Governor Signs Legislation Impacting Water Conservation Rates and Water, Sewer and Refuse Collection Rate Setting. October 6. [E-Bulletin]. Viewed online at: http://www.bbklaw.com/news-firm-245.html.

Black & Veatch. 1999. "California Water Charge Survey, 1999".

———. 2003. "California Water Charge Survey, 2003".

California Air Resources Board. 2013. *Cap-and-Trade Auction Proceeds Investment Plan: Fiscal Years 2013-14 through 2015-16*.

California Department of Water Resources. 2008. *Urban Drought Guidebook 2008 Updated Edition.*

Chesnutt TW et al. 1997. "Designing, Evaluating, and Implementing Conservation Rate Structures." California Urban Water Conservation Council.

Donnelly K and Christian-Smith J. 2013. *An Overview of the "New Normal" and Water Rate Basics*. (Oakland CA): Pacific Institute. Viewed online at: http://pacinst.org/wp-content/uploads/2013/06/pacinst-new-normal-and-water-rate-basics.pdf.

Mann R. 2008. *Economic Efficiency of Water Use and Allocation in California, A Scoping-Level Analysis.* Report prepared for Delta Vision Process. 46 pp. Viewed online at: http://www.deltavision.ca.gov/BlueRibbonTaskForce/June2008/Economic_Efficiency.pdf.

Raftelis Financial Consultants, Inc. American Water Works Association. 2008, "2007 Water Rate Survey." California-Nevada Section.

———. 2012, "2011 California-Nevada Water Rate Survey." California-Nevada Section. American Water Works Association. 22 pp. Viewed online at: http://www.cvwd.org/service/rates/RateSurvey.pdf.

Schofield J. 2007. "A Clash of Equities: Proposition 218 Squares Off Against Tiered Water Pricing." California Water Law and Policy Reporter. December. Viewed online at http://www.argentco.com/htm/f20071206.345402.htm.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 29

Outreach and Engagement

Sacramento County. Children and their families learn about the different properties of water from Jaime Cofer of DWR's Public Affairs Office, at the agency's activity booth during the 2013 Creek Week Celebration event sponsored by the Sacramento Area Creeks Council.

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Chapter 29. Outreach and Engagement

Outreach and engagement for water management in California is use of tools and practices by water agencies to facilitate contributions by public individuals and groups toward good water management outcomes. These contributions include:

- Providing insight to decision-makers on the best approaches for water management.
- Adopting water-wise practices.
- Supporting activities that result in beneficial water management outcomes, including the resource management strategies in this volume.
- Promoting collaboration and interdisciplinary approaches to solving problems, as well as resolving conflicts and addressing multiple interests and needs.
- Ensuring access to water management information and decision-making.

For more than a century, California has benefitted from the exceptional technical knowledge used to select and build California's significant water infrastructure. Water managers have relied on engineering expertise to achieve positive water outcomes and resolve problems. This approach worked well for meeting single-purpose engineering goals, which have supported a growing economy. Even so, some unintended consequences have been revealed. Over time, some water management projects have altered and degraded ecosystems and/or created social injustices as unintended byproducts. Because the water management profession remains primarily a technical discipline, and many agency staff are educated in engineering, economics, or law, these staff see their primary task as managing the physical system. Only later do they engage the public as a way of solving problems or developing policies and programs.

As the demands on water management systems have increased and understanding of the complexity of the water systems has grown, the need for engineers and technical experts to engage others in achieving optimum results has become more apparent. Water managers' new respect for the complexity of the ecosystems from which water projects draw has made them realize the need to access a broader range of expertise. Potential sources of expertise range from the close local knowledge of long-time residents of the area being altered by a water project (such as oral histories from local farms or recollections of historic streams, springs, and wells) to university scientists in disciplines (such as ecology) that have not always participated in water development and management. In addition, water managers are now developing new sophistication about the ways they can serve their communities. This goes beyond the traditional engineering approaches by bringing in expertise from other disciplines, such as economics, public health, and land use planning.

In the past few decades, citizens were given new legal tools that allow them to block water management projects that conflict with their environmental interests. Both the California Environmental Quality Act (CEQA) and the Clean Water Act have citizen suit provisions. Through the referendum process, voters passed Proposition 218 in 1996, which gives ratepayers a way to protest rate increases. Since the 2000s, increasing Internet use and the advent of social media have made organizing people and transferring information easier than ever. With these broad societal changes, water managers have found that an approach developed without consulting the public can suddenly become a focus of negative attention, as interest groups draw attention to aspects of a project, program, or policy they oppose. The most productive means of avoiding project-derailing protests or lawsuits is to use community outreach and engagement to develop projects that address multiple interests from the project's outset and get community buy-in for the goals of the project. Collaborative development of new programs or policies may clarify or make explicit short- and long-term community interests, and ways to meet both or make trade-offs.

California Water Plan Update 2009 (Update 2009) emphasized the need for outreach and engagement (see Box 29-1). This direction has been confirmed by the Legislature and the Executive Branch through requirements for open and transparent decision-making and access to public records; specific instructions to convene advisory committees and conduct public outreach; and legal requirements for notification and hearings on key topics, such as prescribed in CEQA. At the federal level, the National Pollutant Discharge Elimination System has regulatory requirements for education and outreach regarding non-point-source pollution. The U.S. Environmental Protection Agency (EPA) states:

> It takes individual behavior change and proper practices to control such pollution. Therefore, it is important to make the public sufficiently aware and concerned about the significance of their behavior for stormwater pollution, through information and education, that they change improper behaviors.
>
> Phase II MS 4s are required to educate their community on the pollution potential of common activities, and increase awareness of the direct links between land activities, rainfall-runoff, storm drains, and their local water resources. Most importantly the requirement is to give the public clear guidance on steps and specific actions that they can take to reduce their stormwater pollution-potential.

In addition to reaching the broader public, outreach and engagement can also target specific fields or professionals. The California Dairy Quality Assurance Program and the University of California (UC) Cooperative Extension conduct outreach and education on the Central Valley's General Order for Existing Milk Cow Dairies. The Central Valley Water Quality Control Board attributes the successful implementation of the order partly to the education program (California Dairy Research Foundation 2013). Another program that is successful is the Ranch Water Quality Planning Short Course, which promotes the California Rangeland Water Quality Management Plan (State Water Resources Control Board 1995). In the San Francisco Bay Area, this program was used to implement a pathogen total maximum daily load (TMDL) on Tomales Bay, where the impairment was at least partially a consequence of grazing activities. An updated assessment of the program is on San Francisco Bay Regional Water Quality Control Board's Web site: http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/tomalesbaypathogenstmdl.shtml.

At the state level, CEQA has been strengthened to try to assure that public participation is not just a formality, but that it is carried out in a meaningful way. When adopting CEQA, the Legislature found that "Every citizen has a responsibility to contribute to the preservation and enhancement of the environment" (Public Resources Code, Section 2100[e]).

The overall goal of water education is to develop increasingly knowledgeable citizens who can participate in public discussion effectively and debate water issues. Good contextual

Box 29-1 Recommendation 9 from Update 2009, Volume 1, Chapter 2

9. California should increase public understanding and awareness of where water comes from, as well as the value and importance of water, water quality, and water conservation to people, ecosystems, and California's economy.

Water is a limited resource and State government needs to do more to assist water agencies, local governments, and other partners, such as tribes and non-governmental organizations, by developing and disseminating information about the importance of water issues, including water supply, water quality, and ecosystem health. Despite experiencing significant droughts and floods, Californians are not sufficiently aware of the critical water issues confronting them. It is the responsibility of State government to help the public understand the importance of efficient water use, how to protect water quality, how their actions can benefit or harm the watersheds from which they receive their water, and the watersheds in which they live, play, and work.

The California Department of Water Resources and other State agencies should make public outreach and education a priority and achieve efficient dissemination of information by forming partnerships with those experienced in water and resource education and media. Outreach should include high-quality, balanced water information, including programs that are part of elementary school education. With such education, Californians will have a better understanding of where their water comes from; the value and importance of water; and the challenges and opportunities to ensure the coequal goals of water supply, quality, and ecosystem health. The public will also have a better understanding of the benefits, costs, and impacts of the resource management strategies described in Volume 3, especially water conservation and water use efficiency, both of which must become a public ethic.

understanding improves people's ability to examine and evaluate the information presented and perceive when information is not presented. With a basic understanding of water, residents respond to specific and technical issues, such as the need to develop water supplies or wastewater treatment facilities, the costs and benefits of conservation, the dangers associated with leaking contaminants, the risks posed by poor water quality, and the costs and benefits of river restoration or flood control. With education and information, people will form their opinions based on data and information and make informed choices about supporting a water management program.

The degree of engagement and the methods used are tied to the goals of the effort and the individuals involved. Outreach and engagement efforts range from informing and educating to empowering, and the tools used mirror the goals of engagement. The International Association of Public Participation (IAP2) provides a broadly accepted framework on the levels of engagement, as shown in Table 29-1.

The EPA and others have also developed agency-specific frameworks, and these are widely used by public participation professionals. Similar frameworks and tools exist for water educators and public relations professionals.

A successful outreach and engagement strategy must be:

- Relevant — contributes to the missions, goals, and objectives of partner organizations.
- Focused — establishes goals that are measurable, achievable, and targeted toward improving social, economic, environmental, or civic conditions.
- Scale-appropriate — creates designs at local, state, multi-state, or national scales that effectively address the program's focus.

Table 29-1 Levels of Outreach and Engagement

Level	Goal	Public Expectation	Tools
Inform, Educate	Provide information about problems, solutions, alternatives, opportunities, and solutions related to water in California.	Water managers will provide balanced and objective information to the public.	• Web sites. • Fact sheets. • Open houses/town hall meetings. • E-News • Newsletters/Alerts. • Public libraries, designated (gov't) section, provide webinar facilities in libraries
Consult	Obtain public feedback on analysis, alternatives, and/or decisions regarding water in California.	Water managers will provide information, listen, and acknowledge public concerns and aspirations, and provide feedback on how public input influenced the decision.	• Public comment. • Focus groups. • Surveys • Public meetings. • Social media participation
Involve	Work with the public to ensure public concerns and aspirations are understood and considered by water managers.	Water managers will work to ensure that public input informs alternatives and provide feedback on how public input influenced the decision.	• Workshops/town hall meetings. • Deliberative polling. • Social media/webinars.
Collaborate	Partner with the public to develop alternatives and identify preferred solutions for water in California.	Water managers will ask for advice and ideas from the public, and will try to include public input when making decisions.	• Advisory committees • Caucuses. • Include plan alternatives in EIR processes.
Empower	Provide the public the opportunity to make decisions related to water in California.	Water managers will implement or support public decisions.	• Convene forums as requested, when possible. • Support local and regional action

Notes:

EIR = environmental impact report

The information in this table was taken from the Web page "IAP2 Spectrum of Public Participation" (International Association of Public Participation 2007).

- Innovative — integrates research findings and collegial knowledge and experience.
- Collaborative — cultivates and nurtures authentic and appropriately diverse partnerships.
- Factually and Scientifically Sound — bases strategy on integrated or incorporated knowledge and methods derived from research, and brings together the relevant components of the knowledge system (i.e., research, education, and application) around the problem or issue at stake.
- Adaptive — develops and implements continuous feedback and improvement strategies that include strong program planning and evaluation components, and exchanges information about processes, outputs, and outcomes with colleagues at local, state, multi-state, and national levels.
- Visible — interprets processes, outputs, and outcomes in a format that is understandable and accessible to partners and decision-makers.
- Effective — achieves outcomes that meet intended and unanticipated program objectives.
- Sustainable — develops and implements mechanisms to sustain the production of impacts over time, as appropriate to the duration and priority of a public need.
- Measurable — creates a difference that can be tracked and measured.

Public relations professionals help refine important messages about water so the messages are useful to a broad audience. These professionals also assist in preparing informational materials and placing promotional messages on key topics by using all forms of traditional and social media. Another role is to assist with critical outreach on such topics as flood risk notifications to people who live in areas next to substandard levees. These professionals also routinely provide information on topics related to the need for investment in water systems.

Non-profit organizations can connect water managers to specific communities within the broader public. California has many diverse cultural communities; some are also economically disadvantaged. Directly addressing and connecting with people within these cultures may require different skills than when addressing the general public. Such communities may have their own media or special emphases that are not widely known outside those communities. Some professionals at non-profit organizations or within water agencies have focused on developing connections within a cultural community and learned how to craft messages and build processes that will bring members of a culturally distinct group into water management decisions.

Outreach and engagement professionals use opinion polling and academic research to learn more about what is important to key audiences and to identify the best practices for serving those audiences and stakeholders. Opinion polling can measure whether outreach campaigns were able to change beliefs or behaviors by polling the public before and after the campaign, or to determine what factors influence water consumption behavior (such as drought features in the media/news). Water educators also provide continuing education for water professionals in formal educational settings and through seminars, conferences, and events. Academic researchers study water conflicts to identify the sources of conflicts and underlying attitudes, and evaluate whether processes undertaken to reduce conflict are effective.

There has been significant success using outreach and engagement to ask individuals to change simple habits, such as turning off the water when brushing teeth, installing more efficient shower heads, or altering lawn-watering practices. Outreach and engagement has also been essential in creating a better understanding of flood risk in California, the importance of not dumping contaminants down storm drains, and the need to maintain and invest in water systems. For all its success, outreach and engagement could be used more broadly, delivered more efficiently, target and reach key audiences better, and better support Californians' understanding of critical water issues. For example, the general public still has a limited understanding about the watersheds they live in, where the water they use comes from and where it goes when they have finished with it, and the degree of their exposure to flood risk. Likewise, while managers may know how water in their service area is delivered in the aggregate, they may have a poor sense of how their constituents perceive water, what constituents' topmost water-use priorities are, how much individual willingness exists to pay for water, what the level of individual preparation is for water emergencies, and many other facets of personal water use.

Outreach and engagement has contributed to broader use of cross-disciplinary groups to resolve water issues and has been the foundation of some significant water policy decisions, as multiple interests have worked collaboratively to solve problems. Integrated regional water management (IRWM) is now the policy direction of the State. To qualify for grants, regional water managers must coalesce with managers in related fields (such as supply-oriented districts with wastewater treatment districts) and local citizen groups. As they form new ways of working together to write plans, implement grant projects, and raise matching funds, they have had to employ more collaboration techniques than before. Grant funding has been available for the planning stage, which also develops collaboration skills and builds new capacity in water management personnel. A new emphasis on regional management also creates new demands for engagement tailored to local needs and practices.

Potential Benefits

Public outreach and engagement produces two broad types of benefits: instrumental, outcome-oriented benefits (such as designing a program that satisfies multiple criteria) and intrinsic, process-oriented benefits (such as building trust between participants). There are two ways that public involvement leads to instrumental outcomes. First, public involvement results in a citizenry that is more understanding and appreciative of the issue, and thus one that makes informed decisions. Second, public involvement results in an agency that makes better decisions as a direct result of including public knowledge. In addition to instrumental outcomes, public involvement provides many intrinsic benefits, such as enhanced community capital.

Public Involvement

A single regulatory agency or municipal office working alone cannot be as effective in achieving optimized water management unless it has the participation, partnership, and combined efforts of other groups in the community, all working toward the same goal. The point of public involvement is to build on community capital — the connections and wealth of knowledge of interested citizens and groups — to help spread the message on water goals and actions to manage, restore, and protect water resources.

Public involvement also includes facilitating opportunities for direct-action, educational, and volunteer programs, such as riparian planting days, volunteer monitoring programs, storm-drain marking, or stream-cleanup programs. Groups, such as watershed groups and conservation corps teams that want to participate in promoting environmental causes, should be encouraged and offered opportunities to participate in water stewardship. Public involvement can promote other goals, such as developing and implementing a water-oriented public health campaign like mosquito-breeding prevention (see Box 29-2).

Outreach and engagement starts to build a platform for a more sustainable future by helping people take individual and collective action that supports more sustainable water outcomes. Children can participate as well, via class curricula built around stream monitoring and cleanup. In a diverse population such as California's, it is important to reach out to the various populations and invite them to participate via their own language(s). Although that may seem as a given, agencies tend to be monolingual. Because many California populations speak predominately in their native languages, such groups should be addressed in a language that is understandable to them. Bringing these groups into public processes can also be constrained by when and where public meetings are held. Particularly in large cities, many agency meetings are conducted only in English and during the work day. Non-English speakers from rural communities, or people whose jobs do not provide flexible hours, may find it impossible to participate.

Collaborative Policy-Making

Much research exists on the benefits of outreach and engagement and the methods it incorporates. While the time involved in engaging others may seem to slow down projects and programs at the beginning, evaluations have revealed that well-delivered processes reduce the ultimate time to implement desired goals, reduce litigation, and significantly reduce unintended consequences of water policy decisions. In 2011, researchers conducted a study to determine whether citizen participation enhances performance of public programs and attainment of organizational goals, which was defined as increased efficiency and effectiveness. Researchers concluded that, "On average, greater citizen engagement is strongly and significantly related to better performance of public agencies" (Neshkova and Guo 2011). Such research is significant because it supports continued refinement and use of outreach practices. Evolving research on developing culturally appropriate outreach will also contribute to more comprehensive and reliable collaboration with communities in need of water information.

Collaborative policy-making or project selection can have additional benefits. Having stakeholders involved through researching options and selecting a project can create buy-in from the people who will pay for the project. Their participation may help an agency pick an appropriate level of technology and resources for end users, and create a body of people looking forward to seeing a policy put in place or a project completed. Outreach in the form of collaborative policy-making results in improved decision-making, as agencies learn more about what is of concern to stakeholders and the full requirements of any particular watershed or system is revealed.

In the absence of a concerted outreach effort or collaborative policy-making, research and experience suggest that community members' opinions of water issues may be influenced by inaccurate perceptions of project risks or benefits; whether the project is viewed as consistent with the community's long-term goals; social factors, such as the degree of trust placed in the project team and government agencies; and the perceived equity in the process for developing a project. Media coverage, word-of-mouth communication, and such information sources as blogs and other electronic media often influence how individuals form opinions. Perceptions that may seem exaggerated from a technical point of view must be taken seriously. Perceived risks are no less real for purposes of implementing a public outreach program. If these perceptions and concerns are not addressed by water managers, they can rapidly transform into public opposition.

Box 29-2 Mosquito Control

Mosquito control is a good example of a problem that takes strong public involvement to address. Controlling mosquitoes is critical to maintaining both a high quality of life and protecting people from mosquito-transmitted (vectored) diseases, such as West Nile virus. Since many water-related uses and activities can contribute to mosquito breeding areas, a number of best management practices (BMPs) have been developed by the California Department of Public Health and the Mosquito and Vector Control Association of California to promote mosquito control. Getting these BMPS out to the public and getting the public to follow them requires a public health campaign and widespread public involvement. These BMPs include water use activities in both urban and rural areas. The full list of BMPs is available at the following Web site: http://www.cdph.ca.gov/HealthInfo/discond/Documents/BMPforMosquitoControl07-12.pdf (California Department of Public Health, Mosquito and Vector Control Association of California 2012).

Youth Education

Research indicates that public education on water use has a significant return on investment as children may leverage activities at home and influence the behavior of adults with whom they interact. This shift in thinking will be increasingly important as California's growing population and increasing water demands come up against a finite water supply. A population that has been educated since childhood about the sources and uses of water in California and where their own water comes from will be more willing to change their behavior during droughts or stay prepared for floods. Some recommended youth education goals involve:

- More participation in conservation programs.
- More equitable and just usage and distribution of water, including environmental uses.
- More understanding of, and greater contribution to, climate change adaptation and resilience.
- More aesthetic appreciation of water.

In 2003, then-Assemblywoman Fran Pavley authored legislation that required development of an environment-based curriculum to be offered to all California public schools. Assembly Bill 1548 (Statutes of 2003) was sponsored by Heal the Bay, a nonprofit organization, and was signed into law by Governor Gray Davis. The program came to be known as the Education and the Environment Initiative (EEI) (California Environmental Protection Agency 2003).

The curriculum took several years to develop and was approved by the State Board of Education in 2010 (West 2010). It addresses 85 different aspects of the environment. Fifth grade is predominately focused on water resources. One 8th-grade unit is titled "Liquid Gold: California's Water" (California Environmental Protection Agency 2010). This unit teaches students how water is distributed and managed as a natural resource. It examines the importance of water to society, and specifically looks at the challenges California faces in balancing available water supply with societal demands. The section considers the imbalance between water supply and demand in California and examines the spectrum of considerations involved in decisions regarding California's water supplies. The final lesson considers the scope and potential environmental effects of water resource policies and the role of scientific knowledge in the development of the State's water policies.

Climate Change

Climate change can be a polarizing topic that results in mixed messages and confusion. Even the term "climate change" can deter some people from discussing the problems that climate change can cause and from investigating potential solutions to mitigate and prepare for these environmental changes. In addition, many people still tend to view climate change impacts and solutions as global rather than local. Regardless of what people believe is causing the current climatic changes or whether they perceive the changes as a local or global issue, California's water resources are being affected by climate change. Sea levels are rising, snowpack is decreasing, and water temperatures are increasing. These changes affect the State's ability to ensure reliable water supplies and water quality, manage floods, and protect ecosystem functions and critical habitats. California's watersheds are vulnerable to climate change. Communicating about climate change is necessary for making informed local land-use choices, conducting successful water-resource planning, and developing effective hazard-mitigation approaches.

Adaptation and Mitigation

Outreach and engagement are critical components in adapting to climate change. This outreach-and-engagement resource management strategy can improve communication with the public, governmental agencies, industry and businesses, and nonprofit organizations about the susceptibility of California's water resources to climate change. Public engagement helps educate and build commitment and consensus among decision-makers and community members. Developing a consistent message about the state's vulnerabilities to climate change is crucial. Consistent messaging across media platforms reaches a wide audience. For example, a Web site that addresses water management issues, highlights emergencies, and provides guidance, social media, alerts, webinars, and town hall meetings can be effective. An outreach and education program also should highlight the multiple benefits that can result from implementing a variety of water management strategies that complement adaptation strategies and should build on existing relationships with local communities. Moreover, it is important that communication is not one-sided. Agencies should solicit input and provide feedback. Communities need to develop and own their choices and have a vested interest in their water resources decisions. Framing the issues in terms of local impacts and solutions can strengthen communication. Adapting to the impacts of climate change will continue to be an ongoing process. Therefore, it will be critical to improve the accessibility of information, improve monitoring, work together across institutional and social boundaries, and leverage resources.

Mitigation is accomplished by reducing or offsetting greenhouse gas (GHG) emissions in an effort to lessen contributions to climate change. Educating the public about mitigating climate change and reducing their communities' carbon footprint is necessary. The costs of adaptation are far greater than the costs of reducing emissions causing climate change. Offering locally relevant education to water managers will encourage climate change mitigation in planning and will help them identify the best benefits for their community.

Public benefits of mitigating climate change at the community level can improve air quality, provide cleaner, more reliable water, and improve public health. Promoting these benefits can encourage public acceptance and investment in mitigation strategies. Teaching the public to understand the importance of lowering their GHG emissions through access to information, public awareness, and education will foster empowerment and ownership. Education has a central role in mitigating climate change. Instilling awareness at a young age will shape the attitudes and behaviors of the next generation. Developing a K-12 outreach program as part of the regular curriculum can help disseminate knowledge effectively through the community.

Potential Costs

The costs of outreach and engagement campaigns are generally the costs of staff time. A large process or public outreach campaign may require full-time trained staff to schedule meetings, prepare material, refine messaging, and rehearse presenters.

Another notable cost is the time involved. Researchers note that "participation is time consuming and has the potential to slow down decision-making since the public needs to be informed and even educated first in order to meaningfully participate in administrative processes" (Neshkova and Guo 2011). This can require an investment from all participants. Paid advocates' participation time is supported by their advocacy group, but members of the public may have to donate their participation time. If agencies want to ensure that representatives from disadvantaged communities are involved, they may have to give them financial assistance for their travel and time. Large-scale projects may have to budget a significant amount to support participation. Large public information campaigns will require refining messages, producing materials, and buying media time. In general, the costs of doing significant, well-delivered outreach and education are small compared with the usual costs of building and maintaining water infrastructure.

Major Implementation Issues

Widespread Lack of Understanding of Water Management

A major challenge for outreach and engagement is the current lack of understanding about water management in general. Californians' lack of understanding of their physical water system is significant. Although there is often a strong sense that water is scarce and important, even important enough to fight over, many stakeholders and the public do not have much understanding of the physical or governance system that delivers their water. Many, if not most Californians, do not know how water gets to them or the features of the water landscape around them. People do not know their water sources, and consequently they do not know how or why those sources should be protected. In a recent survey, 78 percent of Californians did not know what the Bay Delta is, despite its function as the hub of California's two major water projects.

In addition, people are busy with their lives and the world is full of interesting and complex issues. People may make a considered choice not to engage in water management issues. Some IRWM groups report that, when they have sought citizen engagement, some of their citizens have responded that they pay their water districts to evaluate the options and make choices for them.

Complex Governance Structure

At a local level, few people are able name their particular water sources or their district's board members or managers. Without a doubt, California's water governance structure is difficult to understand and apply to individual situations. As people become more interested in water policy, they report that the State-level governance structure is bewilderingly complicated, with multiple agencies portioning different pieces of water management. Because the public is disengaged from these systems, it does not know how to get involved in public policymaking or discussions. Stakeholders that are not professional issue advocates want to be involved, but they do not know enough about how agencies work to participate in a meaningful way. Often, these stakeholders say they do not even know what questions to ask. They may attend meetings only to find that the topic is related, but the agenda is narrowly focused on a specific topic that they do not have the background to understand.

On the other side, there is also a need for State employees to work with interested stakeholders by providing useful information and considering the public's comments. Because California's water governance is so complex, even water managers and policy-makers have only limited expertise. Moreover, tribes have the perspective that State governing bodies do not understand how tribal water rights interact with the water rights administered by the State, including the historical and cultural significance of how tribes view and use water.

The Public Underestimates Risk

Because people are largely unaware of their local watershed and water delivery systems, they may underestimate the level of risk they face (from many potential water problems, such as flood, interrupted service, and water quality threats). The risks posed by water management problems are not familiar to the public. The public may have no reason to research these risks and may choose to live in areas serviced by vulnerable, small water systems without understanding that their sources of water are variable or that they have bought into under-maintained systems. They may choose to live on floodplains without understanding what flood risk involves, or with the erroneous assumption that the local levees absorb all flood risk. If they have never received notice of this risk, or were only told about the risk in technical language that does not resonate with them, they can become angry when the risk turns into a reality that they are unprepared for, or when told about the costs of addressing the risk. Alerting homeowners about risk takes extensive public outreach campaigns.

Another reason the public may not know about the water management risks or issues that affect them is that their water district may consider the job is well done if the risk is averted without the public ever noticing. If a water district swiftly and professionally repairs a leaking pipe before it causes a sinkhole, it has done its job well, but the public may never become aware that the pipe is reaching the end of its design life and needs replacement soon. They may be surprised by the issue because the district has been managing the warning signs so well, the risk is invisible to the public.

Diverse Communities Require Diverse Outreach

Another significant challenge relates to the varied cultural and geographic diversity of the state's residents. Outreach and engagement tools should not be limited by an assumption that a campaign that reaches the mainstream culture would also reach other diverse cultures equally well. Many current outreach methods do not address these more diverse needs. Much progress is being made in this area with the use of pilot projects and other innovative programs, but more is needed.

Water Managers May Not Want to Use Outreach and Engagement

Some agencies and decision-makers may not have experienced the benefits or high value of outreach and engagement. They may underestimate the importance of the tool and the need to build it into the overall project or policy approach, rather than add it on later because of public outcry. More and more agencies are gaining a better understanding of the value of outreach and engagement. Nonetheless, due to shrinking resources and frequent crushing time frames for resolving urgent issues, outreach and engagement are not always a priority for limited agency staff to spend their limited time and capacity. Outreach and engagement may present up-front costs that do not offer immediate or tangible benefits. Additionally, water managers may perceive outreach or collaboration as giving rise to controversy and do not want to be involved with it. Finally, people who are assigned to conduct outreach and engagement are not necessarily professionals in that discipline. They may be technical staff within the agency who have not been trained in communication skills, or who are not comfortable facilitating public meetings. Public speaking or leading groups intimidates many people, including some assigned to lead outreach on a project or policy.

A common format of public meetings is a formalized process that does not create good dialogue. Public meetings are often centered on a technical presentation that allows limited time for questions or has procedural rules that stifle participation; and some public hearings are highly contentious. Hosts and attendees alike can find these meetings dull or frustrating. If these types of meetings are the only public meetings with which these groups are familiar, and they assume that public meetings must be conducted in these ways, it is not surprising that neither group wants to commit time to a series of stakeholder meetings.

In some cases, it would be more practical for academic institutions or non-governmental organizations to assume the role of delivering these services rather than the various types of water-related agencies. This approach is particularly effective when significant resources and relationships already reside in potential partner organizations.

Poorly Designed Public Processes

If a process for collaboration and engagement is poorly designed or inauthentic, it can backfire. A poorly designed or moderated public process can be hijacked by professional advocates so that the result does not accurately reflect the concerns of all involved. (Often a determined saboteur can bring a process to a halt, even if it is well designed.) It can create stakeholder fatigue, meaning stakeholders tire of attending meeting after meeting.

A Flood of Outreach and Engagement Materials

In some cases, there is too much information in outreach and engagement tools without proper guidance to the best applications of the tools and/or the validity of the approaches as a best practice. A number of efforts have resulted in success, but could have been delivered more effectively and efficiently. In other cases, selecting the wrong tools or application of tools incorrectly results in building cynicism and making future outreach even more difficult. This type of error has profound implications for issues where conflict resolution is required. Many different organizations have developed outreach materials and curricula. Searching and selecting among them can be daunting, as can choosing the right materials for the situation that the water district or agency is encountering.

Well-intentioned agencies and decision-makers, when looking at the wide variety of tools, are known to prescribe a tool to their outreach and engagement personnel that appears to work well from all the papers, books, and other materials they have researched, but these may or may not be the right tool for a particular effort. Without some well-organized or professionally evaluated assessment of information, selection of these methods by non-professionals can have negative results. Major public information campaigns may want to integrate messages among water service agencies.

Distrust of Government and Science

Public trust in government has dropped precipitously since the 1960s, when the last major water projects were built — from 73 percent of people trusting government to 26 percent of people trusting government (Pew Research Center 2013). This drop in trust has come about for reasons mostly outside of water management, but has effects on outreach and engagement in all fields. Many citizens may start a public process by initially doubting the facts and science presented by the hosts. People have been exposed to “purchased science,” which is science funded by an advocate that yields biased results according to what the advocate/funder prefers. The public would then question whether that particular science has been conducted to further an agenda, rather than having a neutral finding of causes and facts. Immigrant communities may have a distrust of government that began in their country of origin. In water management, stakeholders may believe that any examination of their water rights or groundwater levels threatens the continuation of their water use.

A current issue facing water managers is that a small but vocal segment of the population holds increasingly strong beliefs about governance and water-related topics, such as climate change. This active minority doubts or rejects the legitimacy of some planning efforts beyond local government and the science that supports decision-making. This level of skepticism makes crafting public policy difficult. As these types of groups have become more politically involved, they have disrupted public meetings and delayed planning efforts. Their mistrust of science requires evidence of fact-finding beyond a level of certainty that satisfies most academics, scientists, and technical experts. New requirements for additional fact-finding can take considerable time and money to develop. As long as this mistrust persists, outreach and engagement may be perceived and labeled as propaganda.

Victims of Success

An odd but real challenge is the experience of achieving success in outreach and engagement without also considering the consequences of success. During the 2006-2009 drought, some districts that conducted extensive public-information campaigns regarding water conservation were caught off-guard by a sharper drop in per-capita water use than they were prepared for. Also, an economy in recession and five years of cooler weather reduced water demand. Some districts found that their rate structure required that people use water at their historical levels to cover the fixed costs of delivery infrastructure. When these districts conducted an effective water conservation public-information campaign, constituents were not buying enough water to cover the districts’ fixed costs. The districts were forced to increase their base rates, leading to the perception that people were being punished for conserving water. This created resentment and the perception that rates were being set in an arbitrary fashion for the benefit of the agency. In such cases, water districts were not prepared for their public information campaigns to be successful and change people's water use.

Currently, many outreach and engagement programs do not measure effectiveness, possibly because it is difficult to do so. Often when budgets are tight, the first items eliminated are educational programs. Consequently, there is a need to quantify the effectiveness of education and outreach that demonstrates the value of these programs. One of the most commonly applied tools is to conduct surveys before and after the intervention to measure the increase in awareness among the public. In addition to measuring public awareness, there is a need to measure behavior changes. One way to measure urban water conservation is to measure the overall reduction in water use, which can be used to calculate the value of water saved. For other messages, monitoring their effectiveness could be more challenging. All the same, the importance of these messages supports the need to develop monitoring techniques.

Water Policy is Genuinely Complex

A final and difficult challenge is the often bewildering complexity involved in addressing water management issues. Creating or defining a clear public message, something that can be incorporated in a 30-second sound bite, is a challenge. A simple message does not truly represent the situation, but a broad audience may not have the time to appreciate a complex message. In this scenario, water managers may not understand the need to conduct outreach and engagement at multiple levels, at multiple times, to impart multiple messages.

Recommendations

1. Project planning should include a section on what level of public engagement is appropriate.
2. The selected level of public engagement should receive appropriate resources.
    A. Messages and policies should be tested through a variety of sample audiences.
3. Agencies providing grants should include requirements for authentic, well-designed public engagement.
4. Managers should take facilitation and collaboration training and offer it to their staff.
5. Professional conferences and other management venues should include outreach and engagement topics to provide an opportunity to share best practices, leverage activities of their peers, and provide efficiencies.
6. Within regions, water managements should collaborate on outreach campaigns for clarity of message and to better utilize stakeholders' time.
7. Managers should carefully calibrate the extent of the engagement in relation to the policy being developed or the project being designed.
8. Lessons learned from collaboration efforts should be documented to improve future efforts.

References

References Cited

California Dairy Research Foundation. 2013. "Compliance through Education." Davis (CA): California Dairy Research Foundation. [Web site.] Viewed online at http://cdrf.org/home/checkoff-investments/cdqap/.

California Department of Public Health, Mosquito and Vector Control Association of California. 2012. *Best Management Practices for Mosquito Control in California. Recommendations of the California Department of Public Health and the Mosquito and Vector Control Association of California*. Sacramento (CA). 62 pp. Viewed online at http://www.cdph.ca.gov/HealthInfo/discond/Documents/BMPforMosquitoControl07-12.pdf.

California Environmental Protection Agency. 2003. "Education and the Environment Initiative (EEI)." Sacramento (CA): California Environmental Protection Agency. [Web site.] Viewed online at http://www.californiaeei.org/History/default.htm.

———. 2010. *EEI Curriculum Catalog*. (Sacramento (CA): California Education and the Environment Initiative. California Environmental Protection Agency. Office of Education and the Environment. 22 pp. Viewed online at: http://www.calepa.ca.gov/Education/EEI/documents/ExLiteracy.pdf.

International Association of Public Participation. 2007. "IAP2 Spectrum of Public Participation." Thornton (CO). [Web page.] Viewed online at: http://www.iap2.org/associations/4748/files/spectrum.pdf.

Neshkova MI, and H Guo. 2011. "Public Participation and Organizational Performance: Evidence from State Agencies." Journal of Public Administration Research and Theory. 22(2):276-288. [Web page.] Viewed online at: http://jpart.oxfordjournals.org/content/early/2011/07/20/jopart.mur038.abstract.

Pew Research Center. 2013. "Public Trust in Government: 1958-2013." [Web page.] Viewed online at: http://www.people-press.org/2013/10/18/trust-in-government-interactive/.

State Water Resources Control Board. 1995. *California Rangeland Water Quality Management Plan*. Sacramento (CA): State Water Resources Control Board, Division of Water Quality, Nonpoint Source Program. 96 pp. Viewed online at http://www.waterboards.ca.gov/publications_forms/publications/general/docs/ca_rangeland_wqmgmt_plan_july1995.pdf.

West L. 2010. "California Approves New Environmental Curriculum for K-12 Students." New York (NY): About.com Environmental Issues. [Web site.] Viewed online at: http://environment.about.com/b/2010/02/20/california-approves-new-environmental-curriculum-for-k-12-students.htm.

Additional References

Bardach E. 1998. *Getting Agencies to Work Together: The Practice and Theory of Managerial Craftsmanship*. Washington (DC): Brookings Institution Press.

Coglianese C. 1997. "Assessing Consensus: The Promise and Performance of Negotiated Rulemaking." Duke Law Journal 46(6):1255-1349.

Community at Work. 2010. "Resource List for Practitioners Putting Participatory Values into Practice." San Francisco (CA). Viewed online at: http://www.communityatwork.com/Resource%20list_2010_new.pdf.

Ebdon C, and LF Aimme. 2004. "Searching for a Role for Citizens in the Budget Process." Public Budgeting and Finance 24:32-49.

Fiorino DJ. 1999. "Rethinking Environmental Regulation: Perspectives on Law and Governance." Harvard Environmental Law Review 23(2):441-469.

Henry AD, M Lubell, and M McCoy. 2011. "Belief Systems and Social Capital as Drivers of Policy Network Structure: The Case of California Regional Planning." Journal of Public Administration Research and Theory 21(3):419-444.

Jervis R. 2006. "Understanding Beliefs." Political Psychology (27)5:641-662.

John D. 1994. *Civic Environmentalism: Alternatives to Regulation in States and Communities*. Washington (DC): Congressional Quarterly Press.

Johnson BR, and R Campbell. 1999. "Ecology and Participation in Landscape-Based Planning within the Pacific Northwest." Policy Studies Journal 27(3):502-529.

Kagan RA. 1999. "Trying to Have it Both Ways: Local Discretion, Central Control, and Adversarial Legalism in American Environmental Regulation." Ecology Law Quarterly 25(4):718-732.

Kenney DS. 2000. *Arguing About Consensus. Examining the Case Against Western Watershed Initiatives and Other Collaborative Groups Active in Natural Resources Management*. Boulder (CO): Natural Resources Law Center, University of Colorado School of Law School.

———. 2000. *Assessing the Effectiveness of Watershed Initiatives: The Current State of Knowledge*. Boulder (CO): Report to the U.S. Environmental Protection Agency. Natural Resources Law Center, University of Colorado School of Law.

Larsen L, SL Harlan, B Bolin, EJ Hackett, D Hope, A Kirby, A Nelson, TR Rex, and S Wolf. 2004. "Bonding and Bridging: Understanding the Relationship Between Social Capital and Civic Action." Journal of Planning Education and Research 24:64-77.

Leach WD. 2006. "Collaborative Public Management and Democracy: Evidence from Western Watershed Partnerships." Public Administration Review 66:100-110.

Leighninger M. 2011. *Using Online Tools to Engage – and be Engaged by – The Public*. Washington (DC): IBM Center for the Business of Government. Using Technology Series. 41 pp. Viewed online at http://www.businessofgovernment.org/sites/default/files/Using%20Online%20Tools%20to%20Engage%20The%20Public_0.pdf.

Lubell M. 2004. "Collaborative Environmental Institutions: All Talk and No Action?" Journal of Policy Analysis and Management 23(3):549-573.

Marsh LL, Lallas P. 1995. "Focused, Special-Area Conservation Planning: An Approach to Reconciling Development and Environmental Protection." In: Porter DR, Salvesen DA, editors. *Collaborative Planning for Wetlands and Wildlife: Issues and Examples*. Washington (DC): Island Press. Pp. 7-34.

Nevada Division of Water Planning. 2011. *Nevada State Water Plan: Part 3 — Water Planning and Management Issues: Section 5 — Water Planning and Management: Water Education*. Carson City (NV). 6 pp. Viewed online at http://water.nv.gov/programs/planning/stateplan/documents/pt3-5d.pdf.

Petty RE, and JT Cacioppo. 1986. *Communication and Persuasion: Central and Peripheral Routes to Attitude Change*. New York (NY): Springer-Verlag.

Pretty J. 2003. "Social Capital and the Collective Management of Resources." American Association for the Advancement of Science 302:1912-4.

Probolsky Research. 2012. *California Statewide Voter Survey: Report on Results*. Newport Beach (CA). Prepared by Probolsky Research LLC. 36 pp. Viewed online at http://www.probolskyresearch.com/wp-content/uploads/2012/01/Probolsky-Research-CA-Statewide-Survey-Jan.-2012-Water-Issues1.pdf.

State and Regional Water Quality Control Boards. 2011. *Citizen's Guide to Working with the California Water Boards*. Sacramento (CA). 74 pp. Viewed online at http://www.waterboards.ca.gov/publications_forms/publications/general/docs/citizenguide2011.pdf.

Taylor M, and S Singleton. 1993. "The Communal Resource: Transaction Costs and the Solution of Collective Action Problems." Politics and Society 21(2):195-214.

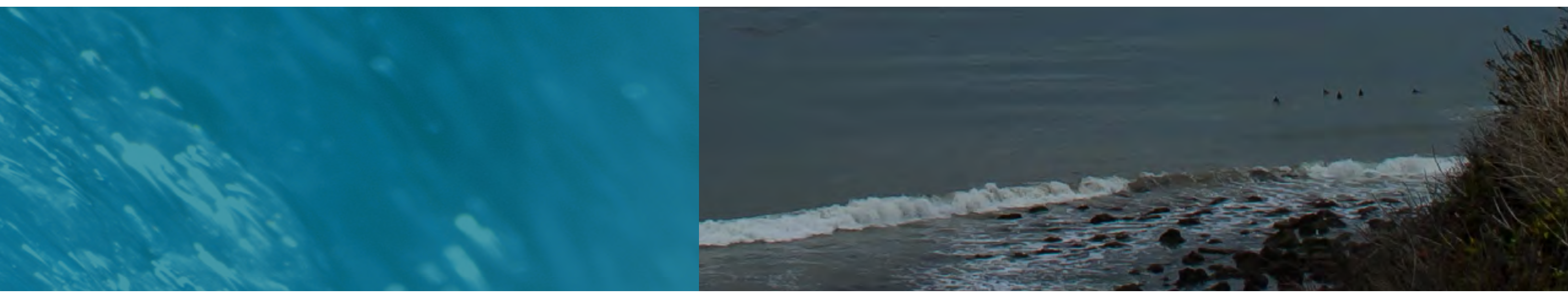
Wholly H2O. 2013. "Resources." Oakland (CA): Mainstreaming Localized Water (Re)Use. [Web site.] Viewed online at http://www.whollyh2o.org/resources.html.

Wilbur M. 2005. "Californians Without Safe Drinking Water: A 2005 Update." In: *California Water Plan Update 2005*. Sacramento (CA): California Department of Water Resources. 82 pp. Viewed online at: http://www.waterplan.water.ca.gov/docs/cwpu2005/vol4/vol4-waterquality-californianswithoutsafewater.pdf.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 30

Water and Culture



Malibu, CA. Chumash ceremonial leader Mati Waiya performs a water blessing ceremony. The Chumash inhabited the central and southern coastal regions of California and three of the Channel Islands.

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Boxes

Chapter 30. Water and Culture

California Water Plan Update 2013 is the first update to include a resource management strategy based on the relationship between water and culture. Chapter 30, "Water and Culture," presents the emerging thinking of many Water Plan Advisory Committee members and other stakeholders regarding the importance of linking cultural considerations to water management. In many respects, the chapter represents more of an annotated outline than a fully developed strategy. Even so, the water plan stakeholders asked that the chapter be included, if only to improve awareness of the need for the strategy and to continue dialogue on what it should include.

Water and culture are connected in myriad ways, with subtle and complex implications for water management in California. Some cultural relationships to water are so pervasive, they may be easy to overlook. Other cultural considerations are less apparent and may be difficult to recognize. Increasing the awareness of how cultural values, uses, and practices are affected by water management, as well as how they affect water management, will help inform policies and decisions. Even regulations reflect cultural values, particularly by how they are put into practice when water is viewed as a commodity, and all the more by the sum total of laws, regulations, and policies intended to control water. (See Box 30-1 for a list of some of the California and federal laws and policies addressing cultural resources.) Water resources have shaped the history of California, contributing to the current social, cultural, and economic patterns across the state. The presence of freshwater sources has influenced the location of settlements and communities for hundreds, even thousands, of years. Water resources have also been pivotal to key economic activities, such as fishing, mining, agriculture, manufacturing, tourism, and recreation. These historic aspects of development continue to have ramifications for water managers today.

Water and water-dependent resources also shape individual and collective experiences that contribute to individual and community well-being, sense of identity, and connection with the natural world. These experiences are inextricably linked to values, traditions, and lifestyles, which in turn inform perspectives and expectations regarding water resources and conditions. Cultural considerations by their nature are inherently linked to every resource management strategy. More importantly, the consideration of culture in water management decisions is, in many cases, legally mandated by State and federal laws. Utilizing cultural considerations in the framing, development, and promotion of management decisions is vital to ensuring legal compliance and sustainable practices.

What is Culture?

Most people have a reference point for the word *culture*, but it is not an easily defined term. Culture is contextual. No single definition of culture satisfies all the diverse perspectives within California. Culture can and does include lifeways, mindsets, spirituality, creation stories, livelihoods, personal and community histories, and artistic and other practices that represent the diversity of California's social fabric.

Likewise, how the scientific community describes and defines culture varies to a substantial degree. Even State, tribal and federal entities have varying definitions whose application is intended to assist the implementation and understanding of laws related to preservation and incorporation of culture via resource management decisions.

Box 30-1 Laws and Policies

California

- California Environmental Quality Act (CEQA) — California Public Resources Code, Section 21000 et seq.
- Native American Historical, Cultural and Sacred Sites — California Public Resources Code (PRC), Sections 5079.60 et seq.
- Preservation of Significant Archaeological Resource Areas and Associated Artifacts — PRC Sections 5079.60 et seq.
- Destruction of Archaeological Sites and Caves — California Penal Code, Sections 622.5 — 623.
- Investigation, Excavation and Preservation of Historic or Prehistoric Ruins — California Water Code, Section 23.
- Governor's Executive Order No. W-26-92 — Management of significant heritage resources under jurisdiction of State agencies.
- Governor's Executive Order No. B-10-11 — Encourages communication and consultation with California Native American Tribes.
- California Natural Resources Agency Tribal Consultation Policy.

Federal

- National Historic Preservation Act (NHPA) — United States Code (USC), Title16, Sections 470 et seq.
- National Environmental Policy Act (NEPA) — 42 USC Sections 4321 et seq.
- Archaeological Resources Protection Act (ARPA) — 16 USC Sections 470aa et seq.
- Archaeological and Historic Preservation Act (AHPA) — 16 USC Sections 469 et seq.
- Native American Graves Protection and Repatriation Act — 25 USC Sections 3001 et seq.
- American Indian Religious Freedom Act — 42 USC Section 1996.
- National Park Service Bulletin 36 — Protecting Cultural Landscapes: Planning, Treatment and Management of Historic Landscapes.
- (Federal) Executive Order 13175 — Consultation and Coordination with Indian Tribal Governments (2000).

Federal Consultation

- http://www.nps.gov/tribes/Documents/Laws.pdf.
- http://www.dot.ca.gov/ser/vol1/sec3/cultural/ch28arch/chap28.htm#definition.
- http://www.dot.ca.gov/ser/vol1/sec3/cultural/ch28arch/chap28.htm.
- http://www.dot.ca.gov/ser/vol1/sec3/cultural/ch28arch/chap28.htm#definition.

Any definition of culture must include far more than what may feasibly be contained in this chapter. Owing to the complex nature of culture and its interconnectedness with water, water management agencies and decision-makers should look to the local communities, groups, and California Native American Tribes to understand those cultures. This process of inquiry facilitates understanding how management decisions affect local cultures, as well as how water resources and water policy are affected by those same cultures.

In some cases, legal requirements mandate that agencies and decision-makers engage with California Native American Tribes. Engaging with tribes and tribal community leaders regarding water resource management in a timely manner is the best way to ensure local, State, federal, and international legal obligations are met.

Cultural Resources and Cultural Resources Management

Cultural resources is a term that is diverse in ways similar to “culture” itself, in that it includes both physical and intangible aspects of social practices, routines, and ways of life. Intangible aspects of culture involve language, beliefs, practices, and traditions. These are often associated with cultural resources comprised of physical objects or places, including structures, cultural landscapes (which combine natural and constructed elements), specific locations with special significance, and/or natural materials.

Management choices for some cultural elements are guided by statutory requirements. For example, cultural resources representing historic artifacts, sites, and buildings may be protected under the National Historic Preservation Act (NHPA). The equitable distribution of effects and benefits is evaluated with regard to environmental justice and public trust factors. Other cultural materials, uses, and practices might need to be assessed within the context of a particular policy or project.

For more information on cultural resources and cultural resources management, see Volume 4, *Reference Guide*, the article “What is Culture? Approaching Cultural Diversity in California and Varying Definitions of Culture.”

Cultural Considerations and Water Management in California

Expression of cultural connections to water and water-dependent resources can involve a wide range of activities and material objects. The following categories of cultural activities are offered to encourage reflection and discussion with the community on the different ways water and culture interface. The categories are for illustrative purposes only and contain areas of overlap.

Subsistence Activities include traditional hunting, fishing, and collecting plants for food sources, medicinal properties, and raw materials. Water flows and water quality are critical aspects of supporting water-dependent subsistence activities. Public health risks can occur if food sources are obtained from contaminated water bodies. These risks are increased with higher consumption levels of locally obtained food sources that can occur in subsistence households and communities. This can well exceed safe consumption levels. For example, no more than three servings a week of fish caught in a particular lake or stream should be eaten, to avoid any health risk present in that particular lake or stream. Also, communication relating to risks or contamination may be hampered by language barriers.

Recreation Activities embrace a broad spectrum of pursuits that range from full-body contact with water (swimming, surfing) to minimal contact (water providing the scenic backdrop for hiking and wildlife viewing). Recreational pursuits encompass motorized and non-motorized activities. These activities range, for example, from boating and riding jet skis to picnicking and kayaking. Here again, water flows and water quality are key factors contributing to recreational experiences. Public health risks can occur if waters are contaminated. Beach closures, which protect public health, also affect recreation and tourism. Another factor that can influence water-related recreation is the availability of facilities, such as boat ramps, parking, restrooms, and general-purpose stores.

Spiritual Activities draw upon the cleansing, healing, and renewing properties of water. Examples include outdoor baptisms, sweat lodges, lakeside weddings, Native American ceremonies, and the blessing of the fleet in fishing communities. While these examples focus on particular activities, some perspectives see an inherent spirituality in water itself, which is always present. These events and perspectives share a common theme in transcending the mundane through a sacred and profound connection to water. In addition to water levels/flows and water quality, those seeking a spiritual experience may include considerations of aesthetics and solitude. A busy pattern of recreational use on public lands could interfere with sacred pursuits.

Historic Preservation seeks to maintain the legacy of the past by protecting historical features (i.e., artifacts, sites, places, buildings, cultural landscapes). Some historic objects may be directly related to water infrastructure (e.g., diversions, flumes, mills). Other historic features may not be directly related to water resources, but are challenged by water management projects and activities. For example, receding waterlines at lakes or reservoirs could expose protected historic features. Conversely, surface storage facilities could inundate historically or culturally significant features or locations that are important to a community. Another example is water system upgrades that need to modify or replace historic infrastructure or support buildings, or new water projects where ground-disturbing activities could destroy historic resources. Water managers are encouraged to review, with their legal office, the legal requirements that might be associated with these situations. A list of key statutory provisions is provided in another section of this resource management strategy.

Public Art has recorded and served as an integrated expression of water in California. This extends to utilizing water infrastructure as the location of art, presentations of art in music and other mediums as a water-related transference of culture, and art providing the platform to express people’s relationship with water and the watershed.

One response to the Rim Fire, a major fire event in 2013, was a community healing process using art as method of expression. Groveland, California, a town of roughly 2500 human inhabitants located less than 25 miles west of Yosemite National Park on State Route 120, was affected in multiple ways by the fire. Economic damages to the tourism economy have closed many local businesses. As the fire burned over several months, local author Elizabeth Dougherty wrote that the citizens turned to the sky “waiting for fall rains to douse the last of its burning fervor. Whether at an art exhibit, a yard sale, a trivia night, a visit to the town dump, the need continues for each person to tell their experience, their story, of how the Rim Fire came into their lives, onto their properties, into the bodies of their cattle, igniting their deeply adored Stanislaus Forest and Tuolumne River Watershed” (Dougherty pers. comm. Oct. 24, 2013).

The relationship of the Rim Fire to the large population centers may not have been readily apparent, yet this same land base is the watershed that provides water to the San Francisco Bay area. A coalition of community advocates organized a mixed-media art show, "Standing with the Watershed," in downtown San Francisco and sought artists to share their visceral experiences of both the Tuolumne River watershed itself and the use of these waters in San Francisco and Silicon Valley. Dougherty wrote, "We want to enliven the souls of those who visit during the two month exhibit with the energy and vitality of this watershed pre-, during-, and post Rim Fire. We want to celebrate the watershed and its inhabitants in all forms. Viva la Tuolumne!" (Dougherty pers. comm. Oct. 24, 2013.)

The Great Wall of Los Angeles, a monumental work by Judith Baca, is a novelization of the city of Los Angeles's past. It is situated on flood infrastructure. The work is symbolic on multiple levels and creates a new relationship with a waterway and the evolution of the city. Still other symbolic and important art-water installations, including the use of bridges, can be found throughout California.

Lifeways represent the larger collective mindsets and practices that represent the diversity of California's social fabric. Shared passions, beliefs, histories, and experiences bring people together to create group and community identities. Several of the lifeways, which have come to typify California to the rest of the world, have a strong connection to water.

- California Native American Tribes often describe their social and cultural identities in terms of being inseparable from the natural world.
- Fishing towns and villages share social and cultural identities that derive from livelihoods that also define ways of life.
- Ranching and agricultural communities were settled near water sources; these working landscapes also provide habitat and vistas that characterize the West.
- The surfing and beach culture of California is directly associated with coastal and ocean resources, projecting an iconic image and serving as a key economic driver.
- The environmental movement in California has strongly advocated for coastal and riverine protections throughout the state.
- Access to water is the foundation of many local economies.

These lifeways are characterized by a close relationship with the land and waters. The well-being of the social fabric, economy, environment, and community are one. This creates responsibilities to long-term stewardship and heightened awareness, knowledge, and expertise regarding local conditions.

Also, any social, cultural, or economic uses of waterways or water-dependent resources can affect the resource base. This can result from trash, overuse, or the introduction of non-native species.

California Native American Tribes' Relationships with Water

In California, the relationship of California Native American Tribes and water is fully rooted. California Native American Tribe village sites and areas for cultural practices are found within a quarter-mile of water, whether it is a spring, creek, river, or lake that still exists or once existed.

It is routine for excavations near a water body to uncover artifacts, such as bedrock mortars, petroglyphs, and tools, affirming the Native American relationship with water (Goode pers. comm. Oct. 18, 2011).

A desire to preserve the California Native American Tribes' relationship to water, among other water-related heritages, has led to enactment of multiple State and federal requirements for protecting various cultural resources. Those requirements are often embedded in other statutes triggered by a wide range of water management actions. As a simple example, any water project that requires a federal permit or uses federal funds may be subject to the NHPA. Depending on the activity, Section 106, which requires agencies to engage in a good faith effort to consult with tribes on a government-to-government basis, may be triggered. Each activity and situation is different; however, the awareness that such triggers may exist allow water managers to take these requirements into account early in a process and conduct meaningful outreach and government-to-government consultation, as appropriate.

A less obvious trigger might include such laws as the California Coastal Act. Section 30244 states, "Where development would adversely impact archaeological or paleontological resources as identified by the State Historic Preservation Officer, reasonable mitigation measures shall be required."

Because each and every situation is different, water managers are advised to consult with their own legal representatives to determine the best course of action. Nonetheless, timely, frequent, and meaningful outreach toward and engagement with California Native American Tribes and stakeholders (when the situation is appropriate to government-to-government consultation) — can help managers identify potential issues and mitigation strategies. Some managers avoid outreach and engagement, thinking that these activities are overly time consuming or costly; however, time and again upfront planning with the appropriate organizations and individuals prevents far more costly implementation delays and/or litigation.

Beyond legal considerations, the California Native American Tribes' traditional practices for land stewardship consider the need for sustainability (Goode pers. comm. Oct. 18, 2011) and regeneration for future generations. As with many other first peoples, these traditional practices and knowledge have been maintained and passed down through generations and make up the basis of what is termed Traditional (or Tribal) Ecological Knowledge (TEK). TEK offers a perspective on California Native American Tribes' culture, their relationships with water, and various sustainable and adaptable water management tools and techniques.

There is a growing awareness among resource managers of the value of this knowledge for present-day decision-making. One example of TEK is cultural burning or prescribed burning, which is becoming more prevalent in land use practices with the aim of improving water flows. When water management (and land use management) decisions are made without reference to California Native American Tribes' relationships to water and/or TEK, these decisions may result in a lack of access to water, adverse changes to water quality, and unmanaged water diversions, all of which have significant impacts on the lifeways of California Native American Tribes.

For more information on TEK and cultural burning, as well as on ways to incorporate them into water management decisions, see the articles related to "Water and Culture" in Volume 4, *Reference Guide*.

Implications for Water Management

Understanding the activities and accomplishments of past groups is important because the decisions made in the present are often influenced by the past. Simply stated, in order to understand the future, there first must be an understanding of the common past and heritage shared by all. This is particularly relevant within California, as the state's history is inextricably bound to the availability and development of water infrastructure. Without understanding the basis and context of existing infrastructure and management, it is difficult to understand the consequences of future actions.

In today's context, cultural practices and perspectives may also be a source of conflict or result in special management needs. When immigrants bring cultural practices to California and continue to observe them, those practices sometimes result in unintended consequences. For example, a food supply even partially based on subsistence fishing may expose a community to high levels of contaminants. In other cases, when well-intended parties introduce non-native species without an understanding of the potential impacts, native species often suffer.

Historic practices that were of high utility at one time, such as gold mining, have created unintended consequences resulting from demands of competing uses or increased concerns over potential negative impacts. Gold mining left residual effects such as erosion, sedimentation, and mercury contamination. Add increased population growth and urbanization, and water quality impacts are exacerbated. Some historic practices may not have been a problem in more rural or agrarian settings, but are now in conflict with other values. Moreover, conflicts can arise as communities attempt to retain historic character in the face of dramatic change.

A sample of other current water management issues directly tied to past economic and development patterns are:

- Placer mining legacy issues of heavy metals contamination.
- Reclamation of floodplains and wetlands and developing them.
- Hydropower operations and consequences for sediment management, fish passage, and water flows and temperature.
- A hybrid system of water rights that encompasses riparian and appropriate rights and adjudicated groundwater basins.
- Historic placement of industrial facilities and dairies near waterways to help manage waste, which now results in legacy issues.
- Logging activities and flash dams, which modified watersheds.
- Construction of large-scale water infrastructure systems, which have fundamentally changed many areas of the state.
- Railroad construction and the dewatering of high-elevation meadows.

Today there is a new urgency in planning and protecting the shoreline for water-dependent uses. Many view the preservation of land for water-dependent uses, in part, as the preservation of the historical and cultural resources that contribute to the charm of coastal communities. Policy-makers have used restrictive zoning, tax abatement, public acquisition of critical parcels through fee-simple or less-than-fee purchases, and transfer of development rights to surrounding lands to conserve those lands best suited for water-dependent uses. The public benefits are protected or required. The unique characteristics of waterfronts provide a wide array of public benefits involving the economy and jobs, the culture of the community, the physical environment, access to the waterfront, and many other dimensions. These public benefits provide local communities with both the rationale and the goals for developing programs to preserve and maintain water-dependent uses (Walker and Arnn 1998).

Potential Benefits

In addition to ensuring compliance with relevant legal mandates to consider culture, the consideration of culture and cultural activities can help frame management decisions. Cultural activities can assist in developing sustainable management decisions (see Volume 4, *Reference Guide*, the articles on cultural burning and TEK). A failure to utilize cultural considerations can have significant cultural and political impacts, which may result in communities delaying projects and or funding for essential projects. Likewise, cultural activities can help frame and promote needed management decisions, particularly in the following ways.

1. Using traditional knowledge and practices to better sustain and integrate water management and provide models of sustainability.
2. Continuing passage of traditional practices and knowledge to future generations.
3. Improving recognition and support of cultural diversity and heritage resources.
4. Creating potential partners and alliances for projects, and leveraging different funding sources.
5. Preserving a community's and a culture's understanding of California's history.
6. Understanding the historical context for community establishment, avoiding repetition of past problems, recognizing the challenges for sustainability, and ensuring remediation.
7. Avoiding conflict and litigation.
8. Avoiding costs (remediation).
9. Understanding cultural implications associated with sea level rise, adaptation, and mitigation responses.
10. Protecting the integrity of peace of mind, quality of life, and life passages.
11. Serving as models of sustainability.
12. Learning more about natural processes (rivers/oceans are teachers).
13. Complying with cultural resource management laws, requirements for State agencies to have inventory of historic assets and report them to the Office of Historic Protection, under the auspices of the California Department of Parks and Recreation.
14. Understanding perspectives that influence water conservation and water management approaches.

Potential Costs

Sample costs associated with furthering the incorporation of cultural considerations into water management decisions include:

- Education and outreach.
- Restoration.
- Research.
- Mitigation.
- Retreat.
- Historic preservation involving taking inventory, evaluating structures for significance, and making management plans (e.g., cultural landscape management plans). Costs depend on scale.
- Interpretive exhibits, markers, plaques.
- Legal considerations. State and federal laws support the consideration of culture in resource management decisions. (Volume 4, *Reference Guide*, provides some information on existing laws.)
- Repatriation.

Major Implementation Issues

1. Lack of information and education regarding which laws apply and the ability to determine who is responsible.
2. Private land owners have considerations that differ from government agencies when cultural remains or artifacts are found on their property.
3. Concerns similar to those associated with habitat for endangered species (i.e., safe harbor) that protection or mitigation efforts may constrain future choices. Once there is a historic designation, it is difficult to remove a building.
4. Inherent rights to access and use the waters of the State — bottom of the river versus banks of the river (Article 10 of the California Constitution).
5. Coastal access triggers discussion of mean low- and high-tide levels.
6. Lack of information regarding whom to contact, which procedures apply, and the hiring process involved for cultural monitors and archaeologists.
7. Lack of agency alignment regarding roles and responsibilities; relevant issues may not be referred to other, related programs.
8. Cultural distrust based on past experiences makes communication difficult with regard to cultural considerations.
9. Economic impacts related to addressing non-native species and dependence on revenue from existing invasive species (e.g., striped bass).
10. Information on cultural and historical resources exists in various databases. Some of the information, such as regional information centers, is a fee-for-service basis.

11. Important water resources may originate in areas with little ability to influence public discourse.

Climate Change

Climate change is projected to have a significant impact on water and water-dependent resources in California. Increased air temperatures will result in warmer water temperatures, a shift in precipitation with more precipitation falling as rain rather than snow, more frequent and intense droughts, and rising sea levels. While future precipitation is somewhat uncertain, greater flood magnitudes are anticipated to result from more frequent atmospheric river-storm events (Dettinger 2011). In addition, changes in the type and timing of precipitation will result in altered surface runoff and volumes, with more runoff occurring in the winter and less in the spring and summer. These changes will affect the water-dependent resources that currently support many cultural activities.

Changes in temperature and precipitation will affect ecosystems throughout the state and affect the subsistence activities that these ecosystems support, especially those that rely on specific species of plants and animals that are particularly vulnerable to the projected changes. Changes in surface runoff and volume, greater salinity intrusion associated with sea level rise, and warmer water temperatures will also affect recreation and spiritual practices associated with water as water levels, stream flows, and water quality are reduced. Historic preservation activities will also be affected, with important cultural sites being at greater risk as a result of exposure during extended drought periods, inundation, or physical damage during extreme flood events. More frequent and intense wildfires could also affect all of these cultural activities.

Adaptation

Probably the biggest impact on water-dependent culture resources will come from large-scale ecosystem changes. On the other hand, while climate change creates challenges for ecosystems, maintaining and creating healthy and resilient ecosystems can also reduce the impacts associated with the anticipated changes in temperature and hydrology. Certain actions, such as high-elevation meadow restoration, can slow down increased winter runoff, allowing it to recharge underlying aquifers and then slowly release that water to help maintain summer in-stream flows. Floodplain restoration also provides similar benefits by protecting water resources while also providing critical habitat for many species. In coastal areas, wetlands can provide a buffer against rising sea levels while improving water quality and providing habitat for many species.

Mitigation

1. Provide outreach and financial and technical assistance to the extent feasible to protect culture resources and increase better understanding of a) carbon sequestration potential with watershed and riparian forests, and b) water conservation and water use efficiency for climate change mitigation.

2. Mitigate, minimize, and reduce greenhouse gas emissions related to water project impacts on culture resources, to the extent feasible.

3. Identify tribal opportunities for water recycling and renewable energy and promote understanding of cultural practices and implications associated with climate change mitigation and responses.

4. Provide benefits and incentives for tribal water and energy-use efficiency projects.

Other Resource Management Strategies

- Chapter 3, "Urban Water Use Efficiency," describes attitudes about recycled water, water meters, lawns, and desalination.
- Chapter 4, "Flood Management," discusses lifestyles and land use.
- Chapter 8, "Water Transfers," discusses how, as timing of water deliveries from natural systems changes, the traditional approaches for water transfers need to be revisited.
- Chapter 17, "Matching Water Quality to Use," recognizes that not all water uses require the same quality of water. Conflicts can occur when water designated as non-potable is accessible to the public, who may not be aware that the water quality does not meet public health standards.
- Chapter 18, "Pollution Prevention," discusses proper land-use management practices to prevent sediments and pollutants from entering water bodies.
- Chapter 22, "Ecosystem Restoration," discusses rehabilitating human-altered landscapes and biological communities for their sustainability and enjoyment of current and future use.
- Chapter 23, "Forest Management," discusses prescribed burning, the impacts of forest management, and other activities that affect water quantity and quality.
- Chapter 24, "Land Use Planning and Management," discusses the physical environmental, economic, and social impacts of land use planning and water management.
- Chapter 29, "Outreach and Engagement," discusses the tools and practices by water management agencies that allow groups and individuals to contribute to good water management outcomes.
- Chapter 31, "Water-Dependent Recreation," provides additional discussion on recreational aspects of culture and water.

The cultural context needs to be considered when implementing any resource management strategy. Every approach requires looking at the cultural context, and any given land use activity may require a cultural resource inventory.

Recommendations

1. Water management agencies should have an appointed preservation officer who is responsible for cultural resource stewardship, developing policies and plans for the protection of historical resources, and ensuring that the agency follows these policies as well as applicable State and federal requirements.

2. Water management agencies should have cultural resource management programs, which include the following:

   A. Inventory of all cultural resources within the jurisdiction of the agency.
   B. Program of systematic condition assessment of cultural resources.
   C. Develop treatment plans and prioritized programs for routine maintenance of individual resources.
   D. Establish and maintain a data file for each cultural resource or groups of resources organized by field division(s).
   E. Identified research goals for archaeological, ethnographic, and historical research proposed within the jurisdiction.
   F. Management of any archaeological or historical object collections maintained by the agency.
   G. Establish and maintain relationships with California Native American Tribes and communities who may have an interest in the cultural resources of the agency.
   H. Staff training and education about cultural resource management.
   I. Coordination with local archaeological and historical societies and other groups with an interest in cultural resource protection.

3. Educate the public about the Surfrider Foundation, the Bolsa Chica $150 million settlement, *Cadillac Desert* (Marc Reisner), Mary Austin, Tahoe Blue, and Friends of the River.
4. Educate children about how watersheds work. Add the hydrologic cycle to the California education standard. Every student should learn the hydrologic cycle from headwater to ocean, as well as the impacts and dependency people have on water.
5. Expand inclusion and integration of traditional/indigenous practices and knowledge in resources management and planning processes and decisions.
6. Educate the public about resource stewardship activities associated with different groups and organizations.
7. Centralize information on cultural and historical resources into a single database.
8. Protect sensitive sites from vandalism.
9. Investigate use of the General Planning Process to better integrate water and cultural considerations.
10. Collaboratively identify statewide, local, and inter-agency efforts to implement early engagement and incorporation of culture to ensure non-duplication of efforts and maximize resources.

References

References Cited

Dettinger M. 2011. "Climate Change, Atmospheric Rivers, and Floods in California – A Multimodel Analysis of Storm Frequency and Magnitude Changes." *Journal of the American Water Resources Association* 47(3):514-523. DOI: 10.1111/j.1752-1688.2011.00546.x.

Walker K, and M Arnn. 1998. “Preserving Waterfronts for Water Dependent Uses.” National Oceanic and Atmospheric Administration, State of the Coast Report. Silver Spring (MD). Viewed online at: http://state_of_coast.noaa.gov/bulletins/html/wdu_11/wdu.html.

Personal Communications

Dougherty E. Director, Wholly H2O, Oakland (CA). Oct. 24, 2013 — e-mail correspondence with Beutler L, executive facilitator, California Water Plan Update 2013, and Water Resources Group, MWH Americas, Sacramento (CA).

Goode R. Chairman, North Fork Mono Tribe, Oct. 18, 2011 — personal communication.

Additional References

California

Alvarez M. 1994/95. “Mount Shasta: A Question of Power.” *News from Native California* 8, no. 3:4-7.

Alvitre C. 2011. “Launching a Dream: Reviving Tongva Maritime Traditions.” *News from Native California* 24, 4:18-23.

Anderson MK. 2005. *Tending the Wild: Native American Knowledge and the Management of California’s Natural Resources*. Berkeley (CA): University of California Press.

Andreas AJ. 1996 (Summer). “Native Americans and Archaeology, California Indians & Archaeology: A Special Report.” *News from Native California* 9, 4:5.

Bacher D. 2010/11. “Ceremony at Danaka: Kashaya Pomo Leaders Mark Closure of Sacred Site,” *News from Native California* 24, 2, 4-5, 9-10, 27.

Belardes DL. 1996. “The Ancestral Homeland and Archaeology, California Indians & Archaeology: A Special Report.” *News from Native California* 9, 4:6-7.

California Department of Water Resources. 2009. *Tribal Water Stories*. 2009 Tribal Water Summit. Sacramento (CA). Viewed online at: http://www.waterplan.water.ca.gov/docs/tws/TribalWaterStories_FullBooklet_07-13-10.pdf.

Castro G. 1996. “Educating Ourselves about Archaeology, California Indians & Archaeology: A Special Report.” *News from Native California* 9, 4:9-11.

Chartkoff J. 1996. “Relationships between Archaeologists and Native Americans in the History of the Society for California Archaeology, California Indians & Archaeology: A Special Report.” *News from Native California* 9, 4:2-3.

Cordero R. 2012. “The Ancestors are Dreaming Us.” *News from Native California* 25, 3:4-5, 24-27.

Cunningham F. 2005. “Take Care of the Land and the Land Will Take Care of You: Traditional Ecology in Native California.” *News from Native California* 18, no. 4:24-34.

Cunningham L. 2010. *A State of Change: Forgotten Landscapes of California*. Berkeley (CA): Heyday.

De Barros P. 1996. “The SCA’s Native American Programs Committee: Improving Communication and Cooperation between Native Americans and Archaeologists, California Indians & Archaeology: A Special Report.” *News from Native California* 9, 4:25-27.

De Buys W, and J Myers. 1999. *Salt Dreams: Land & Water in Low-Down California*. Albuquerque (NM): University of New Mexico Press.

Duane TP. 1999. *Shaping the Sierra: Nature, Culture, and Conflict in the Changing West*. Berkeley (CA): University of California Press.

Dubin M. 2007/08. “’Pull for the Ancient Ones’: Crossing the Santa Barbara Channel in a Tomol.” *News from Native California* 21, 2:20-29.

———. 2010. "Wishtoyo Brings Life to Ancient Chumash Village Site." *News from Native California* 23, 3:4-5, 22-23.

Foster DG, and J Betts. 2004. *History of California Department of Forestry and Fire Protection Archaeology Program 1970-2004*. CDF Archaeological Report, No. 30. June. Viewed online at: http://www.fire.ca.gov/resource_mgt/archaeology/downloads/cdf_history.pdf. Accessed: March 26, 2013.

Fuller R. 1996. "The Sierra Me-Wuk Cultural and Historic Preservation Committee, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:7-9.

Goode RW. 1996. "Archaeology and the Native American Perspective, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:11-14.

Gordon J. 1996/97. "Hooking Eels." *News from Native California* 10, 2:9-10.

Hallowell J, and C Hallowell (eds). 2011. *Take Me to the River: Fishing, Swimming, and Dreaming on the San Joaquin*. Berkeley (CA): Heyday.

Hanly B. 1996/97. "Fish Camp." *News from Native California* 10, 2:3-7.

Haro D. 1996. "The Good, the Bad, and the Ugly, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4, 15-19.

High K. 2011. "Haramokngna Comeback." *News from Native California* 24, 3:24-27.

Jurmain C, D Lavender, and LL Meyer. 2011. "Rancho Los Alamitos: Povuu'ngna, a Time of Beginning." *News from Native California* 24, 3:8-10.

Kalt J. 2007 (Summer). "Public Lands Traditional Gathering Policy Finalized." *News from Native California* 20, 4:7-8.

Kampion D. 1997. *Stoked: A History of Surf Culture*. Los Angeles (CA): General Publishing Group.

Kennard C. 2005/06. "Afloat on the Sacramento." *News from Native California* 19, 2:8-11.

Klasky PM. 2009/10. "The Salt Song Trail Map: The Sacred Landscape of the Nuwuvi People." *News from Native California* 23, 2:8-10.

Frank L, and K Hoagland. 2007. *First Families: A Photographic History of California Indians*. Berkeley (CA): Heyday Books.

Lara Sr., W. 1996. "Respect for the Dead, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:21-22.

Lightfoot KG, and O Parrish. 2009. *California Indians and Their Environment: An Introduction*. Berkeley (CA): University of California Press.

Lightfoot KG. 2006. "Rethinking Archaeological Field Methods." *News from Native California* 19, 3:21-24.

———. 2006 (Fall). "Sensing Archaeology Under Our Feet: The Potential for Geophysical Survey in Native California." *News from Native California* 20, 1:29-31, 37.

Love B. 1996. "Strategies for Indian Participation in Cultural Resource Management, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:29-31.

Lucich G. 2001. "Along the Feather River." *News from Native California* 14, 3:6-8.

Madrigal A. 2008. *Sovereignty, Land and Water: Building Tribal Environmental and Cultural Programs on the Cahuilla and Twenty-Nine Palms Reservations*. Riverside (CA): California Center for Indian Nations.

Margolin M. 1994/95. "Living in a Well-Ordered World: Indian People of Northwestern California." *News from Native California* 8, 3:1-16.

Middleton BR. 2007/08. "Mercury in Our Water, Our Fish and Our People: Raising Awareness," *News from Native California* 21, 2:40, 43.

———. 2009/10. "'Let This All Return to Us:' Working to Reclaim Land through the Pacific Forest and Watershed Lands Stewardship Council." *News from Native California* 23, 2:4-7, 15, 34-35.

———. 2011. *Trust in the Land: New Directions in Tribal Conservation*. Tucson (AZ): University of Arizona Press.

Morrison P. 2001. *Río L.A.: Tales from the Los Angeles River*. Santa Monica (CA): Angel City Press.

Moisa R, and M Margolin (eds). 1996. "California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:1-32.

Ortiz B. 2003. "Sudden Oak Death and California Indian Cultures." *News from Native California* 17, 1:8-10.

Paulson L, with L Shoshone. 2011/12. "Saving Washoe Meadows." *News from Native California* 25, 2:24-25.

Peña L. 2005. "Journey to the Sea." *News from Native California* 19, 1:4-7.

Planas-Beck L. 1996. "When Archaeologists and Indians Cross Paths, California Indians & Archaeology: A Special Report." *News from Native California* 9, 4:23.

Ramirez R, and D Small. 2009. "Revitalizing Ethnobotanical Knowledge in Southern California." *News from Native California* 23, 1:4-5, 26-27.

Roberts C. 2011. "The Cycle of Life: An Indigenous Perspective on the Station Fire." *News from Native California* 24, 3:28, 41-42

Ross J. 2000. "From Tide to Table." *News from Native California* 13, 3:38-39.

Shoshone L. 2011/12. "Language Links the Washoe to Their Land and History." *News from Native California* 25, 2:26-27.

Sonoquie M. 2011. "Koo-ko (Sturgeon)." *News from Native California* 25, 1:28-30.

Stercho AM. 2006. The Importance of Place-Based Fisheries to the Karuk Tribe of California: A Socioeconomic Study. Master's Thesis, Arcata (CA): Humboldt State University, 222 pp. Viewed online at: http://humboldtdspace.calstate.edu/bitstream/handle/2148/87/STERCHO_FINAL_PROJECT.pdf?sequence=1. Accessed: October 31, 2012.

Suntree S. 2010. *Sacred Sites: The Secret History of Southern California*. Lincoln (NE): University of Nebraska Press.

Trevor, T. 1996/97. "Tomol Trek." *News from Native California* 10, 2:10-11.

Cultural Values and Natural Resources

Galla A. (ed). 2012. *World Heritage: Benefits beyond Borders*. Cambridge (MA): Cambridge University Press.

Kempton W, JS Boster, and JA Hartley. 1996. *Environmental Values in American Culture*. Cambridge (MA): MIT Press.

Mann AT. 2010. *Sacred Landscapes: The Threshold between Worlds*. New York (NY): Sterling Publishing.

National Research Council. 2008. *Hydrology, Ecology, and Fishes of the Klamath River Basin*. Washington (DC): National Academies Press.

Stephenson J. 2007. "Many Perceptions, One Landscape." *Landscape Review* 11(2):9-30.

Stephenson J. 2008. "The Cultural Values Model: An Integrated Approach to Values in Landscapes." *Landscape and Urban Planning* 84:127-139.

U.S. Environmental Protection Agency. 2002. *Community Culture and the Environment: A Guide to Understanding a Sense of Place* (EPA 842-B-01-003), Office of Water, Washington, DC.

Verschuuren B. 2006. *An Overview of Cultural and Spiritual Values in Ecosystem Management and Conservation Strategies*. Viewed online at: http://www.bioculturaldiversity.net/Downloads/Papers%20participants/Verschuuren.pdf. Accessed: March 23, 2013.

———. 2007. *Believing is Seeing: Integrating Cultural and Spiritual Values in Conservation Management*. Foundation for Sustainable Development in collaboration with EarthCollective and The World Commission on Protected Areas of IUCN. Viewed online at: http://cmsdata.iucn.org/downloads/believing_is_seeing_reportfinal_07__verschuuren.pdf. Accessed: October 31, 2012.

Cultural Resource Management, Historic Preservation, and Public Lands Management

Alanen AR, and RZ Melnick (eds). 2000. *Preserving Cultural Landscapes in America*. Baltimore (MD): Johns Hopkins University Press.

Brown J, N Mitchell, and M Beresford (eds). 2005. *The Protected Landscape Approach: Linking Nature, Culture and Community*. Gland: IUCN-The World Conservation Union.

Burton L. 2002. *Worship and Wilderness: Culture, Religion, and Law in Public Lands Management*. Madison (WI): University of Wisconsin Press.

California Department of Transportation. 2000. *Water Conveyance Systems in California: Historic Context Development and Evaluation Procedures*. Sacramento (CA): Division of Environmental Analysis, California Department of Transportation. Viewed online at http://www.dot.ca.gov/ser/downloads/cultural/CanalsDitches.pdf. Accessed: October 31, 2012.

———. 2008. *A Historical Context and Archaeological Research Design for Mining Properties in California*. Sacramento (CA): Division of Environmental Analysis, California Department of Transportation. Viewed online at: http://www.dot.ca.gov/ser/downloads/cultural/mining_study.pdf. Accessed: October 31, 2012.

———. 2007. *A Historical Context and Archaeological Research Design for Agricultural Properties in California*. Sacramento (CA): Division of Environmental Analysis, California Department of Transportation. Viewed online at: http://www.dot.ca.gov/ser/downloads/cultural/agstudy.zip. Accessed: October 31, 2012.

Conservation Study Institute PLF/Atlantic Center for the Environment. 2003. *A Handbook for Managers of Cultural Landscapes with Natural Resource Values*. Conservation Stewardship Publication No. 5. Viewed online at http://www.nps.gov/csi/csihandbook/handbook.pdf. Accessed: October 31, 2012.

Hardesty DL, and BJ Little. 2000. *Assessing Site Significance: A Guide for Archaeologists and Historians*. Walnut Creek (CA): AltaMira Press.

Harmon D. 2004. "Intangible Values of Protected Areas: What Are They? Why Do They Matter?" The George Wright Forum 21, 2:9-22. Viewed online at: http://www.cr.nps.gov/history/hisnps/npshistory/212harmon.pdf. Accessed: October 31, 2012.

Head L. 2000. *Cultural Landscapes and Environmental Change*. New York (NY): Oxford University Press.

Hufford M (ed). 1994. Conserving Culture: A New Discourse on Heritage. Urbana and Chicago (IL): University of Illinois Press.

Hutt S, CM Blanco,WE Stern, and SN Harris. 2004. *Cultural Property Law: A Practitioner's Guide to the Management, Protection, and Preservation of Heritage Resources*. Chicago (IL): ABA Publishing.

Infield M, and A Mugish. 2010. *Integrating Cultural, Spiritual and Ethical Dimensions into Conservation in a Rapidly Changing World*. MacArthur Foundation White Paper Series. Viewed online at: http://production.macfound.org/media/files/CSD_Culture_White_Paper.pdf. Accessed: October 31, 2012.

Ishitani-Hata N. 1992. *The Historic Preservation Movement in California, 1940-1976*. Sacramento (CA): California Department of Parks and Recreation.

Josep-Maria M, and T Papayannis (eds). 2007. *Protected Areas and Spirituality: Proceedings of the First Workshop of The Delos Initiative, Montserrat 2006*. Gland, Switzerland: IUCN and Montserrat, Spain: Publicacions de l'Abadia de Montserrat.

King TF. 1998. *Cultural Resource Laws & Practice: An Introductory Guide*. Walnut Creek (CA): AltaMira Press.

———. 2001. *Federal Planning and Historic Places: The Section 106 Process*. Walnut Creek (CA): AltaMira Press.

———. 2002. *Thinking about Cultural Resource Management: Essays from the Edge*. Walnut Creek (CA): AltaMira Press.

———. 2003. *Places That Count: Traditional Cultural Properties in Cultural Resource Management*. Walnut Creek (CA): AltaMira Press.Longstreth R (ed). 2008. Cultural Landscapes: Balancing Nature and Heritage in Preservation Practice. Minneapolis (MN): University of Minnesota Press.

Parker PL. 1990. *Keepers of the Treasures: Protecting Historic Properties and Cultural Traditions on Indian Lands*. Washington (DC): U.S. Department of the Interior, National Park Service.

Parker PL, and TF King. 1998. *National Register Bulletin 38: Guidelines for Evaluating and Documenting Traditional Cultural Properties, Appendix I*. Washington (DC): U.S. Department of the Interior, National Park Service. Viewed online at: http://www.nps.gov/nr/publications/bulletins/pdfs/nrb38.pdf. Accessed: April 18, 2013.

Richman JR, and MP Forsyth. 2004. *Legal Perspectives on Cultural Resources*. Walnut Creek (CA): AltaMira Press.

Native Americans and Cultural Resource Management

Gulliford A. 2000. *Sacred Objects and Sacred Places: Preserving Tribal Traditions*. Boulder (CO): University Press of Colorado.

Stapp DC, and MS Burney. 2002. *Tribal Cultural Resource Management: The Full Circle to Stewardship*. Walnut Creek (CA): AltaMira Press.

Swidler N, KE Dongoske, R Anyon, and AS Downer (eds). 1997. *Native Americans and Archaeologists: Stepping Stones to Common Ground*. Walnut Creek (CA): AltaMira Press.

Watkins J. 2000. *Indigenous Archaeology: American Indian Values and Scientific Practice*. Walnut Creek (CA): AltaMira Press.

Traditional Ecological Knowledge/Indigenous Knowledge

Berkes F. 1999. *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. Philadelphia (PA): Taylor & Francis.

Karuk Tribe. 2010. *Integrating Traditional Ecological Knowledge within Natural Resource Management*. Viewed online at: http://tribalclimate.uoregon.edu/files/2010/11/Karuk_profile_5_14-12_web1.pdf.

MacKendrick K. 2009. "Climate Change Adaptation for Cultural and Natural Resource Resilience: A Look at Planning for Climate Change in Two Native Nations in the Pacific Northwest." (Master thesis.) Viewed online at: http://www.tribesandclimatechange.org/docs/tribes_304.pdf.

Menzies CR (ed). 2006. *Traditional Ecological Knowledge and Natural Resource Management*. Lincoln (NE): University of Nebraska Press.

Pretty J., B Adams, F Berkes, SF de Athayde, N Dudley, E Hunn, L Maffi, K Milton, D Rapport, P Robbins, C Samson, E Sterling, S Stolton, K. Takeuchi, A Tsing, E Vintinnerk, and S Pilgrim. 2008. "How Do Biodiversity and Culture Intersect?" Plenary paper presented at Conference "Sustaining Cultural and Biological Diversity In a Rapidly Changing World: Lessons for Global Policy". Organized by American Museum of Natural History's Center for Biodiversity and Conservation, IUCN-The World Conservation Union/Theme on Culture and Conservation, and Terralingua, April 2-5, 2008. Viewed online at: http://www.greenexercise.org/pdf/How%20do%20biodiversity%20and%20culture%20intersect.pdf. Accessed: March 23, 2013.

Pretty J, B Adams, F Berkes, SF de Athayde, N Dudley, E Hunn, L Maffi, K Milton, D Rapport, P Robbins, E Sterling, S Stolton, A Tsing, E Vintinnerk, and S Pilgrim. 2009. "The Intersections Biological Diversity and Cultural Diversity: Towards Integration." Conservation and Society 7(2):100-112, 2009. Viewed online at: http://woods.stanford.edu/sites/default/files/documents/20121112-YES-The-Intersections-of-Biological-Diversity-and-Cultural-Diversity-Pretty-etal.pdf. Accessed: October 31, 2012.

Ross A¸ R Sherman, JG Snodgrass, and HD Delcore. 2011. *Indigenous Peoples and the Collaborative Stewardship of Nature*. Walnut Creek (CA): Left Coast Press.

Stevens S. 1997. *Conservation through Cultural Survival: Indigenous Peoples and Protected Areas*. Covelo (CA): Island Press.

Vale TR (ed). 2002. *Fire, Native Peoples, and the Natural Landscape*. Covelo (CA): Island Press.

Federal Agencies

National Marine Fisheries Service. 2007. Local Fisheries Knowledge Project. Viewed online at: http://www.st.nmfs.noaa.gov/lfkproject/02_c.definitions.htm. Accessed: April 18, 2013.

U. S. Department of Agriculture, Natural Resources Conservation Services. 2010. Indigenous Stewardship Methods and NCRS Conservation Practices: Guidebook. Washington (DC). Viewed online at: http://www.fws.gov/nativeamerican/graphics/NRCS_Indigenous_Stewardship_Methods.pdf. Accessed: April 18, 2013.

U.S. Environmental Protection Agency. 2009. *Impacts of Climate Change on Tribes in the United States*. Viewed online at: http://www.epa.gov/oar/tribal/pdfs/Impacts%20of%20Climate%20Change%20on%20Tribes%20in%20the%20United%20States.pdf. Accessed: April, 18, 2013.

U.S. Fish and Wildlife Service. 2005. "Traditional Environmental Knowledge in Federal Natural Resource Management Agencies." Sepez J., and H. Lazrus. Practicing Anthropology, 27, no 1. Viewed online at: http://www.fws.gov/nativeamerican/graphics/TEK_J_Sepez.pdf. Accessed: April 19, 2013.

———. 2011. *Traditional Ecological Knowledge for Application by Service Scientists*. Viewed online at: http://www.fws.gov/nativeamerican/graphics/TEK_Fact_Sheet.pdf. Accessed: April 18, 2013.

U.S. Fish and Wildlife Service, Native American Liaison. 2013. "Traditional Ecological Knowledge." [Web page.] Viewed online at: http://www.fws.gov/nativeamerican/TEK.html. Accessed: April 18, 2013.

U.S. Geological Survey. 2012. "Traditional Ecological Knowledge (TEK): An Introduction and Discussion of TEK's Potential to Inform Adaptive Management." MS Powerpoint presentation, April 16. Viewed online at: http:www.gcmrc.gov/about/twg/4_16_12/Fairley_TEK_PPT.pdf.

University of Oregon and U.S. Department of Agriculture Forest Service. 2012. *A Synthesis of Literature on Traditional Ecological Knowledge and Climate Change*. Primary author: K. Vinyeta. Viewed online at: http://www.tribesandclimatechange.org/docs/tribes_511.pdf.

———. 2012. *Guide for Tribal Leaders on U.S. Climate Change Programs*. Donoghue E, and K. Lynn. Viewed online at: http://tribalclimate.uoregon.edu/files/2010/11/tribal_leaders_CC_guide_1-4-2012.pdf.

———. 2014. "Tribal Climate Change Project." [Web page.] Viewed online at: http://tribalclimate.uoregon.edu/.

Selected Articles, Case Studies, and Guidelines

Assembly of Alaska Native Educators. 2000. *Guidelines for Respecting Cultural Knowledge*. Fairbanks (AK): Alaska Native Knowledge Network. Viewed online at: http://www.ankn.uaf.edu/publications/Knowledge.pdf.

———. 2003. *Guidelines for Cross-Cultural Orientation Programs* Fairbanks (AK): Alaska Native Knowledge Network. Viewed online at: http://www.ankn.uaf.edu/publications/xcop.pdf.

Calamia MA. 1999. "A Methodology for Incorporating Traditional Ecological Knowledge with Geographic Information Systems for Marine Resource Management in the Pacific." SPC Traditional Marine Resource Management and Knowledge Information Bulletin #10. Viewed online at: http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/TRAD/10/TRAD10_02_Calamia.pdf.

Donoghue EM, SA Thompson, and JC Bliss. 2010. "Tribal-Federal Collaboration in Resource Management." Journal of Ecological Anthropology 14:1. Viewed online at: http://shell.cas.usf.edu/jea/PDFs/DonoghueJEAVol14.pdf.

Folke C. 2004. "Traditional Knowledge in Socio-Ecological Systems," Ecology and Society 9(3):7. Viewed online at: http://www.ecologyandsociety.org/vol9/iss3/art7/main.html.

Lertzman DA. 2010. Best of Two Worlds: Traditional Ecological Knowledge and Western Science in Ecosystem-Based Management. BC Journal of Ecosystems and Management 10(3):104-126. Viewed online at: http://jem.forrex.org/index.php/jem/article/viewFile/40/12.

Mazzocchi F. 2006. "Western Science and Traditional Knowledge: Despite their variations, different forms of knowledge can learn from each other." Heidelberg (DE): European Molecular Biology Organization. EMBO reports 7:5. Viewed online at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1479546/pdf/7400693.pdf.

McClean KG. 2010. *Advance Guard: Climate Change Impacts, Adaptation, Mitigation and Indigenous Peoples — A Compendium of Case Studies*. Darwin (AU): United Nations University — Traditional Knowledge Initiative. Viewed online at: http://www.ias.unu.edu/resource_centre/UNU_Advance_Guard_Compendium_2010_final_web.pdf.

Pretty J, B Adams, F Berkes, S Ferreira de Athayde, N Dudley, E Hunn, L Maffi, K Milton, D Rapport, P Robbins, E Sterling, S Stolton, A Tsing, E Vintinner, and S Pilgrim. 2009. "The Intersections Biological Diversity and Cultural Diversity: Towards Integration." Conservation and Society 7(2):100-112. Viewed online at: http://woods.stanford.edu/sites/default/files/documents/20121112-YES-The-Intersections-of-Biological-Diversity-and-Cultural-Diversity-Pretty-etal.pdf.

Pretty J, B Adams, F Berkes, S Ferreira de Athayde, N Dudley, E Hunn, L Maffi, K Milton, D Rapport, P Robbins, C Samson, E Sterling, S Stolton, K Takeuchi, A Tsing, E Vintinner, and S Pilgrim. . "How Do Biodiversity and Culture Intersect?" Viewed online at: http://www.greenexercise.org/pdf/How%20do%20biodiversity%20and%20culture%20intersect.pdf.

Shebitz D. 2005. "Weaving Traditional Ecological Knowledge into the Restoration of Basketry Plants." Journal of Ecological Anthropology 9. Viewed online at: http://www.kean.edu/~dshebitz/publications/Weaving%20TEK%20into%20Restoration%20of%20Basketry%20Plants.pdf.

Simonelli R. 2008. "Climate Change and Indigenous Knowledge." Winds of Change (Summer). Viewed online at: http://www.cbp.ucar.edu/documents/Winds_of_Change_ClimateChange.pdf.

Water and Values

Bodley JH. 1997. *Cultural Anthropology: Tribes, States, and the Global System*. Second edition. Mountain View (CA): Mayfield Publishing Company.

Fagan B. 2011. *Elixir: A History of Water and Humankind*. New York (NY): Bloomsbury Press.

McCool SF, RN Clark, and GH Stankey (eds). 2008. Water and People: Challenges at the Interface of Symbolic and Utilitarian Values. Gen. Tech. Rep. PNW-GTR-729. Portland (OR): U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Scheldwald-van der Kley L, and L Reijerkerk. 2009. *Water: A Way of Life, Sustainable Water Management in a Cultural Context*. Boca Raton (FL): CRC Press.

United Nations Educational, Scientific and Cultural Organization, World Water Assessment Program. 2003. *Water for People, Water for Life: The United Nations World Water Development Report*. New York (NY): Berghahn Books. Viewed online at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/wwdr1-2003/downloads/. Accessed: December 12, 2012.

Strang V. 2001. *Evaulating Water: Cultural Beliefs and Values about Water Quality, Use and Conservation*. Hadleigh (UK): Water UK Publications.

———. 2004. *The Meaning of Water*. Oxford (UK): Berg Publishers.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 31

Water-Dependent Recreation

Sacramento-San Joaquin Delta. A young couple fishes on a breezy summer evening in the Delta.

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Chapter 31. Water-Dependent Recreation

A Multitude of Recreation Opportunities

With its temperate climate, more than 1.3 million acres of water surface, 2,600 miles of waterways, and 3,427 miles of coastline, California offers a variety of water-dependent recreation opportunities in any season. Each year, millions of California residents and visitors come to California's inland lakes and rivers seeking recreation experiences. In 2010, beach and waterfront activities helped make California one of the most visited states in the nation. The Sierra Nevada and the Cascade Range also draw residents and visitors to recreate on snowy slopes and meadows, which store summer water supplies naturally.

California residents and visitors can choose from a variety of water-dependent recreation activities managed by federal, State, and local agencies, as well as businesses and not-for-profit organizations. They may enjoy recreation activities in or on water, including fishing, swimming, skiing, and snowboarding, waterfowl hunting, motor boating, surfing, and kayaking. They also may participate in recreation activities that can be enhanced by water, such as wildlife viewing (including birding), picnicking, biking, relaxing on the beach, camping, and hiking. Although the latter activities do not require water, they are frequently enjoyed near waterways, lakes, floodways, and the sea. This chapter will not address water parks, swimming pools, and water-thirsty lawn-dependent recreational facilities, such as ball fields and golf courses; however, these are examples of popular off-stream recreational facilities that may require significant water resources.

Californians Value Water-Dependent Recreation Opportunities

The right to access waterways for boating and fishing has been embedded in California's Constitution since the founding of the State. It is an important part of Californians' heritage and culture. A number of surveys validate the importance of water in Californians' outdoor recreation activities. For example, *Draft Findings, Public Opinions and Attitudes on Outdoor Recreation in California 2012*, the 2012 release of a survey conducted by the California Department of Parks and Recreation (California State Parks) every five years to better understand residents' recreation habits, found that 52 percent of California's adults participated in beach activities; 35.4 percent swam in freshwater lakes, rivers, or streams; and 25.6 percent fished in fresh waters. More than 46.6 percent used a beach or water recreation area during their most recent park visit. Significant numbers also enjoyed water-enhanced nature-based activities, such as wildlife viewing (48.6 percent), hiking on trails (60.2 percent), and camping in developed sites (25.8 percent) (California Department of Parks and Recreation, Planning Division 2012).

The same survey also reveals the importance of recreation facilities at lakes, rivers, and reservoirs: 67.8 percent indicated that recreation facilities, such as picnic or camping sites, are needed at lakes and reservoirs (39.4 percent agree and 28.4 percent strongly agree). Also, 61.8 percent felt that the government should place more emphasis on cleaning up pollution of the ocean, lakes, rivers, and streams in park and recreation areas, and 72.1 percent of the respondents indicated that the availability of recreation facilities at lakes, reservoirs, rivers, and wetlands was important or very important.

Public agencies might consider the following value statements to guide water recreation planning and programming:

- California has a strong outdoor recreation legacy because of its pleasant climate, natural beauty, geographic diversity, diversity of habitats, fish and wildlife resources, and bountiful open space.
- Open space lands set aside for water resource protection, storage, or extraction are often suitable for recreational use. These include protected watershed lands, floodways, and reservoirs.
- Providing recreational opportunities that draw Californians outside increases public health, a significant State and local government responsibility (California Department of Parks and Recreation, Planning Division 2009).
- Generations of Californians have, and will, benefit from laws protecting the public's access to navigable waterways and ocean beaches.
- Providing and clearly identifying safe access to waterways where it is feasible increases public safety and reduces trespass on adjacent lands.
- Maintaining the affordability of recreational opportunities allows more Californians to engage in healthy outdoor activities (California Department of Parks and Recreation, Planning Division 2009).
- Recreation and tourism are economic engines that improve the quality of life, increase property values, and provide jobs for many Californians (California Department of Parks and Recreation, Planning Division 2011a).
- The *California Children's Outdoor Bill of Rights* states that every child should have the opportunity to explore nature, learn to swim, go fishing, go boating, and do six other recreation activities (California Roundtable on Recreation, Parks and Tourism 2012).

Water Managers' Role in Recreation Planning

By planning for water-dependent recreation activities in water projects, water managers play a critical role in ensuring that all Californians today and into the future are able to enjoy such activities. Demand for outdoor recreation opportunities in many parts of California exceeds the capacity of the current infrastructure (California Department of Parks and Recreation, Planning Division 2009). As a result, facilities are likely to be overused, jeopardizing natural and cultural resources on which they depend and degrading the recreational experience.

Furthermore, as California's population continues to grow, public demand for water-dependent recreation opportunities will only increase. Today's population of 39 million is estimated to reach 49 million by 2030 and almost 59.5 million by 2050 (California Department of Finance 2013). Meeting this growing demand is a significant challenge for water managers.

Water managers must comply with a significant body of law because the right of public access to navigable waterways, lakes, and beaches is protected throughout the United States, a concept originating in ancient Roman law. Major federal provisions are:

- The Commerce Clause of the U.S. Constitution insists that public access be maintained by the States.
- The congressional act admitting the State of California into the union declares that "all the navigable waters within the said state shall be common highways, and forever free … to the inhabitants of said state as to the citizens of the United States, without any tax, impost or duty therefor" (Stevens [date unknown]).
- The Clean Water Act outlines the beneficial uses of waterways, including water-based recreation, subject to regulation.
- The Reclamation Recreation Management Act of 1992 authorizes the U.S. Bureau of Reclamation to cost-share up to 50 percent of the cost of operating and maintaining recreation facilities at federal lands and waters under its jurisdiction.
- Section 10a of the Federal Power Act requires the Federal Energy Regulatory Commission (FERC) to consider other beneficial public uses in adopting a new license for hydropower facilities, including recreation.

California law also guards and supports the right of public access to the State's surface waters. Some of these provisions are described below:

- California Constitution, Article 10, Section 4, states, "No individual, partnership, or corporation, claiming or possessing the frontage or tidal lands of a harbor, bay, inlet, estuary, or other navigable water in this State, shall be permitted to exclude the right of way to such water whenever it is required for any public purpose, nor to destroy or obstruct the free navigation of such water; and the Legislature shall enact such laws as will give the most liberal construction to this provision, so that access to the navigable waters of this State shall be always attainable for the people thereof."
- California's Bill of Rights, Article 1, Section 25 states, "The people shall have the right to fish upon and from the public lands of the state and in the waters thereof."
- California Civil Code, Section 830, describes the public trust easement that occurs between the ordinary high and low water mark of non-tidal waterways.
- The Harbors and Navigation Code, Section 68-68.2, states, "[T]he Legislature hereby finds and declares that there is a statewide and continuing interest in the public's use of the state's inland waterways for recreational purposes. The Legislature further finds and declares that there exists a need to provide for recreational resource planning of the waterways in a manner that provides access and utilization for recreational purposes." Section 100 reiterates, "Navigable waters and all streams of sufficient capacity to transport the products of the country are public ways for the purpose of navigation and of such transport."
- The public trust doctrine recognizes recreation as a public trust use of water that must be considered when managing tidelands and navigable waters and their tributaries (California State Lands Commission 2001, 2010). California's Public Resources Code, Section 6301, gives the California State Lands Commission (SLC) jurisdiction over these lands.

Recreational access is protected and encouraged in regional laws throughout California, including those described below:

- The California Coastal Act, managed by the California Coastal Commission, protects public access to the coastline and tidelands.
- The Delta Reform Act of 2009 states that one of the fundamental goals for managing land in the Sacramento-San Joaquin Delta (Delta) is to "[m]aximize public access to Delta resources

and maximize public recreational opportunities in the Delta" (California Water Code [CWC] Section 85022[d][3]).

- The Integrated Regional Water Management Planning Act requires integrated regional water management (IRWM) plans (IRWMPs) to consider California Water Plan recommendations (CWC Section 10541[e][1]).

Recreational facilities increase the benefits of public access while reducing potential impacts on natural and cultural resources, public health, and adjacent landowners. Providing recreational facilities as part of water resources management is also part of California law. California's 1961 Davis-Dolwig Act requires State water projects to integrate recreation facilities as well as fish and wildlife enhancement.

- The act outlines responsibility for project costs allocated to recreation, to fish and wildlife enhancement, and for costs of acquiring property for recreation development, for "the Central Valley Project and every other project constructed by the State itself or by the State in co-operation with the United States, including, but not limited to, the State Water Resources Development System." (CWC Section 11905.)
- CWC Section 12842 also requires that "planning and construction of all flood control and watershed protection projects shall include such features as may be determined to be necessary and desirable to preserve and enhance the state's fish and wildlife resources and to achieve the full utilization of such projects for recreational purposes consistent with the construction and operation of such projects to protect life and property."

This resource management strategy offers water managers and recreation professionals examples and ideas for working together to provide many more opportunities for public access and water-dependent recreation to meet the demand of California's residents and visitors now and into the future. The State agencies with the most significant legislative authority and expertise in water-dependent recreation planning are:

- The California Department of Boating and Waterways (DBW).
- The California Department of Parks and Recreation (California State Parks).
- The California State Lands Commission (SLC).
- The California Department of Fish and Wildlife (DFW) (formerly known as the California Department of Fish and Game).
- The California Department of Water Resources (DWR).

Potential Benefits

Residents and visitors flock to California's beaches, reservoirs, lakes, floodways, waterways, and snow-covered mountains for a variety of fun and healthy outdoor activities. Recreation provides myriad benefits — not only to individuals, but also to communities, the environment, and the economy.

Health and Social Benefits

Swimming, kayaking, snowboarding, and water-skiing are just a few of the vigorous, fun, and healthy activities available at outdoor recreation areas. For example, in the winter of 2009-2010, California's snowy mountains hosted 7.5 million skier visits (Natural Resources Defense

Council and Protect Our Winters 2012). More than 12 million California residents participate in marine recreation annually (Pendleton and Rooke 2006). By offering opportunities for outdoor exercise, government agencies and other entities can help counteract significant negative health trends, such as the increase in childhood obesity (California Department of Parks and Recreation, Planning Division 2009). A collection of research can be found at http://www.parks.ca.gov/?page_id=25026.

Other, less vigorous outdoor recreation activities refresh and relax mind and body, reducing stress and improving health (Gies 2006). Recreationists enjoy river rafting; sunbathing or playing on beaches; telling stories around a waterfront campfire; strolling near rivers, creeks, and marshlands; and photographing wildlife and plants. These opportunities also provide the public a means to adapt to increasing temperatures brought on by climate change. Local recreational areas that have water and shade create a microclimate that reduces the heat island effects of urbanization. Having access to such areas helps residents cope with heat stress.

In addition to providing the chance for exercise and relaxation, recreation in, on, or near water offers a variety of other social benefits to individuals, communities, and the environment. The following examples illustrate some of those benefits.

- A family picnicking at a popular reservoir enjoys socializing with family and friends while sharing the recreation area with other visitors of many ages, races, and creeds. Leisure experiences such as these help improve cultural understanding and strengthen social bonds.
- A young couple observing nature as they walk or bike along a shady path near a river is making a meaningful connection with the natural environment. Such activities encourage an appreciation for water resources and wildlife. In turn, this can lead to an increase in volunteerism and stewardship of natural resources and can help strengthen communities.
- Led by a park interpretive specialist, a boy and his classmates learn about the importance of watersheds and water-related environments and explore ways they can save water at home. Experiences such as these enrich formal education, instill life-long positive values, deter irresponsible behavior, and help meet the State’s commitment to wise use of water resources.
- Riverbanks, lakeshores, and beaches, because of their linear nature, offer excellent opportunities to provide non-motorized recreational and commuter trail routes with fewer motorized traffic conflicts. These routes provide a healthy, affordable, and nonpolluting transportation option for schoolchildren and adults, which may reduce short and mid-range auto trips, improve air quality, and reduce travel costs.
- Relaxing in natural hot springs is widely believed to convey therapeutic benefits and is a traditional activity of some California Native American tribes.

Another illustration of how water-dependent recreation opportunities can provide health and social benefits is Sacramento’s American River Parkway that parallels about 30 miles of the American River downstream of Folsom Dam. Visitors may participate in a variety of activities; they walk, run, bike, ride horses, picnic, fish, swim, watch wildlife, and paddle along a boating trail. The parkway also provides access to a rowing facility and a fish hatchery where visitors can view salmon and steelhead trout (County of Sacramento 2009), and it is a popular bicycle commuting route.

Economic Benefits

Water-dependent recreation has a major influence on California's economy. In 2008, the estimated direct and indirect economic benefit of recreational boating alone was more than $19 billion. As one of the most popular recreational pursuits among California travelers, water-dependent recreation helped attract millions of tourists to California in 2010, making it one of the most visited states in the nation. During 2010, travel spending in California directly supported 873,000 jobs with earnings of $30 billion. Travel spending generated the greatest number of jobs in arts, entertainment, and recreation (226,000), and accommodation and food services (520,000) (California Department of Parks and Recreation, Planning Division 2011a). A study by DBW reported that non-motorized boating contributed $1.7 billion to California's economy in 2006 (California Department of Boating and Waterways 2009d). In 2006, 7.4 million residents and nonresidents 16 years and older fished, hunted, or watched wildlife in California — spending a total of $8 billion (U.S. Department of the Interior, Fish and Wildlife Service 2012). Winter tourism provided almost 24,000 California jobs and added almost $1.4 billion to California's economy in the winter of 2009/2010 (Natural Resources Defense Council and Protect Our Winters 2012). Estimated 2005 expenditures on marine recreation fishing were $205-$545 million (Pendleton and Rooke 2006). Surfers contributed an estimated $5.7 million to Orange County's economy in 2009 and $20 million statewide (Surf-First and the Surfrider Foundation 2011).

Commercial businesses offering recreation equipment, programs, and services boost local economies and create jobs. For example, visitors to Sacramento County's American River Parkway frequently combine a trip to the parkway with eating and shopping at local businesses. Such activities generate about $260 million annually for the local economy (Gies 2006).

Water-dependent recreation adds economic value to lands that might otherwise have limited economic use, such as those subject to frequent flooding or set aside for watershed protection. This increases the benefits of protected open spaces and viewsheds, prompts long-term investments in more livable communities, and increases adjacent property values. Communities with significant tourism resources, such as San Diego's beaches, can generate revenue from tourism taxes such as hotel occupancy fees. Communities with significant recreation resources, such as many in Marin County, enjoy generous tax revenues from higher property values. Some park districts, such as East Bay Regional Park District, gain public support for parcel taxes that fund open space preservation and recreational development (East Bay Regional Park District 2012). Watersheds that do not contribute significantly to California's water supply, such as the Truckee River, generate much of their economic value from water-dependent recreation.

Water-dependent recreation also generates significant revenue for federal and State recreation and environmental management programs through taxes, fees, permits, and licenses:

- In 2010, 808,649 boats were registered in California generating nearly $2 billion for the state (California Department of Boating and Waterways 2011)
- Sales of sport fishing and hunting licenses and stamps generated more than $81 million in revenue for the California Department of Fish and Game (now named the California Department of Fish and Wildlife) in 2011. Fishing-related expenditures are included in Table 31-1 (California Department of Fish and Game 2012a).
- The Federal Aid in Wildlife Restoration Act (also known as the Pittman-Robertson Act) and the Federal Aid in Sport Fish Restoration Act (also known as the Dingell-Johnson Act) fund wildlife habitat restoration, enhancement, and management through excise taxes paid

Table 31-1 Fishing-, Hunting-, and Wildlife-Associated Recreation Statistics in California, 2011[a]

Description of Activities/Expenditures	Amount
Californians who fished or hunted	1.9 million or 7 percent of residents
Californians who participated in wildlife-watching activities	6.5 million or 23 percent of residents
California days of fishing	23.7 million
California days of hunting	6.7 million
Total fishing expenditures	$2.27 billion
Total hunting expenditures	$0.97 billion
Total wildlife-watching expenditures	$3.78 billion

Source: U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau 2011.

Notes:

[a] Residents and nonresidents 16 years and older.

by hunters, boaters, and anglers (U.S. Department of the Interior, Fish and Wildlife Service 2012).

- The Outdoor Industry Association (2012) reports that, nationwide, outdoor recreation generates almost $40 billion in federal tax revenue and $40 billion in state/local tax revenue annually.

Value-Added Benefits from Flood Management Projects

Flood protection facilities provide opportunities for integrating sui recreation facilities, such as trails, picnic sites, wildlife viewing areas, and watercraft launching sites that provide many benefits. Establishing greenways as part of flood management projects and replacing concrete channels with more natural creek environments can improve residents' quality of life as well as support property values and businesses in urban areas. For example:

- The Tujunga Wash Greenway and Stream Restoration Project is a good example of a value-added project in the San Fernando Valley. The project will provide open space for recreation, improved water quality, and groundwater recharge by diverting water from the concrete channel into a naturalized streambed.
- The Napa River Flood Protection Project includes a user-friendly environment with greenways, walking paths, trails, and open space.
- Lake Elizabeth in Fremont is a critical component of the local flood management program and includes a natural setting with many recreation attributes designed around an urban area.
- The Three Rivers Levee Improvement Authority recently decided to allow public access to some Feather River properties. The organization expects this will reduce vandalism, improve security, and increase the quality of life and property values of nearby communities.

Funding for recreation development can sometimes be generated by including flood management projects in urban development or redevelopment projects. Modern urban design that includes both recreational and natural flood management components increases the desirability and property values of these neighborhoods.

Value-Added Benefits from Climate Change Projects

Water-dependent recreation complements adaptation and mitigation strategies to address climate change, while making communities more resilient to it. As indicated in the "Climate Change" section later in this chapter, this type of recreation can provide many added benefits, such as mitigating emissions of greenhouse gases (GHGs) and decreasing pollutants in waterways. Protected watershed lands, greenways along waterways, floodways and flood bypasses, marshes, and seashores can provide room to implement both climate change adaptation and mitigation strategies. Incorporating recreation improves the economic sustainability and social benefits of these land uses.

These strategies can include planting vegetation to sequester carbon while creating an inviting recreation area. In some cases, however, the mitigating benefits of water-dependent recreation could be offset — for example, by the use of motorized watercrafts and the vehicles required to tow them to the recreation point. Increasing paddling opportunities encourages less fuel-intensive recreation, and providing boat storage at recreation sites reduces fuel-intensive transportation. Providing commuter bikeways and neighborhood trails along natural or constructed waterways can reduce vehicle miles traveled and GHG generation, especially for short trips. When Californians can safely and comfortably traverse their neighborhoods on foot or on bike, fewer and smaller motor vehicles are necessary, which allows more compact communities with smaller garages, narrower streets, less energy use, and less transportation fuel infrastructure. For example:

- An escalation of gasoline prices created a measurable spike in bicycle commuters using the American River Parkway as a travel alternative. The parkway's trails connect to paddle and sailboat rental facilities at Willow Creek and Lake Natoma, allowing local recreationists to walk or ride bicycles to enjoy boating at these lakes (Groth et al. 2008).
- Climate adaptation strategies include the provision of buffer lands to accommodate increased storm runoff and rising seas. Greenways and beaches subject to periodic flooding are suitable for recreation, so they can generate revenue and improve the livability of communities. Greenways can be designed to connect habitats, giving native species adaptation corridors, and are often suitable for stormwater infiltration, which increases local water self-sufficiency.

Potential Costs

Significant investments in water-side recreation facilities are made by individuals, businesses, and not-for-profit associations, such as private docks, marinas, boat-in restaurants, marine services, and duck clubs. Public investments are also necessary to provide safe public access and affordable recreational opportunities for all Californians. The State invests significant funds to manage multiuse public lands and waters on which recreationists depend. Accommodating population growth and climate change will require increasing levels of investment to maintain safe access to snow-covered mountains, waterways, lakes, and the ocean.

Facility Development Costs

Information on the statewide costs of providing and operating public water-dependent recreation opportunities is not readily available; however, below are some examples of facility development costs.

- The required Federal Energy Regulatory Commission (FERC) relicensing protection, mitigation, and enhancement (PM&E) measures cost an average of $25 per kilowatt (kW) capacity of a hydroelectric project for wildlife, $95 per kW for fisheries, and $22 per kW for recreation. This allocation is somewhat useful to describe the scale of anticipated costs. PM&E measures benefiting wetlands, aesthetics, cultural resources, and water quality cost about $24 per kW. Recreation facilities include boat ramps, canoe portages, hiking trails, and fishing access areas, as well as operational changes to augment downstream flows to protect and enhance fisheries and create recreational opportunities, such as whitewater boating, and hydropower education programs. These funds may also be used to operate and maintain facilities, so there is not a direct parallel between the funding available and facility development costs (Federal Energy Regulatory Commission 2001).
- Between 2007 and 2012, DBW funded $24 million in 43 boating facility projects, ranging in cost from $85,000 to $3.25 million, on State lands. During this period, DBW also provided local assistance funding of $57 million in grants and about $65 million in loans for the rehabilitation and construction of local boating facilities, including marinas and boat launching facilities. Typically, improvements included adding launching ramps, parking lots, boarding floats, restrooms/floating restrooms, lighting, berthing, moorings, boat-in day-use, and camping/RV sites (California Department of Boating and Waterways 2012a).
- The Tujunga Wash Greenway and Stream Restoration stream channel diversion project mentioned above cost $7 million to complete and provided multiple benefits (Santa Monica Mountains Conservancy 2013a).
- The *Sacramento-San Joaquin Delta Boating Needs Assessment 2000-2020* estimated that repairing or replacing the existing public and private facilities in all six Delta zones would cost between $107 million and $159 million, spread over 20 years (California Department of Boating and Waterways 2003).
- The *2002 California Boating Facilities Needs Assessment* surveyed 646 of California's boating facilities, which included marinas, launch ramps, dry storage facilities, resorts, recreational areas, and yacht clubs.
- Estimated costs to prepare and process applications, and implement environmental permitting measures, including Clean Water Act Section 401 and Section 404 permits and Section 106 compliance, is unavailable at this time, but is reported to be significant.

Operation and Maintenance Costs

Operation and maintenance costs vary with each facility and its individual characteristics. Operational costs include public safety and maintenance staff salaries, electrical and water utility costs, and vehicles and equipment. Facility replacement and repair needs can include docks/slips, dry boat storage, launch ramp lanes, parking lots, pump stations, restrooms, and transient docks. Maintenance of infrastructure to service facilities, such as utilities, roads, channels, and trails, is also necessary. Maintenance costs, especially in remote areas, are not easily estimated, and no statewide analysis has been prepared. Even the statewide *California Boating Facilities Needs Assessment* survey found that 25 percent of the respondents could not provide cost estimates. As these facilities get upgraded, one must also factor in the cost of adapting to the impacts of climate change so that these facilities can be resilient to environmental changes, such as rises in sea level. Examples of operations and maintenance costs include those described below.

- In 2008, California State Parks spent $162,000 on housekeeping and operating costs for the Lake Oroville State Recreation Area's 84 boat-in campsites and $137,000 maintaining its 74 miles of non-motorized trails.
- Between 2007 and 2012, DBW provided about $80 million for local boating law enforcement, including personnel, boats, equipment, and training; and grants for abandoned vessel removal and vessel surrender. DBW provided $40 million in boating education and safety programs statewide, including to schools and the general public (including school curricula and life-jacket programs); aquatic center grants for classroom and on-the-water safety education to universities, colleges, and local entities; boating safety education multimedia campaign; and boating clean and green education. DBW treated tens of thousands of acres in the Delta at a cost of $30 million to control the growth of the aquatic invasive weeds *Egeria densa* and water hyacinth (California Department of Boating and Waterways 2012a).
- The *Sacramento-San Joaquin Delta Boating Needs Assessment 2000-2020* estimated it would cost $27 per square foot to make extensive repairs to an existing marina (California Department of Boating and Waterways 2003).
- The *California Boating Facilities Needs Assessment* noted that estimates for dredging costs varied widely, depending on factors such as tidal flows, location, and dredge disposal options. Estimated costs per cubic yard ranged from $10 to more than $50, and costs of $1,000,000 or more per facility were not uncommon (California State University, Sacramento Foundation 2002).
- DBW provided $26 million for local assistance funding for beach erosion control and protection infrastructure projects (California Department of Boating and Waterways 2012a).

Research to identify California's recreational trends is necessary to understand the demand and efficiently make facility investments that meet the state's recreation needs. A recent California State Parks survey of State park visitors cost more than $500,000.

Major Implementation Issues

Lack of Access

Californian's navigable waterways are a public trust resource, and access along those waterways is a long-standing right. In many areas, however, it is difficult to find access points. Non-motorized boats, in particular, need safe launching and takeout areas in locations that allow them to avoid in-stream water infrastructure and hazardous areas. Without clear signage, bank anglers may find it difficult to determine whether they are traversing or standing on private or public land, leaving them subject to charges of trespass. Even public lands along waterways, such as road rights-of-way and floodways, often do not provide clearly identified access.

Changes in demographics, population, and types of use may stress the capacity of water-dependent recreation resources. Population growth, if accompanied by static recreation opportunities, may cause overcrowding at existing recreation areas. The Central Valley, for example, has experienced a dramatic population boom but remains an area with insufficient access to recreation opportunities. Changes in recreation preferences resulting from demographic shifts in California's cultural makeup could also cause capacity issues if the types of recreation resources that serve the preferences of growing ethnic groups are not available, especially in disadvantaged communities. The Outdoor Foundation's *2011 Outdoor Recreation Participation Report* found that almost 10 percent of Americans would participate in paddle sports more often if there were nearby facilities.

Economic changes can have a major impact on visitor demand and availability of recreation facilities. In a depressed economy, people have less money to spend on activities and vacations. They tend to recreate closer to home, creating increased demand on public facilities near population centers. If recreation providers are also operating with reduced budgets, they may need to increase fees to an extent that activity costs become an access barrier for low-income residents at the same time that demand is increasing.

A lack of recreation facilities and safety programs in urban areas limits youths' access to the activities shown in Table 31-2. While today's youths express an interest in many types of recreation, they may not know how to safely enjoy these activities. A 2007 study found that inexperience was the most common cause (67 percent of the time) of personal watercraft accidents involving youth operators. Excessive speed was a factor in 57 percent of the accidents, followed by inattention (53 percent) (California Department of Boating and Waterways 2008).

Lack of access to State Water Project (SWP) reservoirs can reduce boating recreation. Security concerns after the September 11, 2001, terrorist attacks, and concerns about water quality impacts have reduced recreational access to some facilities. As aging SWP recreation facilities degrade, communities in the Central Valley, Los Angeles Basin, and Inland Empire regions lose these opportunities and the benefits they provide. The U.S. Coast Guard's *Recreational Boating Statistics 2011* shows that boating registration (one measure of demand) increased by 50 percent nationwide between 1988 and 2000, and California's population and boating participation days were increasing strongly (California Department of Parks and Recreation, Planning Division 2009b), but attendance at the SWP reservoirs dropped by 30 percent (California Department of Water Resources 2012).

The following examples illustrate various successful enhancements related to water recreation.

- Bringing nature back into neighborhoods and creating parkland and recreational opportunities in densely populated urban areas increases access. A section of the drainage pipe was removed from under Marsh Street Park adjacent to the Los Angeles River. The ground was then lowered to filter urban runoff before it reached the Los Angeles River. This "daylighting" of an underground stream and converting the water channel to a more natural environment has increased the recreation opportunities in this underserved area (Santa Monica Mountains Conservancy 2013b).
- Coordination between recreation and water management professionals and with urban land-use management strategies can expand the availability of water-dependent recreation resources. The secretary of the interior highlighted both the San Joaquin River Restoration Program and the Los Angeles and San Gabriel River trail improvements as "among the highest investments in the nation to support a healthy, active population … and create travel, tourism and outdoor-recreation jobs" in October 2011 (U.S. Department of the Interior 2012).
- Expanding recreation safety education in urban schools increases safe access. DWB's Boating Safety Education Program educates thousands of school age children through its

Table 31-2 California Youth's Top Rated ActivitiesThat They Would Like to Do More Often

Activity	Percent
Horseback riding	50.2
Camping (tent, recreational vehicle, trailer)	47.1
Backpacking (overnight hiking)	46.3
Mountain biking (unpaved dirt surfaces on trails or roads)	46.3
Archery	44.9
Beach activities, surf play (including sunbathing, wading, playing on beach)	43.9
Rock climbing	43.9
Day hiking on unpaved trails	42.9
Jet skis or wave runners	42.9
Paddle sports (kayaking, canoeing, rowing)	42.9
Sledding, ice skating, snow play	42.7
Snowboarding	42.7
Picnicking	41.0
Exploring tide pools	40.5
In-line skating or rollerblading	40.5
Swimming in a pool	40.5
Target shooting	40.2
Downhill skiing (snow skiing with a lift)	39.8
Visiting historical or cultural sites, museums, zoos, gardens	39.5
Waterskiing or wakeboarding	39.5
Operating motor vehicles on dirt roads or trails	39.3
Surfing or boogie boarding	39.0
Swimming in ocean, lakes, rivers, and streams	39.0
Going on a scenic ride	38.3
Martial arts/tai chi/yoga	38.0
Snowmobiling	37.6
Hunting	37.3
Cross-country skiing	37.1
Fishing	37.1
Tennis	37.1
Attending outdoor events (festivals, fairs, concerts, historical reenactments, outdoor theatre)	36.3

AquaSMART outreach program, distributing millions of copies of boating safety literature (California Department of Boating and Waterways 2009a, 2009b).

- "Nature-deficit disorder," explained in Richard Louv's book, *The Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder* (2005), can be addressed by creating opportunities for recreation activities listed in the *California Children's Outdoor Bill of Rights* (California Roundtable on Recreation, Parks and Tourism 2012). The water-dependent activities that every child should experience by their 14th year include learning to swim, going fishing, and going boating.
- Day use and camping fees at many State parks in California have increased substantially (California Department of Parks and Recreation 2012a). The department is proposing to begin collecting parking fees at many locations that were previously free (California Department of Parks and Recreation 2012b).
- The basic resident sport-fishing license fee issued by DFW has increased to $45.93 annually (California Department of Fish and Game 2012b).

Climate Change

Climate change provides both opportunities, as discussed earlier in this chapter, and challenges for California's recreation lands and programs. Not only does it affect recreational activities that are water-dependent, including boating, fishing, swimming, shoreline hiking, and winter sports (e.g., skiing and ice skating), but it also is altering the management of and demand for these recreation resources. As California's climate continues to change, existing recreational facilities situated along California's rivers, reservoirs, and beaches may be affected first. Sea level rise; changes in precipitation, temperature, and water levels; and reservoir management all affect water-side recreational opportunities and attendance. As temperatures increase, more people seek water-dependent recreation for cooling, which in turn creates more crowded conditions, less available parking, more stress on water quality, and increased trash. During the winter season, snowpack in the Cascades and Sierra Nevada is projected to decrease between 40 percent and 70 percent by 2050, reducing available areas for winter recreational activities (Natural Resources Defense Council and Protect Our Winters 2012). Higher fuel prices and other potential strategies for reducing GHGs are changing recreation preferences and the affordability of traveling to remote recreation areas. These changes increase recreational demand close to population centers and reduce recreation in wilderness areas and at remote reservoirs. However, it is unclear how these changes might intersect with current unmet demand and an increasing population.

Increased variability in annual precipitation volumes and patterns affects recreation. Furthermore, less overall rain leads to lower lake and stream levels and, combined with higher temperatures, can affect aquatic, riparian, and shoreline ecosystems. Such changes could result in decreased populations of edible fish and more pollutant accumulation in fish tissues and, thus, could affect recreational anglers, as well as subsistence fishers. Less water also adds stress to riparian habitats, which provide shade for streams as well as recreationists. On the other hand, more intense rain events localize pollutants, such as sediments, into recreational lakes and streams, increase the instability of recreation sites due to infrastructure failure (e.g., sloughing of banks and erosion of trails), and affect public safety. Changes in water levels also can affect the navigability of waterways. Rising sea levels, more intense wave actions, and changes in beach replenishment patterns squeeze coastal recreation that is bounded by development and transportation systems and damage the coast and its beaches, creating a higher need for coastal protection. Armoring coastlines and bays pose a particular threat to recreational access and beach sustainability.

Adaptation

Adaptation is a key element in preparing for the effects of climate change. As these changes to the environment continue to occur and affect water-dependent recreation (shown in Table 31-3), recreation demands shift to accommodate new climatic conditions, and more strain is put on the other management strategies, such as ecosystem restoration and water treatment. All of the above will increase costs for maintenance, restoration, and development and will affect the quality and availability of the recreation experience.

Developing adaptation strategies to prepare for these impacts will require significant planning and collaboration with multiple agencies. Research is essential for understanding the impacts of both population growth and climate change and is an important step toward efficiently addressing California's water-dependent recreation demand.

Existing and new water-dependent recreation facilities should be designed to be resilient to these environmental changes.

Increasing access to existing water-dependent recreation opportunities, such as providing more local swimming opportunities and increasing shading around existing recreation sites, would help residents adapt to a warmer climate while minimizing issues of overcrowding. Planners should take advantage of providing education and outreach at existing facilities, to inform members of the public about what they can do to adapt to and mitigate for climate change and to involve them. Education and outreach programs should stress a multi-benefit approach.

Developing urban greenways and open space to manage floods better, increase local water supply, improve water quality, and increase local recreation opportunities would provide more options for a growing population to recreate closer to home. Nevertheless, with changes in climate, there will be stress on water systems. Water-dependent recreation must be balanced with competing uses so that communities can continue to provide clean drinking water to a growing population, suitable water for agricultural production and other industrial uses, and water for the diverse water-related ecosystems in California.

Examples of how the balancing of competing water uses might be addressed include these proposed actions:

- California State Parks is preparing climate adaptation strategies to guide development in beachfront parks subject to sea level rise. For instance, sewage treatment systems are often near waterways and beaches at the lowest elevation of parks and are subject to damage from sea level rise, increased storm surge, and increased flooding. Restrooms protect water quality and public health, so a lack of sewage treatment can require closing down campgrounds and picnic areas, too.
- As coastal recreation areas become damaged and submerged as a result of rising sea levels, recreationists may select inland destinations more frequently, creating an increased demand for inland water facilities. As average reservoir levels drop, there may be a need to emphasize river recreation, such as by implementing California State Parks' "Central Valley vision for increased river access and water trails for rafters and boaters (California Department of Parks and Recreation, Planning Division 2009a).

Mitigation

Mitigation is accomplished by reducing or offsetting GHG emissions in an effort to lessen contributions to climate change. Providing local opportunities for water-dependent recreation encourages residents to use forms of transportation that are less carbon-intensive, such as running or biking. Creating more open space for water-dependent recreation in urban areas can reduce the amount of stormwater runoff, increase groundwater recharge rates and stormwater filtration opportunities, filter roadway pollution, and increase carbon sequestration, thereby reducing the energy needed to accomplish these tasks through more active measures. Mitigation strategies also should include methods to limit the impacts of visitors; to reduce GHG emissions during park development and operation; to encourage less-carbon-intensive recreational pursuits; and to incorporate existing federal, State, and local climate change strategies into water-dependent recreation areas.

Lack of Funding

Despite significant and long-standing State and federal policies supporting public access and water-dependent recreation, funding has been inadequate to meet the demand for nearby safe and affordable opportunities for all citizens. Financing influences the ability to address most outdoor recreation issues, including water-dependent recreation. Funding issues fall into four categories: (1) research and planning, (2) acquisition and development of new recreational sites, (3) operation and maintenance, and (4) the "beneficiaries pay" principle.

1. Research is critical to discerning recreation trends and needs. Recreation providers often rely on special interest research funded by manufacturers of recreation equipment or advocacy groups. California State Parks conducts impartial statewide recreation trends research every five years, which provides valuable guidance on most efficiently serving the public's needs, but public funding is scarce. Applying research findings requires planning, but funding for this step is also difficult to secure, even as California's growing population puts additional pressures on existing recreation resources.

2. When dam, reservoir, levee, or canal projects are being planned or upgraded, funding to include land acquisition and recreational facility development such as boat ramps, fishing access points, and picnic areas may not be included. One reason is that recreation beneficiaries may be different from the water project beneficiaries, which means complex funding mechanisms are required. This is a significant issue at the SWP. The Davis-Dolwig Act specifies that water contractors shall not bear the cost of recreational enhancements, but the California Environmental Quality Act (CEQA) requires project proponents to avoid or bear the cost of mitigation of significant environmental impacts (including the cost of recreational mitigation). The State has struggled to develop funding sources to meet the recreation mandates in the California Water Code.

3. Publicly owned recreation facilities strive to keep fees affordable to all segments of the population, so they often cost more to operate than they generate in entrance, rental, service, and sales revenues. This operational deficit must be funded with public dollars. Because of public funding reductions, and the difficulty of fairly assessing all beneficiaries, many water-dependent recreation facilities are aging and suffer from a lack of maintenance. As facilities age and are removed from service, recreation opportunities are reduced. Less attendance translates into reduced revenues, further reducing opportunities. Without an infusion of capital, these recreation opportunities and the benefits they bring to the State are lost.

Table 31-3 Potential Climate Change Impacts

Impact	Effect on Water-Dependent Recreation Facilities and Amenities	Effect on Recreationists
Increased sea levels and storm surges	Flooding of coastal beaches and estuaries. Erosion and damage to coastal beaches, reefs, wetlands, archaeological, and cultural sites. Sewage treatment facilities, beach restrooms, coastal roadways, lodging, homes, and marinas inundated, armored, or moved. Visual resources degraded. Armored beachfront communities may lose connectivity to the sea and associated economic benefits.	Seasonal or permanent loss of coastal trail, camping, and beach recreation. Historic facilities and sites unavailable. Impaired visual resources. Increased water quality impacts and beach closures from loss of coastal restrooms and sewage treatment facilities. Surfing opportunities degraded, relocated, or lost.
Irregular seasonal precipitation	Less water available for natural groundwater and surface water systems. More polluted water bodies.	Less opportunity to swim, boat, fish, or enjoy other water-dependent recreation. Navigation increasingly difficult.
Higher temperatures	Warmer rivers and streams will impair the coldwater food web from headwaters to the ocean. Less healthy riparian and wetland habitat.	Fewer coldwater fish (such as salmon and trout) available for anglers. Fewer predators, such as orcas and eagles, to view.
Worse ozone air pollution	More air pollution at public lands. Environmental damage to sensitive native habitats.	Increased public health impacts of outdoor recreation. Less recreation opportunity for sensitive receptors, such as children and those with respiratory difficulties. Fewer wildlife-associated recreation opportunities.
Increased seasonal flooding	Natural resources and amenities more likely to be flooded seasonally. Damage to sites and facilities. Increased construction of flood control facilities, such as levees.	Less opportunity to enjoy outdoor activities such as picnicking, camping, or trails. Visual impacts in flood-prone areas.
Increased fire danger	Possible closures of recreation areas. Risk of destruction of sites and facilities. More brush clearing around facilities and communities.	Loss of opportunity to enjoy recreation areas. Potential health threats from smoke and particulates. Visual and natural habitat impacts.
Less snow in winter	Reduced natural snow and shorter season at lower elevations. More manufactured snow necessary at winter recreation areas. Existing facilities and tourism-driven communities may become economically unsustainable and must relocate or diversify.	Less opportunity to ski, snowboard, play in the snow, or enjoy other winter recreation. Increased costs. Must drive farther from population centers to winter recreation areas.

Impact	Effect on Water-Dependent Recreation Facilities and Amenities	Effect on Recreationists
Decreased river flows/ more diversions	Decreased water quantity and quality in rivers and streams. Less sediment deposition on wetlands and beaches.	Less opportunity to boat, swim, fish or enjoy other river recreation. Loss of wetlands and beaches. Fewer wildlife-associated recreation opportunities. More costly beach replenishment activities.
Increased fuel costs	Visitation shifts to areas closer to population centers. More crowding and associated environmental impacts of exceeding carrying capacity. Shift to less-fuel-intensive recreation.	Reduced recreation choices and affordability, especially for the economically disadvantaged.

Without reliable funding, it is difficult for recreation providers to deliver quality, consistent, and relevant facilities and services to meet increasing demand. Many parks and recreation providers, faced with leaner budgets, have reduced programs and operating costs, raised fees, reduced or eliminated services, and delayed equipment purchases — as well as deferred land acquisition, facility developments, and rehabilitation and renovation of aging infrastructure. Inconsistent funding also reduces the willingness of many service providers to offer new programs even as the population increases and becomes more diverse.

4. Applying the "beneficiaries pay" principle of water management to recreation raises many questions worthy of debate. Does it conflict with public access laws (see the section "Water Managers' Role in Recreation Planning," above)? How should public land managers comply with these laws while generating the revenue they need to build, operate, and maintain facilities? Who are the beneficiaries of efforts to protect natural and cultural resources? How can recreational management costs be apportioned fairly among all beneficiaries of California's reservoirs, rivers, coastline, snowy mountains, and forests?

Examples of how to balance revenue generation with protection of natural and cultural resources and fair apportionment of recreational management costs include the following actions:

- The federal Land and Water Conservation Fund provides 50 percent of the funding for impartial research, such as the California Outdoor Recreation Plan prepared by California State Parks. Matching funds are becoming more difficult to secure.
- Operational deficits (the difference between revenues and expenses) at SWP recreational units operated by California State Parks are as high as $2.6 million annually. State funding for public safety at water-dependent recreation areas along the SWP can ease the burden on local communities.
- Eighty percent of California's hydropower dams are regulated through long-term licenses issued by the Federal Energy Regulatory Commission (FERC). One half of those facilities (150 dams), many with degraded recreational facilities, are scheduled to be relicensed in the next 15 years. Many recently issued FERC licenses contain enhanced terms and conditions to protect or improve recreation, fisheries, wildlife, water quality, wetlands, and cultural resources. For instance, when the Sacramento Municipal Utility District (SMUD) filed a

FERC license application for its Upper American River Project, SMUD proposed to spend approximately $12.5 million over the life of the license, including a new recreation plan to enhance recreation throughout the project boundary by reconstructing facilities. The application included implementation of a maintenance plan for service roads in forests, which would coordinate access to recreational opportunities. SMUD also proposed to incorporate releases of additional water from Ice House Dam, during the three weekends after Labor Day during "wet" and "above normal" water years, for whitewater recreation (Sacramento Municipal Utility District 2005, 2008).

- Local taxes may be more acceptable to voters when tied to specific projects that benefit them. East Bay Regional Parks District is funded, in part, by a homeowner's tax of $10 annually per $100,000 of assessed valuation. This tax funds popular water-based recreation improvements at Big Break Regional Shoreline, along the San Francisco Bay Trail, in the Delta, and in many other areas of Contra Costa County. The list of planned projects and benefits was included in the campaign literature for this measure, which was approved by voters in 2008 (East Bay Regional Park District 2012).

Natural Resources Degradation

Natural resource values often define the character and aesthetic appeal of water-dependent recreation, making it desirable and interesting to visitors. For instance, whitewater rafting occurs where rivers and streams descend rapidly through the landscape. Bicycling and hiking is popular along vegetated rivers and streams, and surfing and swimming require good water quality. Fishing often depends on the seasonal availability of game fish, water quality and quantity, riverine habitat qualities, and access. Hunting and viewing of migratory waterfowl require the timely flooding of seasonal and permanent wetlands with sufficient water to provide food resources, protective cover, and brooding areas. California is home to two World Surfing Reserves locations, which acknowledge the "worth of a wave and its environs" (World Surfing Reserves 2011). Degradation of these natural resources can affect the recreation experience and reduce usage.

Recreation is often a concurrent use, not a sole use, of many open space lands, so a wide range of natural resource management actions can affect recreational experiences. Pollution or diversion of surface waters can limit visitor use and enjoyment of waterways and lakes. Dams and other flood management measures can affect recreation through reducing the fishery, making navigation more difficult, changing bank characteristics, and reducing native habitat. Water infrastructure and bank protection measures can decrease the sediment supply to the coast, narrowing beaches and diminishing coastal access and recreation opportunities. More frequent and prolonged drought events can further degrade the natural resources and provide an opportunity for invasive species to take over natural areas.

Without adequate recreation resource management, outdoor recreation visitors can also threaten ecosystem functions; disrupt and displace wildlife; or degrade the natural, environmental, and aesthetic quality of an area. Visitors unfamiliar with ecological processes or environmental ethics are often unaware of the consequences of their actions. California's increasing population puts additional stress on parklands and their natural resources.

Invasive Species Impacts

The expansion of invasive species, particularly from the San Francisco estuary and the Colorado River, could have far-reaching effects on California's ability to provide adequate water to its constituents.

Recreational uses of waterways, including along the SWP, have been negatively affected in the Delta region by invasive plant species. Invasive aquatic plants such as *Egeria densa* and water hyacinth limit recreational and commercial vessel navigation and passage, restrict water flows, clog water intakes, and entrap sediments. These nonnative plants potentially decrease productivity of Delta fisheries by hindering and impeding anadromous and pelagic fish migration, competing with native vegetation, causing anoxic (low-oxygen) conditions and threatening water quality. These invasive plants also increase agricultural pumping maintenance requirements and other associated costs. The expansion rate of these invasive species in the Delta is approximately 10 percent per year. Invasive plants also are opportunistic and are able to occupy areas stressed by drought, fire, and other conditions caused by changes in climate. Once established, these plants not only out-compete native vegetation, but also tend to utilize more water than natives and can create greater fire and flooding hazards in riparian areas (California Department of Boating and Waterways 2012a).

The quagga mussel is a close relative of the zebra mussel, and both have similar environmental and economic impacts. Quagga mussels were first found in the Colorado River system in January 2007 and later were found in San Diego and Riverside counties. Zebra mussels were found in a San Benito County reservoir in January 2008. Recreation users can inadvertently spread these invasive species to other water bodies, adversely affecting natural resources, native species, and maintenance costs. They can be easily transported by a boat or its trailer. Boat engines and other parts of the craft also can carry mussel larvae — called veligers — which can spread into waterways and lakes. The spread of the mussels threatens water delivery systems, hydroelectric facilities, agriculture, recreational boating and facilities, fishing, and the environment in general, in some of the following ways (California Department of Boating and Waterways 2012b):

- Reducing fish populations.
- Limiting or eliminating recreational opportunities to boaters.
- Damaging boat engines by blocking the cooling system.
- Jamming boat steering equipment.
- Increasing drag at the bottom of a boat, wasting fuel and reducing speed.
- Requiring scraping and repainting of boat bottoms.
- Colonizing boat ramp and boat docks.

Invasive species control is increasing park operational costs. Recreational boaters and facility managers bear some of the cost of protecting water supplies, even though they were not responsible for the initial invasions.

Examples of attempts at invasive species control and associated costs include the following actions:

- The Santa Ana and Santa Clara rivers have been invaded by the giant reed (*Arundo donax*). Many resources and much money have been spent in trying to eradicate this species from recreational waterways (California Department of Boating and Waterways 2012a).

- The East Bay Municipal Utility District's reservoirs have restricted access, requiring all incoming boats to be inspected. Boats coming from outside California or Southern California counties are being turned away (East Bay Municipal Utility District 2012).
- A multiagency taskforce that includes DFW, DWR, DBW, the California Department of Food and Agriculture, California State Parks, and multiple federal partners have developed a boater education program aimed at preventing the spread of quagga and zebra mussels. The campaign asks boaters to clean, drain, and dry their boats before moving from one water body to another (California Department of Boating and Waterways 2009c).

Water Quality Impacts

Water quality can both affect and be affected by water-dependent recreation. California has a variety of water-dependent recreation opportunities, with differing levels of public contact. In some cases the public contact is a consequence of impaired water quality, and in other cases it is because of the potential impact of recreational activities on domestic water supplies. Water quality issues may be used to determine levels of recreation access, such as prohibiting all public access; prohibiting any body contact with the water; or allowing swimming, fishing, paddling, or motor boating.

Untreated or partially treated sewage released into the ocean has led to highly publicized closures of public beaches. Stormwater runoff and non-point-source pollution have major impacts on coastal water quality. According to the Heal the Bay organization, funding for monitoring is often difficult to find (Heal the Bay 2012). Fertilizers and chemicals from agricultural runoff may also contribute to poor water quality. With the potential for flashier floods and more frequent extreme storm events due to changes in climate, increased erosion of streambanks and siltation of waterways is anticipated. Contaminated lakes, rivers, and streams, as well as eroded banks and trails, not only present both health and safety risks to those participating in contact and non-contact water recreation, but also can significantly diminish the recreation experience. Poor water quality can cause marina closures to protect both the users and the environment, such as pollution-related beach closures or navigable waterway barriers. Water diverted from natural streambeds reduces opportunities for whitewater boating, causes higher water temperatures that cannot sustain healthy fisheries, and may increase pollutant concentrations.

Water-dependent recreation can also negatively affect water quality. Human-source contamination, such as untreated sewage and petroleum products discharged from houseboats and other pleasure craft, can be a significant problem in reservoirs, in bays, and along beaches. Some watershed land and reservoir managers restrict public access because of these concerns.

Examples:

- Heal the Bay has been publishing an *Annual Beach Report Card* for 21 years, which identifies impaired beaches (Heal the Bay 2012).
- The State Water Resources Control Board (SWRCB) is currently proposing a statewide policy for bacterial standards for water contact recreation in the fresh waters of California. Elements of the final policy may include a revised indicator organism (such as *E. coli*), a risk protection level, and expanded and standardized bacteria control implementation (State Water Resources Control Board 2008).

- The SWRCB maintains a Web site to help recreationists investigate water quality at beaches, at rivers, and in fish (State Water Resources Control Board 2013).

Water Quantity Changes

Dramatically changing water levels affect the availability of different recreation opportunities. Low levels can separate boat ramps and launches from the water's edge. Folsom Lake and Lake Oroville are examples where changing water levels often affect recreation opportunities. In the summer of 2008, the water level at Folsom Lake was so low that a 5-mile-per-hour speed limit was imposed on all vessels and all the boat ramps were closed.

Low river flows can block public access, eliminating opportunities to boat or fish. Water diverted from natural streambeds affects opportunities for whitewater boating. Early summer season water transfers and prolonged drought periods can cause extremely low water levels at reservoirs later, affecting the availability of recreation opportunities.

Inadequate Agency/Organization Coordination

Funding deficiencies and impacts on recreation resources are exacerbated by a lack of coordination among agencies, both those that manage water resources and those that provide recreational services. Agencies are too often limited in scope and effectiveness in recognizing and mitigating trends affecting resource conditions, particularly those outside their immediate jurisdiction. Although partnerships and cooperation among agencies, organizations, and individuals have grown, efforts at the watershed or landscape level are often fragmented, and opportunities to achieve broader goals are missed, placing both resources and the public at risk. Good coordination between reservoir operators and recreation facility operators is needed to maximize recreation potential while meeting other authorized purposes. A lack of coordination between the managing agencies and the recreation providers can result in unreliable water recreation resources, unbudgeted financial implications, staffing problems, and missed partnerships that could provide expanded recreation opportunities.

Examples of collaborative processes aimed at maximizing recreation potential, while meeting other authorized purposes, include the following proposals and actions.

- The integrated regional water management (IRWM) planning process is aimed at securing long-term water supply reliability within California by first recognizing the interconnectivity of water supplies and the environment and then pursuing projects yielding multiple benefits for water supplies, water quality, and natural resources. The IRWM planning process also must address reducing GHG emissions and being resilient to climate change, which in turn provides an opportunity for communities to identify water-dependent recreation strategies that assist in mitigating and adapting to climate change (citation needed). Adding recreation coordination within the IRWMs would help leverage existing water-dependent recreation resources, increase dependable opportunities, and disperse recreation demand.
- The Santa Ana Watershed Project Authority has been working with the Crest-to-Coast Partnership to complete the Santa Ana River Trail and add parkway elements to the river. The effort is funded by the counties and cities in the watershed and by environmental groups interested in completing a 110-mile trail system (Santa Ana Watershed Project Authority 2012).

- California State Parks is proposing partnerships between land-owning agencies and recreation businesses in the Central Valley and the Delta to concentrate intensely developed recreational facilities and services, such as campgrounds and equipment rentals, into "base camps" to minimize impacts on natural resources while providing low-impact recreational access (California Department of Parks and Recreation, Planning Division 2009a, 2011b).
- The State Water Project Recreation Coordinating Committee, established in 1960, provides interagency collaboration.

Recommendations

Lack of Access

1. All public agencies in California should endeavor to better protect and enhance public access to waterways, lakes, and beaches within their jurisdiction.
2. The California State Lands Commission (SLC) could lead an identification and education effort to clarify existing legal points of river access.
3. Recreation and water management agencies need to increase partnerships with schools to provide public safety education that introduces youths from urban and low-income communities to water-dependent recreation activities near them and that includes injury and drowning prevention strategies, such as DWR's Aquatic Adventure program and California State Parks' Junior Lifeguard Program.
4. In developing water-dependent recreation opportunities, agencies should consider the needs of the public and low-income communities, and increased population and diversity as identified in planning documents such as the *California Outdoor Recreation Plan* updates.
5. Use existing data and new surveys to determine recreation needs that might be met by incorporating recreation more fully into State and regional water management planning.
6. Collect data on visitation rates versus reservoir water levels and downstream flow rates and use these data to help optimize the timing of water that is released or held for recreation, to the degree possible consistent with other water needs. This information could be used to plan recreation facility schedules and staffing.
7. DWR should include recreation use data and trends, unmet demand, improvement goals, and development milestones in Bulletin 132 about the management of the SWP.
8. Develop partnerships between recreation planners, recreation equipment manufacturers and retailers, and universities to coordinate the monitoring of public recreation use, equipment, and emerging water-dependent recreation trends.
9. Develop strategies to incorporate recreation facilities, such as trails, in the planning design of new floodways, levees, environmental restoration, and other water facilities.
10. Maintain access to public beaches.
11. Participate in the National Water Trails System.
12. Consider removal of unnecessary navigational barriers.

13. Consider legislation or regulatory changes to address public access liability concerns of private property owners adjacent to navigable waterways.

14. Construct water-dependent recreational facilities in urban areas and disadvantaged communities.

15. Develop more robust marketing strategies, including free days, special events, and incentives to visit more often to attract new users.

16. California State Parks should quantify unmet recreation demand in the SWP and Central Valley Flood Protection Plan market regions and develop a comprehensive strategy for meeting the needs identified.

17. Incorporate public transit and bicycle access to water-dependent recreational facilities and lands in county or regional transportation plans.

18. Perform research on the water quality impacts of recreation and develop best management practices for monitoring and reducing these impacts.

19. Develop multilingual adult education programs to introduce safe practices in water-dependent recreation.

Climate Change

20. Water-dependent recreation providers should create/participate in a climate change network of agencies that keeps members abreast of new data and strategies and provides opportunities for collaboration.

21. Conduct climate change adaptation planning for each region of the state. Create a geographic-information-systems-based tool to identify water-dependent recreation areas and resources vulnerable to climate change impacts, such as low elevations vulnerable to sea level rise, floodplains, and areas with plants and wildlife sensitive to drought.

22. Identify a procedure to incorporate climate change assessments within all infrastructure planning, budgeting, and project development that reveals challenges to, and opportunities for, water-dependent recreation resources.

23. Design facilities to accommodate environmental and management changes, including longer boat ramps, as well as moveable facilities such as floating campsites, lifeguard towers, and restrooms. Conduct systematic assessments of potential impacts of climate change on recreation resources to identify suggested adaptations.

24. If average reservoir levels drop, there may be a need to emphasize river recreation, such as through implementing California State Parks' *Central Valley Vision Implementation Plan* for increased river access and water trails for rafters and boaters.

25. Consider developing artificial reefs to prevent coastal beach and bluff erosion and to enhance surfing.

26. Develop climate change education programs at parks.

27. Consider regulatory changes to facilitate easier climate change adaptation and mitigation project permitting at public parks and beaches.

28. Develop a CEQA checklist for potential impacts of climate change adaptation infrastructure, such as sea walls, on recreation resources.

Lack of Funding

29. Develop more robust funding streams for impartial recreation research, including assessments of the full benefits of water-dependent recreation.

30. Strengthen the requirement that IRWM plans consider water-dependent recreation and that multi-benefit projects, such as those with recreation components, receive funding priority.

31. Update the Davis-Dolwig Act provisions to fund water-dependent recreation enhancements more fully at federally authorized and State-authorized water projects.

32. Work closely with hydroelectric dam operators participating in FERC relicensure to identify adequate funding sources for proposed recreation enhancements.

33. Update State funding programs, such as that authorized by the Davis-Grunsky Act, which prioritize multi-benefit projects and encourage future grant programs to give priority to multi-benefit flood control and water supply projects and programs that incorporate recreation.

34. Quantify how reduced water-dependent recreation opportunities — such as low lake/reservoir levels occurring during peak visitation periods that affect visitor spending — can affect park budgets and local economies.

35. Develop more realistic cost/benefit analyses that allow appropriate cost-sharing among all beneficiaries of water projects.

36. Develop more stable State and local funding sources to ensure safe, affordable public access to recreational opportunities.

37. Maintain an updated list of deferred maintenance of recreational facilities to facilitate applications for federal, State, and philanthropic funding.

38. Develop funding to resolve legacy impacts, such as reduced fisheries and restricted access to inland waterways, especially in or near disadvantaged communities.

39. Develop more flexible funding strategies for facilities that can be constructed only during low-water periods (e.g., boat ramps and docks).

40. Consider providing mitigation funding for recreational facilities affected by reservoir reoperation for flood management and water supply.

41. Reduce construction costs for water-dependent recreation projects by revising water quality standards such that turbidity levels may be allowed up to levels found in the waterway during heavy rainstorms.

42. Consider expanding recreation-equipment-based fees, such as fees on hunting and fishing equipment, to a wider array of recreation equipment to fund new recreation facilities or renovate existing ones.

Natural Resources Degradation

43. Conduct flow assessments on major river systems to analyze the impacts of flow levels on wildlife, habitats, and recreation opportunities.
44. Evaluate and periodically re-examine scientifically valid studies of the carrying capacity of proposed and existing sites for water-dependent recreation, to help prevent degradation of water quality and wildlife habitat. Examine and utilize data collected by agencies such as the U.S. Bureau of Reclamation, the U.S. Army Corps of Engineers, and FERC.
45. Maintain and restore vegetation along rivers and streams that support and enhance outdoor recreation.
46. Restore sustainable populations of native and/or game fish.
47. Consider river naturalization or de-channelization to provide urban open space along rivers or canals for recreation.
48. Create multi-benefit flood control, water transfer, and storage facilities that emulate natural ecological systems and accommodate recreational access.
49. Create partnerships with education providers to educate youths about outdoor ethics and about preserving and protecting natural resources. Examples of progress on this recommendation include work being done by the Biodiversity Council and Stewardship Council. Use waterside parks as outdoor classrooms to teach water resources management topics.
50. Improve sand flow for natural beach replenishment by reestablishing soft-bottom creeks and rivers, removing dams that impede sand flow, and preventing groins and jetties that also impede sand flow.
51. Develop and share sand replenishment and conservation strategies among agencies.
52. Integrate recreational facilities into habitat mitigation projects.

Invasive Species Impacts

53. Inventory water facilities and measure their vulnerability to specific invasive species known to be transported by recreation users.
54. Prioritize and develop preventive measures and response strategies for the most at-risk facilities providing water-dependent recreation.
55. Develop stable funding to expand monitoring and preventative measures with a combination of “beneficiary pays” and “stressor pays” principles.

56. Develop long-term watershed-based strategies for invasive species control that affects water-dependent recreation.

57. Develop regional and statewide recreation provider partnerships to establish consistent inspection guidelines, reduce cost, and allow easier compliance with invasive species inspection programs.

58. Expand research into efficient management strategies to reduce recreation-related impacts.

59. Engage volunteer groups in management programs that reduce recreation-related impacts.

Water Quality Impacts

60. Educate residents and businesses in the watershed about their role in protecting water quality and recreational opportunities. Explain water quality issues to the public in more understandable and compelling ways.

61. Test surface water quality more often and make real-time water quality information for surface waters more accessible online and at recreation sites.

62. Develop best management practices guidance for reducing recreation-based water quality impacts, including impacts from recreation vehicles — such as reduced pollution of marine engines and parking lot runoff.

63. Enter into agreements with other agencies and governing bodies, as appropriate, to secure their cooperation in maintaining or restoring the quality of water resources utilized for recreation.

64. Take proactive measures to limit sea level rise impacts on water-side sewage facilities.

65. Integrate stormwater management devices/techniques into open space or parks, or both, to address water quality and quantity issues. Stormwater can be redirected from impervious surfaces (e.g., roads, driveways, sidewalks, and rooftops) and into open space/park land where stormwater devices (e.g., vegetated swales, retention areas, infiltration basins, and porous pavement) capture runoff, remove pollutants, and recharge aquifers.

66. Develop a plan to resolve legacy pollution impacts on recreational waters.

Water Quantity Changes

67. Develop and maintain closer working relationships between water management agencies, such as DWR and the U.S. Bureau of Reclamation, and water-dependent recreation providers, such as East Bay Regional Park District and California State Parks, so that recreation planning and operations are better incorporated into water management planning.

68. Design and construct facilities to accommodate environmental and management changes, including longer boat ramps as well as moveable facilities, such as floating campsites, lifeguard towers, and restrooms.

69. Develop plans for accommodating increased precipitation variability and uncertainty, including drought contingency planning, for parks.

70. Develop and implement plans to minimize artificial sedimentation that creates recreational boating barriers.

Agency/Organization Coordination

71. Promote and establish effective partnerships among federal agencies, State and local governments, California tribes, and the private sector for operation, maintenance, and law enforcement at water-dependent recreation sites.

72. Work to maintain consistency between the *California Water Plan* and other agency reports, such as the *California Outdoor Recreation Plan* updates and all federally authorized and State-authorized water projects.

73. Coordinate research needs with recreation-serving businesses and manufacturers.

74. Provide an online searchable database of recreation-oriented educational opportunities offered by agencies and organizations.

75. Provide an online searchable database of recreation-oriented volunteer opportunities offered by agencies and organizations.

76. Include collaboration time and funding in project schedules and budgets to determine whether the project can accommodate water-dependent recreation needs.

77. Invite stakeholder collaboration in the project formulation stage to determine whether the project can accommodate water-dependent recreation needs.

References

References Cited

California Department of Boating and Waterways. 2003. *Sacramento-San Joaquin Delta Boating Needs Assessment 2000-2020*. Sacramento (CA): California Department of Boating and Waterways. Viewed online at: http://www.dbw.ca.gov/Reports/deltaindex.aspx. Accessed: December 2009.

———. 2008. *2007 California Boating Safety Report*. Sacramento (CA): California Department of Boating and Waterways. 68 pp. Viewed online at: http://www.dbw.ca.gov/Reports/BSRs/2007/PDF/2007CABoatingSafetyReportComplete.pdf. Accessed: December 2009.

———. 2009a. "The Wonderful World of AquaSMART." Sacramento (CA): California Department of Boating and Waterways. [Web page.] Viewed online at: http://www.dbw.ca.gov/AquaSmart/. Accessed: December 2009.

———. 2009b. "Safety and Education." Sacramento (CA): California Department of Boating and Waterways. [Web page.] Viewed online at: http://www.dbw.ca.gov/BoaterInfo/Education.aspx. Accessed: December 2009.

———. 2009c. *Protect Your Boat! Fight Quagga and Zebra Mussels: A Guide to Cleaning Boats and Preventing Mussel Damage*. Sacramento (CA): California Department of Boating and Waterways. 20 pp. Viewed online at: http://www.nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=4957. Accessed: August 2012.

———. 2009d. *Non-Motorized Boating in California*. Sacramento (CA): California Department of Boating and Waterways.

———. 2011. *Total Vessel Registrations by County as of 31 Dec. 2010*. Sacramento (CA): California Department of Boating and Waterways. Viewed online at: http://dbw.ca.gov/PDF/VesselReg/Vessel10.pdf. Accessed: March 2010.

———. 2012a. "Aquatic Weed Control Program." Sacramento (CA): California Department of Boating and Waterways. [Web page.] Viewed online at: http://www.dbw.ca.gov/Environmental/Aquatic.aspx. Accessed: August 2012.

———. 2012b. "Quagga & Zebra Mussels." Sacramento (CA): California Department of Boating and Waterways. [Web page.] Viewed online at: http://www.dbw.ca.gov/BoaterInfo/QuaggaLoc.aspx. Accessed: August 2012.

California Department of Finance. 2013. "Demographic Research." Sacramento (CA): California Department of Finance. [Web page.] Viewed online at: http://www.dof.ca.gov/research/demographic/. Accessed: March 8, 2012.

California Department of Fish and Game. 2012a. Department of Fish and Game Statistics. Sacramento (CA): California Department of Fish and Game. [Web page.] Viewed online at: http://www.dfg.ca.gov/licensing/statistics. Accessed: March 2012.

———. 2012b. Sport Fishing Fees and Descriptions. Sacramento (CA): California Department of Fish and Game. [Web page.] Viewed online at: http://www.dfg.ca.gov/licensing/fishing/fishdescrip.html. Accessed: December 2012.

California Department of Parks and Recreation. 2009a. *Central Valley Vision Implementation Plan: Outdoor Recreation for a Growing Population*. Sacramento (CA): California State Parks. 40 pp. Viewed online at: http://www.parks.ca.gov/CentralValleyVision. Accessed: April 10, 2013.

———. 2009b. *Complete Findings: Survey on Public Opinions and Attitudes on Outdoor Recreation in California 2009.* Sacramento (CA): California Department of Parks and Recreation. 300 pp. Research conducted by California Polytechnic State University's Recreation, Parks, and Tourism Administration Department and the University of Utah. Viewed online at: http://www.parks.ca.gov/pages/795/files/2009%20spoa%20complete%20findings%209_28_09.pdf. Accessed: April 10, 2013.

———. 2012a. "Reservations and Fees." Sacramento (CA): California Department of Parks and Recreation. [Web page.] Viewed online at: http://www.parks.ca.gov/?page_id=737. Accessed: December 2012.

———. 2012b. "Fee-Based Parking Implemented to Help Keep South Yuba River State Park Open." Sacramento (CA): California Department of Parks and Recreation. [News release: April 20, 2012.] Viewed online at: http://www.parks.ca.gov/pages/712/files/2012south%20yuba%20river%20parking%20fees%20begin%20news%20release%20.pdf. Accessed: April 10, 2013.

California Department of Parks and Recreation, Planning Division. 2009. *California Outdoor Recreation Plan 2008.* Sacramento (CA): California Department of Parks and Recreation. 150 pp. Viewed online at: http://www.parks.ca.gov/pages/795/files/2009-2014%20corp.pdf. Accessed: April 10, 2013.

———. 2011a. *California Outdoor Recreation Economic Study: Statewide Contributions and Benefits*. Sacramento (CA): California Department of Parks and Recreation. Prepared by BBC Research & Consulting. Viewed online at: http://www.parks.ca.gov/pages/795/files/ca%20outdoor%20rec%20econ%20study-statewide%2011-10-11%20for%20posting.pdf. Accessed: August 2012.

———. 2011b. *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*. Sacramento (CA): California Department of Parks and Recreation. Viewed online at: http://www.parks.ca.gov/DeltaRecreation. Accessed: April 10, 2013.

——— 2012. *Draft Findings, Survey on Public Opinions and Attitudes on Outdoor Recreation in California 2012.* Sacramento (CA): California Department of Parks and Recreation. Research conducted by California Polytechnic State University's Recreation, Parks, and Tourism Administration Department and the University of Utah.

California Department of Water Resources. 2012. *Management of the California State Water Project*. Bulletin 132-08. Covers activities during calendar year 2007. Sacramento (CA): California Department of Water Resources.

California Roundtable on Recreation, Parks and Tourism. 2012. *California Children's Outdoor Bill of Rights.* Sacramento (CA): California Roundtable on Recreation, Parks and Tourism. Viewed online at: http://calroundtable.org/Copy_of_cobor.htm. Accessed: April 10, 2013.

California State Lands Commission. 2001. *Public Trust Doctrine*. Sacramento (CA): California State Lands Commission. 16 pp. Viewed online at: http://www.slc.ca.gov/policy_statements/public_trust/public_trust_doctrine.pdf. Accessed: April 11, 2013.

———. 2010. "Public Trust." Sacramento (CA): California State Lands Commission. [Web page.] Viewed online at: http://www.slc.ca.gov/Policy_Statements/Public_Trust_Home_Page.html. Accessed: April 11, 2013.

California State University, Sacramento Foundation. 2002. *California Boating Facilities Needs Assessment*. Sacramento (CA): California Department of Boating and Waterways. Prepared for the California Department of Boating and Waterways. Five volumes. Viewed online at: http://www.dbw.ca.gov/Reports/CBFNA.aspx. Accessed: April 10, 2013.

County of Sacramento. 2009. "Regional Parks." Sacramento (CA): County of Sacramento. [Web page.] Viewed online at: http://www.msa2.saccounty.net/parks/Pages/RegionalParksDetails.aspx?pn=American%20River%20Parkway. Accessed: August 2012.

East Bay Municipal Utility District. 2012. "Invasive Mussel Prevention." Oakland (CA): East Bay Municipal Utility District. [Web page.] Viewed online at: https://www.ebmud.com/recreation/quaggazebra-mussel-prevention-program. Accessed: August 2012.

East Bay Regional Park District. 2012. "Measure WW." [Web page.] Viewed online at: http://www.ebparks.org/planning/ww. Accessed: May 2012.

Federal Energy Regulatory Commission. 2001. *Report on Hydroelectric Licensing Policies, Procedures, and Regulations: Comprehensive Review and Recommendations Pursuant to Section 603 of the Energy Act of 2000*. Washington (DC): Federal Energy Regulatory Commission, Office of Energy Policy. 145 pp. Viewed online at: http://www.ferc.gov/legal/maj-ord-reg/land-docs/ortc_final.pdf. Accessed: April 11, 2013.

Gies E. 2006. *The Health Benefits of Parks: How Parks Help Keep Americans and Their Communities Fit and Healthy*. San Francisco (CA): Trust for Public Land. 26 pp. Viewed online at: http://cloud.tpl.org/pubs/benefits_HealthBenefitsReport.pdf. Accessed: April 15, 2013.

Groth P, Miller R, Nadkarni N, Riley M, and Shoup L. 2008. *Quantifying the Greenhouse Gas Benefits of Urban Parks*. San Francisco (CA): Trust for Public Land. 43 pp. [White paper.] Prepared by ICF International. Prepared for: Trust for Public Land. Viewed online at: http://cloud.tpl.org/pubs/benefits_greenhouse_gases_and_parks_whitepaper.pdf. Accessed: August 2012.

Heal the Bay. 2012. *Annual Beach Report Card*. Viewed online at: http://brc.healthebay.org/. Accessed: August 2012.

Louv R. 2005. *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*. Chapel Hill (NC): Algonquin Books. 323 pp.

Natural Resources Defense Council and Protect Our Winters. 2012. *Climate Impacts on the Winter Tourism Economy in the United States*. 33 pp. Prepared by Elizabeth Burakowski and Matthew Magnusson, University of New Hampshire. Viewed online at: http://www.nrdc.org/globalwarming/files/climate-impacts-winter-tourism-report.pdf. Accessed: April 16, 2013.

Outdoor Industry Association. 2012. *The Outdoor Recreation Economy*. Boulder (CO): Outdoor Industry Association. Viewed online at: http://www.outdoorindustry.org/pdf/OIA_OutdoorRecEconomyReport2012.pdf. Accessed: October 2012.

Pendleton LH, and Rooke J. 2006. *Understanding the Potential Economic Impact of Marine Recreational Fishing: California*. 20 pp. Viewed online at: http://www.dfg.ca.gov/marine/pdfs/binder3di.pdf. Accessed: April 16, 2013.

Sacramento Municipal Utility District. 2005. Upper American River project application. Sacramento (CA): Sacramento Municipal Utility District. 309 pp. FERC Project No. 2101.

———. 2008. "Upper American River Project Hydro Relicensing." Sacramento (CA): Sacramento Municipal Utility District. [Web page.] Viewed online at: http://hydrorelicensing.smud.org/. Accessed: December 2009.

Santa Ana Watershed Project Authority. 2012. "Santa Ana River Trail & Parkway." [Web page.] Viewed online at: http://www.sawpa.org/collaboration/projects/santa-ana-river-trailparkway/. Accessed: April 11, 2013.

Santa Monica Mountains Conservancy. 2013a. "Tujunga Wash Greenway Restoration Project." [Web page.] Viewed online at: http://www.lamountains.com/parks.asp?parkid=671. Accessed: April 11, 2013.

———. 2013b. "Los Angeles River Greenway." [Web page.] Viewed online at: http://www.lamountains.com/parks.asp?parkid=20. Accessed: April 11, 2013.

State Water Resources Control Board. 2008. Proposed revision to the bacterial standards for water contact recreation in fresh waters of California (under development). Sacramento (CA): State Water Resources Control Board. Viewed online at: http://www.swrcb.ca.gov/plans_policies/. Accessed: December 2009.

———. 2013. "Welcome to My Water Quality." Sacramento (CA): State Water Resources Control Board. [Web site.] Viewed online at: http://www.mywaterquality.ca.gov/index.shtml. Accessed: April 15, 2013.

Stevens J. [Date unknown.] Common Highways, and Forever Free: The Public Right of Navigation. Public Trust Doctrine Appendix E. Viewed online at: http://www.dbw.ca.gov/PDF/PublicTrustDoctrine.pdf. Accessed: October 2012.

Surf-First and the Surfrider Foundation. 2011. *A Socioeconomic and Recreational Profile of Surfers in the United States*. Prepared by Wager GS, Nelson C, and Walker M. 13 pp. Viewed online at: http://www.surfrider.org/coastal-blog/entry/a-socioeconomic-and-recreational-profile-of-surfers-in-the-united-states. Accessed: April 15, 2013.

U.S. Coast Guard. 2012. *Recreational Boating Statistics 2011*. Viewed online at: http://www.uscgboating.org/assets/1/Publications/2011BoatingStatisticsreport.pdf. Accessed: April 8, 2013.

U.S. Department of the Interior. 2012. *America's Great Outdoors: A Promise to Future Americans*. Viewed online at: http://americasgreatoutdoors.gov/.

U.S. Department of the Interior, Fish and Wildlife Service. 2012. *FY 2012 Budget Justification*. Wildlife Restoration. Viewed online at: http://www.fws.gov/budget/2012/PDF%20Files%20FY2012%20Greenbook/25.%20Wildlife%20Restoration%202012.pdf. Accessed: October 2012.

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2011. *2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*. Washington (DC): U.S. Fish and Wildlife Service. 70 pp. Viewed online at: http://www.census.gov/prod/2013pubs/fhw11-ca.pdf. Accessed: April 23, 2013.

World Surfing Reserves. 2011. "World Surfing Reserves Manifesto." Viewed online at: http://www.worldsurfingreserves.org/wsr-manifesto. Accessed: Jan. 3, 2012.

Personal Communications

California Department of Boating and Waterways. 2012. E-mail correspondence May 8, 2012.

State Water Project Recreation Coordinating Committee. Meeting May, 2012.

Additional References

California Department of Boating and Waterways. 2006. *24th Biennial Report of the California Department of Boating and Waterways: July 1, 2002-June 30, 2004*. Sacramento (CA): California Department of Boating and Waterways. 48 pp. Viewed online at: http://www.dbw.ca.gov/PDF/Reports/24Biennial.pdf. Accessed: April 10, 2013.

California Department of Parks and Recreation. 2009. *Changing Climate, Changing Parks: An Outline of Key Concepts*. Sacramento (CA): California Department of Parks and Recreation. 6 pp. [Internal document.]

California Department of Parks and Recreation, Planning Division. 2002. *California Outdoor Recreation Plan 2002*. Sacramento (CA): California Department of Parks and Recreation. Viewed online at: http://www.parks.ca.gov/pages/795/files/2002corp%20%282%29.pdf. Accessed: April 10, 2013.

———. 2011. The California Park Planner. November 2011 issue. Sacramento (CA): California Department of Parks and Recreation. Viewed online at: http://www.parks.ca.gov/pages/795/files/nov%202011%20capp_final_11_29_11.pdf. Accessed: August 2012.

California Travel and Tourism Commission. 2012. *California Tourism Highlights, 2010*. 2 pp. Viewed online at: http://industry.visitcalifornia.com/media/uploads/files/editor/Research/California_Tourism_Highlights_2010_July18.pdf. Accessed: March 2012.

Dean Runyan Associates, Inc. 2011. *California Travel Impacts by County 1992-2009*. Sacramento (CA): California Travel and Tourism Commission. 149 pp. Viewed online at: http://www.visitcalifornia.com/media/uploads/files/editor/Research/2010_California_Tourism_Impact.pdf. Accessed: March 2012.

Friends of the River and the California Hydropower Reform Coalition. 2006. *Rivers of Power: A Citizen's Guide to River Restoration through Hydropower Reform*. Berkeley (CA): California Hydropower Reform Coalition. 12 pp. Viewed online at: http://www.hydroreform.org/sites/www.hydroreform.org/files/Rivers%20of%20Power.pdf. Accessed: December 2009.

Outdoor Foundation. 2011. *Outdoor Recreation Participation Report 2011*. Boulder (CO): Outdoor Foundation. Viewed online at: http://www.outdoorindustry.org/participation-studies.php?action=detail&research_id=146. Accessed: August 2012.

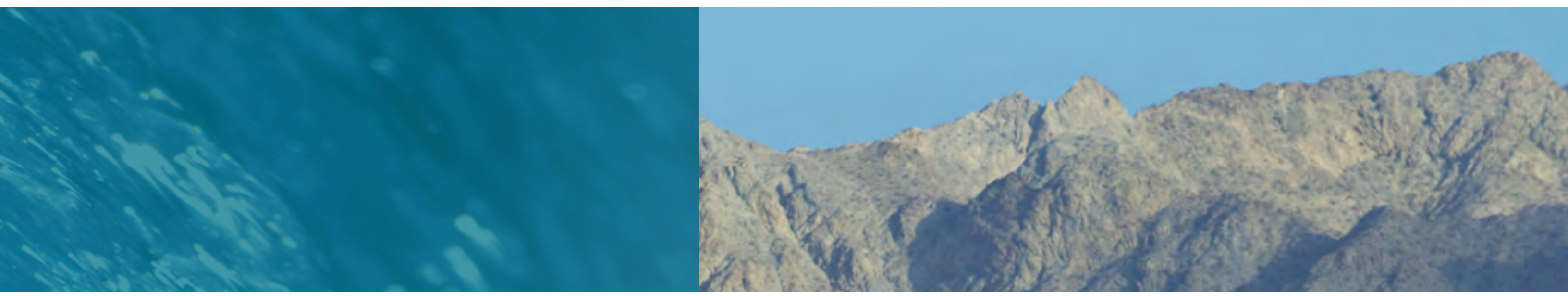
U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. 2007. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: California*. Washington (DC): U.S. Fish and Wildlife Service. 90 pp. Viewed online at: http://www.census.gov/prod/2008pubs/fhw06-ca.pdf. Accessed: April 15, 2013.

Weiser M. 2012. "California Creeks, Levees May Be Next Battleground for Public Access." Sacramento (CA): The Sacramento Bee. [News article.] Viewed online at: http://www.sacbee.com/2012/03/25/4364085/california-creeks-levees-may-be.html#disqus_thread. Accessed: August 2012.

VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 32

Other Resource Management Strategies



Coachella Valley. Crops are often fallowed in response to severe drought conditions. While the decision to idle crops can result in socioeconomic and environmental impacts, it also can enhance water supply reliability by temporarily reducing demand, enhancing water quality, and protecting and restoring fish and wildlife. Economic impacts of fallowing, even for permanent plantings such as grapevines or nut trees, can sometimes be substantially mitigated via crop idling payment programs and avoided costs of new water supply. (July 2014)

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Chapter 32. Other Resource Management Strategies

This narrative highlights a variety of water management strategies that can potentially generate benefits that meet one or more water management objectives, such as water supply augmentation or water quality enhancements. However, these management strategies have limited capacity to strategically address long-term regional water planning needs. These are unique strategies and do not fit into the other classified strategies in this volume. In some cases, such as dewvaporation, the strategy involves emerging technologies that will require more research and development. Other cases, such as crop idling and irrigated land retirement, involve voluntary and often temporary tradeoffs from one sector of use to another (i.e., agricultural to urban) that will likely be unpredictable and limited in scope over the time horizon of *California Water Plan Update 2013*. Finally, implementation of strategies, such as rainfed agriculture, will have limited applicability in California because of the variability and uncertainty of precipitation patterns from year to year.

The strategies discussed in this chapter are:

- Crop idling for water transfers.
- Dewvaporation or atmospheric pressure desalination.
- Fog collection.
- Irrigated land retirement.
- Rainfed agriculture.
- Snow fences.
- Waterbag transport/storage technology.

Crop Idling for Water Transfers

Crop idling is removing lands from irrigation with the aim of returning the lands to irrigation at a later time. Crop idling may be done once or can be episodic. Crop idling for water transfers is done to make the water that would have been used to grow a crop available for transfer (see “Water Transfers,” Chapter 8 in this volume for more information). If growers increase their irrigation efficiency and reduce the consumptive use of surface water applied for irrigation, then the volume of water saved can also be transferred under the category of cropland idling. Land retirement for water transfer and for solving drainage and drainage-related problems is discussed in the land retirement strategy later in this chapter. Crop idling, with the intent of soil and crop management and for soil and crop sustainability and productivity, is discussed in Chapter 21, “Agricultural Land Stewardship,” of this volume.

Crop Idling Programs

Westlands Water District Lease-Back Program

The Westlands Water District (WWD) has implemented a lease-back land fallowing program for about 30,000 acres. These lands are expected to be returned to irrigation if the U.S. Bureau of Reclamation (USBR) provides drainage service to the lands.

Palo Verde Irrigation District Land Management, Crop Rotation, and Water Supply Program

This crop idling program helps provide more reliable water supply for urban Southern California, while helping Palo Verde Irrigation District (PVID) farmers and the local economy. PVID's program includes crop idling of a predetermined duration. The principles of the proposed agreement followed a pilot program from 1992 to 1994. Under the pilot program, Metropolitan Water District of Southern California (MWD) compensated farmers for setting aside a portion of the land for two years in return for the water that otherwise would have been used to grow hay, cotton, or other field crops. Program participants reported spending 90 percent of the money on farm-related investments, purchases, and debt repayment.

Wetlands Reserve Program

The objective of the Natural Resources Conservation Service's Wetlands Reserve Program (WRP) is to preserve and enhance the nation's wetlands. Under the WRP, willing farmers sell long-term agricultural production easements to the federal government. Creating new wetlands under the WRP may result in improving the quality of drainage waters from irrigated lands, if that drainage flows through the wetlands.

Summer Alfalfa Dry-Down Research Program

Alfalfa summer dry-down is the practice of cutting off irrigation for one or two summer months and then reapplying water again in the fall when temperatures are cooler. The water saved during this period can be transferred to other uses. Summer cuttings have a low yield and quality. Early alfalfa production in desert regions used alfalfa summer dry-down to control weeds and conserve water. This episodic event/program is currently under research and development, and offers a unique tool for drought water management for several reasons. The program has potentially large water savings. It might save one acre-foot (af) per acre or 0.5 million af to 1 million af statewide, and net water savings can easily be verified. Water storage and transfer decisions can be made as late as June. Yield is generally reduced by only 20 to 40 percent, which diminishes the impact of crop idling on local communities. Research on alfalfa summer dry-down during the past 15 years has had mixed results, with crop loss being the major limitation.

Potential Benefits

Crop idling could enhance water supply reliability by making water available for redistribution, enhance water quality, and protect and restore fish and wildlife. The water made available from crop idling depends on how long irrigation is interrupted. The Palo Verde Irrigation District Land Management Program is expected to have an estimated annual water supply of 25-111,000 af for transfer to the MWD.

The crop idling program helps the farming community and urban areas by infusing money into the local economy while increasing the reliability of water supplies for urban consumers. Avoided costs of new water supply should also be considered in the cost-benefit analysis of crop idling. Payments to farmers would provide stable income that can be used on farm-related investments, purchases, and debt repayment, as well as for local community improvement programs.

Potential Costs

Costs include loss of crop productivity and the annual cost of managing the lands to avoid negative impacts. Additional costs can include program development, administration, and mitigation of local and regional socioeconomic impacts.

Major Implementation Issues

Socioeconomic Impacts

Loss of agricultural productivity and loss of revenue to the local communities and regional and statewide socioeconomic impacts are issues of concern. Crop idling can significantly change the local population’s way of life. It can reduce local tax revenues and cause a loss of community businesses and farm-related jobs locally and regionally. The third-party impacts can be significant, especially when crop idling is concentrated in areas where the communities provide labor and other services. If there is a significant amount of idled land, it can also have a statewide impact on the economy, food production, and food security.

Environmental Impacts

Land use changes can affect neighboring land and its productivity. They can introduce new wildlife species, weeds, pests, and illegal refuse dumping. They can affect the disposition of water and water rights issues and alter such resources as soils, groundwater, surface waters, cultural resources, and recreation, as well as have adverse biological and environmental impacts that involve human health, dust, and air quality. In addition, agricultural communities inherently have a high percentage of low-income and disadvantaged groups that can be affected by crop idling. Endemic impacts of land use changes, land idling, and land retirement can be seen in the fluctuation of school attendance by farm workers’ children and the use of food banks in farm communities. The cumulative effects of short- and long-term crop idling could have impacts on habitat, water quality, and wildlife caused by changing the location, timing, and/or quantity of applied water, as well as reducing agricultural return flows to wildlife areas. For example, rice growing areas could have significant secondary benefits as wildlife habitat. Crop idling in these areas could either harm or benefit different species, depending on the implementation.

Crop idling can also be inconsistent with statutory mandates. This is discussed below in the “Land Retirement” section.

Recommendations to Encourage Crop Idling Programs **to Benefit Water Management Strategy**

1. The agency or entity leading the crop idling program must begin consultation early with other agencies and develop the necessary coordination structure to satisfy the agency's policy requirements and avoid conflicts.

2. Study local community impacts and other third-party impacts and develop and implement the necessary actions for maintaining the economic stability of local communities and mitigation of socioeconomic impacts.

Dewvaporation or Atmospheric Pressure Desalination

Dewvaporation is a specific process of humidification-dehumidification desalination. Brackish water is evaporated by heated air, which deposits fresh water as dew on the opposite side of a heat transfer wall. The energy needed for evaporation is supplied by the energy released from dew formation. Heat sources can be combustible fuel, solar, or waste heat. One design is a tower unit built of thin plastic films to avoid corrosion and to minimize equipment costs. Towers are relatively inexpensive because they operate at atmospheric pressure.

The technology of dewvaporation is still being developed. Arizona State University (ASU) laboratories have built and operate final demonstration project towers. The Salt River Project and the ASU Office of Technology Collaborations and Licensing are sponsoring the dewvaporation pilot plant program as an extension of grassroots support by the USBR.

Potential Benefits

Dewvaporation can provide small amounts of water in remote locations. The basic laboratory test unit produces up to 150 gallons per day. Eight of these units produced 1,000 gallons per day in a demonstration pilot plant by using the dewvaporation process.

Areas such as Yuma, Arizona and California's desert regions could reclaim salt water at a relatively low cost by taking advantage of their dry climates via this process.

Potential Costs

The capital cost of a 1,000-gallon-per-day desalination plant ranges between $1,100 and $2,000. Operating costs range from $0.80 to $3.70 per 1,000 gallons distillate, or about $260 to $1,200 per af, depending on fuel source, humidity levels, and plant size.

Major Implementation Issues Facing Dewvaporation

The major issues facing dewvaporation are (1) cost and affordability, (2) small scale, and (3) concentrate disposal.

Fog Collection

Precipitation enhancement also includes other methods, such as physical structures or nets, to induce and collect precipitation.

Precipitation enhancement in the form of fog collection has not been used in California as a management technique. However, it occurs naturally with coastal vegetation. Fog provides an important portion of summer moisture to California's coastal redwoods.

Several years ago, Dr. Paul Ekern had success capturing measurable amounts of water from fog by using a louvered device with slats set vertically for rapid draining. Dr. Ekern is certain that the device or other devices are applicable to areas such as the California coast, where fog may be more frequent than actual rainfall (California Department of Water Resources 1981).

Potential Benefits

Globally, interest in fog collection for domestic water supply has been expressed by some who reside in dry areas near the ocean, where there is frequent fog. Experimental projects have been constructed in Chile. Some areas in the Middle East and South Africa are also considering this. The El Tofo project in Chile yielded about 10,600 liters per day from about 3,500 square meters of collection net, about 3 liters per day per square meter of net (Schemenauer and Puxbaum 2001). Like Chile, South Africa has many places that are ideal for fog collection. The average daily yields in South Africa range from 5 liters to 10 liters per square meter of collecting surface. Because of its relatively small production, fog collection is limited to producing domestic or small community water where few other viable water sources are available (Dower 2002).

Potential Costs

The lowest cost for fog collection in Chile, where labor is much less expensive than in California, was about $1.40 per 1,000 liters, or about $1,750 per af.

Major Implementation Issue Facing Fog Collection

Water quality is important if the water is used for drinking. The collecting net should be monitored to identify any chemical or biological material and atmospheric deposition that may pose a health threat.

Irrigated Land Retirement

Irrigated land retirement is the practice of removing farmland from irrigated agriculture. Permanent land retirement is perpetual cessation of irrigating lands from agricultural production, which is done for water transfers or for solving drainage-related problems (see Chapter 8, "Water Transfers," in this volume for more information). Crop idling, or land fallowing, for crop management and for soil and crop sustainability and productivity is discussed in Chapter 21, "Agricultural Land Stewardship," in this volume.

Central Valley Project Improvement Act Land Retirement Program

The 1992 Central Valley Project Improvement Act (CVPIA) authorized purchases of agricultural land and associated water rights and other property interests which receive Central Valley Project (CVP) water from willing sellers. The program is expected to retire about 100,000 acres of irrigated farmland (Land Retirement Technical Committee 1999).

The CVPIA Land Retirement Program applies to lands that:

- Would improve water conservation or improve the quality of an irrigation district's agricultural drainage water.
- Are no longer suitable for sustained agricultural production because of permanent damage resulting from severe agricultural-drainage water management problems, groundwater withdrawals, or other causes.

From 1993 to 2011, the CVPIA Land Retirement Program acquired 9,203 acres of land — the Tranquility Site in the Westlands Water District and the Atwell Island Site in the Tulare Basin. The USBR manages the Tranquility Site, and the U.S. Bureau of Land Management (BLM) manages the Atwell Island Site.

USBR's Settlement Agreements

About 3,000 acres of problem drainage lands in the WWD have been retired as a part of the *Britz v. U.S. Bureau of Reclamation* settlement. Also, 33,000 acres in the WWD are planned for retirement over a three-year period as part of the *Sumner-Peck v. U.S. Bureau of Reclamation* settlement. These lands have been permanently retired and the associated water allocation was given to the WWD under an agreement.

Potential Benefits

Land retirement could enhance water supply reliability by making water available for redistribution, enhance water quality, and protect and restore fish and wildlife resources. However, the result is the loss of agricultural lands. The total water made available by irrigated land retirement is potentially 2 to 3.5 af per year for each retired acre, assuming the lands receive their water allocation.

Permanent land retirement in problem drainage areas would improve water quality, specifically reducing the risk of selenium exposure to fish and wildlife. Permanent land retirement can reduce drainage volume annually by about 0.3-0.5 af per acre, reducing the costs associated with drainage disposal. Permanent retirement of lands also creates an opportunity to establish upland or other habitat for wildlife.

Land retirement reduces agricultural drainage volume from impaired farmland. Land retirement demonstration projects reduced agricultural drainage by more than 3,700 af in 2011 (U.S. Bureau of Reclamation 2011).

Potential Costs

Costs include the price of land and the annual cost of managing the land to avoid environmental impacts similar to the impacts of crop idling discussed above. Additional costs may include program development, administration, and mitigation of local and regional socioeconomic impacts.

Major Implementation Issues Facing Land Retirement

Finding Willing Participants

Land retirement is voluntary, and most farmers do not want to sell their land or abandon their way of life.

Growth Inducement of Land Retirement

Land retirement could result in urban growth if water from retired lands is made available to urban areas for development.

Socioeconomic Impacts

Loss of agricultural productivity and loss of revenue to the local communities and regional and statewide socioeconomic impacts are issues of concern. Land retirement can significantly change the local population's way of life. It can cause a decline in the local tax base and the loss of community businesses and farm-related jobs locally and regionally. The third-party impacts can be significant, especially when land retirement is concentrated in areas where the communities provide labor and other services. Endemic impacts of land use changes, land idling, and land retirement can be seen in the fluctuation of school attendance by farm workers' children and the use of food banks in such communities. If a significant amount of land is retired, it can also have a statewide impact on the economy, food production, and food security.

Environmental Impacts

Land use changes can affect neighboring land and its productivity. They can introduce new wildlife species, weeds, pests, and illegal refuse dumping. They can affect the disposition of water and water rights issues and alter such resources as soils, groundwater, surface waters, cultural resources, and recreation, as well as have adverse biological and environmental impacts that involve human health, dust, and air quality. In addition, agricultural communities inherently have a high percentage of low-income and disadvantaged groups that can be affected by land retirement. Cumulative effects of land retirement could have impacts on habitat, water quality, and wildlife, caused by changing the location, timing, and quantity of applied water and reducing agricultural return flows to wildlife areas. Land retirement could either harm or benefit different species, depending on the specific land use change.

Inconsistency with Statutory Mandates

Land retirement can contradict the statutory mandates of the California Water Code that promote orderly and coordinated control, protection, conservation, development, and utilization of the state's water resources. The contradiction is rooted in the reallocation of water supply to other competing sectors of society when an existing use is eliminated to make that supply available. It can also be pointed out that land retirement is inconsistent with many State and federal policies that promote agriculture and the preservation of productive agricultural lands.

Recommendations to Facilitate Land Retirement Programs to Benefit Water Management

1. The agency or entity leading the land retirement program should begin early consultation with other interested agencies and develop the necessary coordination structure to satisfy the agency policy requirements and avoid conflicts.
2. The land purchase price should be fair and costs associated with the mitigation of all impacts should be considered in developing the program. Land retirement programs should be voluntary.
3. Since alternative land-use management scenarios may achieve similar objectives, alternatives to permanent retirement to achieve the same objectives should be considered in developing land retirement programs. Also, there is a need to assist local water agencies with using land retirement as appropriate for local conditions regarding state and local benefits. This may include voluntary integration of land fallowing with conjunctive use and water exchange and transfers. When retiring lands, the highest priority should be given to lands of poor quality, low productivity, and high trace element contents.
4. The lead agency should evaluate the growth-inducement impacts of the program and ensure that the urban area receiving the water made available by land retirement has exhausted all means of reasonable water conservation, does not incur growth as a result of the program, and will put the land being retired to reasonable and beneficial uses.
5. Study local community impacts and other third-party impacts and develop and implement the necessary actions for maintaining the economic stability of local communities and mitigation of socioeconomic impacts.
6. Study regional impacts resulting from land retirement, including impacts from reduced agricultural production inputs, reduced farm income, and income received from land payments and habitat restoration.
7. Land retirement should comply with the California Environmental Quality Act. Land retirement programs should include the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies.

Rainfed Agriculture

Rainfed agriculture is when all crop consumptive water use is provided directly by rainfall in real time. Owing to the unpredictability of rainfall frequency, duration, and amount, there is significant uncertainty and risk in relying solely on rainfed agriculture. This is especially true in California, where there is little or no precipitation during most of the spring and summer growing season.

Climatic conditions in California provide excellent conditions for crop production. Little cloud cover provides ample solar radiation during the spring and summer growing season. Rain and snow occur mainly during the fall and winter months. However, the lack of sufficient and timely rainfall during the spring and summer throughout much of California severely limits the potential for expansion of rainfed agriculture.

Winter crops in California's interior valleys, North Coast, and Central Coast are fed directly by rain and, if needed, by irrigation water during the latter part of the winter season. These areas provide a relatively high return from high-value winter crops, such as vegetables in the coastal areas. Other important agricultural production sectors dependent on rainfall are pastoral areas, rangelands, and rolling hills. These areas produce significant amounts of feed and provide grazing areas for the state's large cattle industry, which produces dairy products and meat. Winter small-grains crops, such as winter wheat, account for about 4 percent (400,000 acres) of agricultural lands and provide a relatively small contribution to the state's total agricultural economy. University of California researchers found that, even on the west side of the San Joaquin Valley, which has an average rainfall of 7 inches per year, farmers can reap benefits from growing winter cover crops without irrigation (University of California Agricultural and Natural Resources 2012).

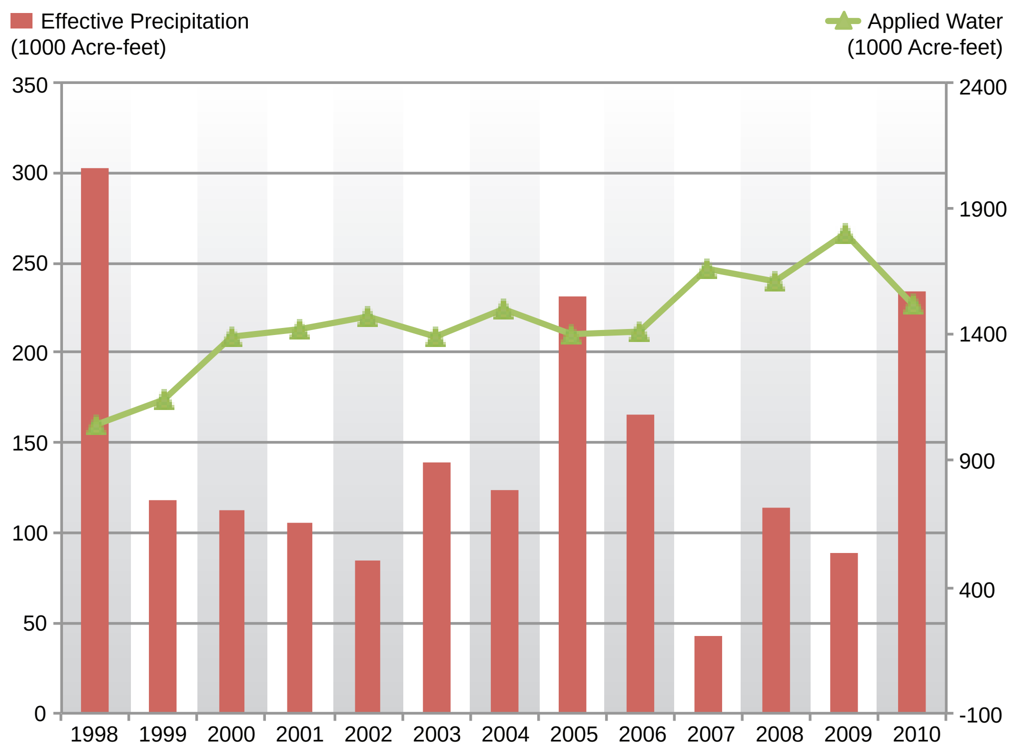
The vast majority of California's agricultural production requires irrigation. Rainfall occurring before and during the irrigation season can reduce irrigation water requirements. During years with heavy springtime rains, soil moisture remains higher for a longer period and can measurably reduce irrigation requirements for the year. Growers and water districts factor effective rainfall into their water management practices. In addition, California Department of Water Resources (DWR) water-balance calculations for each region account for the portion of crop water requirements provided directly by rainfall.

As demonstrated in Figure 32-1, applied water and rainfall events are closely related. More rainfall, particularly during the early growing season, provides a significant quantity of rainfall for crop consumptive use. The figure shows the inverse relationships between effective rainfall and applied water. Based on the 13 years (1998-2010) of data for an area on the west side of the San Joaquin Valley, effective rainfall provided an average about 10 percent of the total crop consumptive use. In 1998, 2005, and 2010, which were above-average rainfall years with early season rainfall, effective rainfall amounted to 29 percent, 21 percent, and 18 percent of the crop consumptive use, respectively. In 2007, a dry year, effective rainfall amounted to only 4 percent of the total crop consumptive use. Similar examples exist in other regions in the state.

Potential Benefits

Improvements in rainfed agricultural production currently offer limited opportunities to further increase water supply in California. More acreage for winter crop production will reduce runoff flowing through surface water systems and to ocean outflows. Improvements in rangelands and grazing areas through improved plant varieties can provide crop yield benefits, but not a significant increase in water supply. One important aspect of improved rainfed agriculture is a better post-harvest/pre-planting soil management for such winter crops as wheat. Many winter

Figure 32-1 Effective Precipitation and Applied Water



wheat growers are already implementing prudent and adequate soil management practices for water and erosion management. Tilled land left fallow after harvest can cause the soil surface to seal with the first and second rainfall and increase runoff and erosion. Improved tillage practices, no-till or minimum-till, may improve water infiltration into the soil root zone, thereby increasing soil-water storage, and could contribute to the water supply by eliminating the first seasonal irrigation. Additionally, increased soil moisture reduces soil erosion, helps improve water quality, and may help increase water use efficiency and economic efficiency. Advances in plant genetics to provide higher crop yields from direct rainfall could replace some crops that rely on irrigation.

The quantification of potential water savings from improved rainfed agriculture, while very small, is not possible due to insufficient information. However, research conducted by the University of California is yielding more information about rainfed cover crops.

Potential Costs

Potential costs consist of on-farm soil management; the cost of research and development; and the demonstration, education, training, and dissemination of the technology. On-farm cost is an integral part of soil management, which is already part of growers' practices. Soil management practices may need to be adjusted for timing with no additional or minimal cost. It is possible that such activities can be funded by the DWR Water Use Efficiency Program's loans and grants.

Major Implementation Issues Facing Rainfed Agriculture

While rainfed agriculture provides some opportunities for increasing yield and water supply reliability, efforts will likely result in insignificant and unquantifiable contributions to the water supply. Nonetheless, increases of winter crops and winter cover-crop yields can be significant and benefit overall water management in California. Water supply improvements will require development of new varieties of plants and new and innovative soil and water management. Also, this strategy does not provide water supply benefits on a real-time basis. For example, improvements in soil management may provide the future benefit of storing more rainfall in the root zone only if the predicted weather conditions occur.

Recommendations to Increase Water Use Efficiency in Rainfed Agriculture

1. Develop improved varieties of winter rainfed crops, such as wheat, other small grains, cover crops, and winter crops. Provide funding for research and development institutions to develop new and improved varieties of winter rainfed crops. In addition, develop research that demonstrates innovative water management practices where growers with marginal lands and marginal production may shift from irrigated agriculture to rainfed winter crops.

2. Provide technical and financial assistance to promote no-till or minimum-till practices by growers who prepare their lands for planting during spring, but leave it fallow during the fall and winter. Cooperative efforts with the state's research and development institutions can provide benefits of this important aspect of rainfed agriculture.

3. Develop new and innovative technologies, management, and efficient water management practices for rainfed crops, particularly winter wheat.

4. Provide technical and financial assistance to implement better technologies and management practices for rainfed agriculture.

5. Develop and promote new and innovative activities and management practices for intensive and managed grazing.

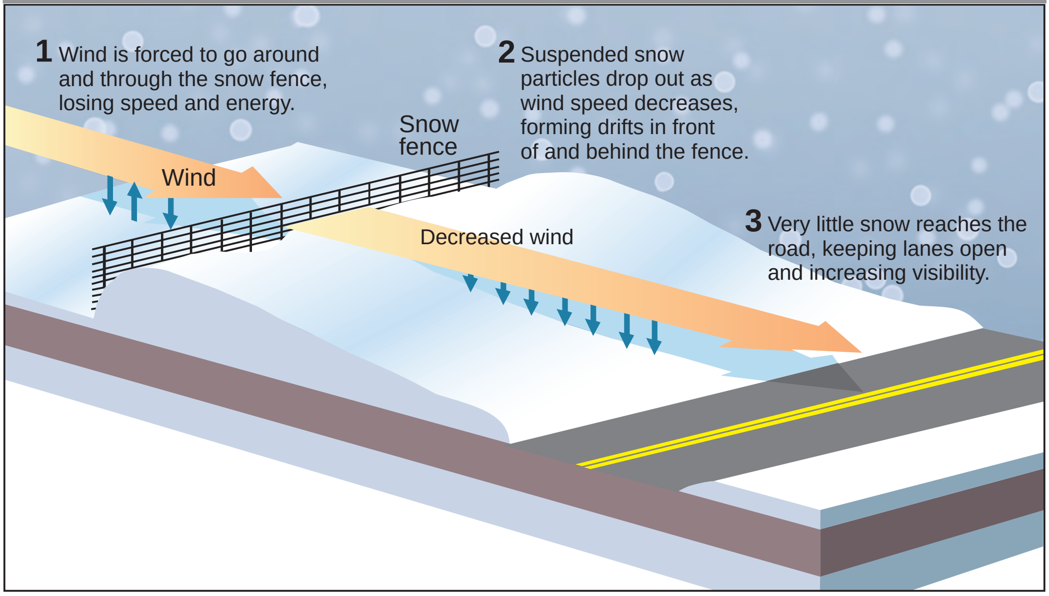
6. Maximize, collect, and store runoff from rainfed agriculture. Develop cooperative efforts to link runoff from rainfed agriculture with water banking, conjunctive use activities, and groundwater recharge.

7. Disseminate practical information through educational and training opportunities.

Snow Fences

Snow fences have been used extensively by State transportation departments to reduce snow drifting over roadways. To improve watershed management, snow fencing could be strategically placed in small openings (clear-cut tree harvest areas or high-elevation meadows) of 1.25 acres or less. Effective snow fences are 6-12 feet high. As shown in Figure 32-2, when positioned perpendicular to the prevailing wind, snow fencing intercepts the wind to reduce snowflake velocity and create a snow sedimentation basin downwind of the fence. Snow mass collected behind the fence is distributed over a longitudinal area that can be up to 25 times the fence height.

Figure 32-2 Snow Transport and Deposition Mechanism



Mountain stream runoff is expected to result in higher flows over shorter durations in the coming years, and thus cause earlier and greater spring flooding followed by a longer, drier summer. Local-scale strategic placement of properly designed snow fencing could be used as an effective tool for water management to strengthen forest and watershed management, protect sensitive environments, and facilitate slower snowmelt to extend runoff into the summer. For example, the Sierra Nevada produces more than 50 percent of California's water, and snow fences could be used in some locations to accumulate larger volumes of snow mass, particularly when positioned strategically atop ridgelines adjacent to cliffs and ravines, as well as to extend water delivery for supply and power generation. This may reduce water loss that results from evaporation and sublimation, increase soil moisture retention, and enhance forest wildlife habitat. In addition, snow fences can be placed parallel to planted rows of trees that serve as a natural, living fence. After the trees mature, the fence can be removed.

Details of a proposed pilot study on snow fences, application in neighboring states, preliminary cost estimates, and a work plan outline and schedule appear in *Catch the Drift: An Innovative Application of Snow Fencing Technology* (California Department of Water Resources 2012).

Potential Benefits

Water Management

- Reduce spring runoff and extend snowmelt.
- Augment water supply.
- Support better local flood control.
- Help extend hydroelectric generation into summer.

Environment and Habitat

- Accelerate ecosystem restoration.
- Improve habitat by decreasing sedimentation and erosion and increasing reforestation, meadow improvement, and forest sustainability.
- Enhance soil moisture retention.
- Augment streams with colder water in summer to benefit aquatic life by increasing dissolved oxygen levels.

Social Impacts

- Strengthen public relations by suggesting realistic, simple, and economic solutions that could be implemented at the local level with some technical support from DWR staff and suggestions for funding mechanisms, if these are available at that time.
- Benefit tribal lands.
- Increase interagency water management collaboration.

Potential Costs

Snow fencing is a highly economical alternative to snowplowing, and the application of snow fencing for water management and environmental purposes would follow the same basic cost structure as fencing for transportation uses. An unknown factor, however, is the benefit-to-cost ratio for the application of snow fencing for water management and environmental purposes in California.

Major Implementation Issues Facing

Besides the benefit-to-cost ratio not yet being known, permitting requirements for snow fencing would depend on the specific area in which the fencing would be applied. Whether the fencing would be proposed for placement on public or private land could be a factor, as would interagency cooperation and the willingness of private landowners to work with the agency or agencies involved in the fencing project. Potential sponsors of these fencing projects, as well as the funding, would have to be found. How the fences would be placed, by whom, and maintained are also matters that would need to be addressed.

Waterbag Transport/Storage Technology

Waterbag transport/storage technology involves diverting water in areas that have unallocated freshwater supplies, storing the water in large inflatable bladders, and towing them on the ocean by a tug boat to an alternate coastal region. Fresh water is lighter than sea water, so the bags float on the surface, which makes towing them easier. After discharging the contents, the empty bags are reeled to the deck of the tug boat, allowing for a speedier return to the source water area.

Although this strategy is not currently used in California, there have been several proposals to implement this technology throughout the world. The most recent was the proposal by Alaska

Water Exports Company to divert up to 30 thousand af from the Albion and Gualala rivers in Northern California and transport the water to the San Diego metropolitan area. The proposal was greeted with significant local opposition in Northern California. In 2003, California designated the Albion and Gualala rivers as recreational via Public Resources Code Section 5093.53(c) and added them to the California Wild and Scenic Rivers System. This ended the plan to divert and export fresh water from these rivers to Southern California via waterbag transport technology.

Potential Benefits

- Provides water supply benefit.
- Improves drought preparedness.
- Improves water quality.
- Increases operational flexibility and efficiency.
- Provides environmental benefits
- Provides energy benefits.
- Reduces groundwater overdraft.

Potential Costs

The total cost for waterbag transport is highly project-specific and contingent upon several factors, such as facility costs for diverting and off-loading water, environmental mitigation, administrative costs, bag construction costs, and towing costs.

Major Implementation Issues Facing Waterbag Transport/Storage Technology

Third-Party Impacts

As with any type of transfer, there may be impacts on the area of origin. This includes projects that use surplus water and water that currently has a beneficial use. Other issues of concern expressed to proponents of recent projects include aesthetics and noise pollution from diversion facilities and the dissatisfaction on the part of origin communities that others are exporting a local resource.

Environmental Impacts

Although most proposed diversions for waterbag transport take place near the mouth of a source river, facilities may need to be built to convey the water from a significant distance upstream to prevent blending with high-salinity ocean water. Some areas may already have conveyance facilities in place, which could be accessed for waterbag storage and transport.

Water Rights

The implementation of this strategy would require a lengthy and expensive permitting process to ensure no water rights are violated, which would include environmental impact studies.

Climate Change

The projected climate change impacts include shifts in historical weather patterns, increased storm intensities, prolonged and more frequent droughts, continued sea level rise, and higher and increasing temperatures. These changes will threaten water supply reliability and, in most cases, increase the demand for water supplies. Climate change is already altering the way California manages it water, and the continued effects will require a portfolio of options to react effectively. Preparing adaptation strategies in advance of additional impacts will give water managers the flexibility to react to various conditions.

Adaptation

Climate change adaptation strategies will vary and also depend on the needs and capabilities of communities. Being prepared will minimize adverse consequences. Because droughts are expected to become prolonged and more frequent, maintaining the ability to move water through crop idling for water transfer, irrigated land retirement, or waterbag transport can serve as a potential climate adaptation strategy. Droughts and sea level rise may impede implementing crop idling and irrigated land retirement strategies because these climate changes reduce the amount of water available for transfer and hinder water conveyance systems (for more information, see Chapter 8, “Water Transfers,” in this volume). Waterbag transport can be a short-term adaptation strategy by allowing one area the benefit of disposing excess water while providing this water to an area in need. For communities that do not have access to large water conveyance systems, dewvaporation and fog collection can be localized adaptation strategies to combat growing water demand from higher temperatures and droughts. However, fog formation and location may be altered by climate change. Rainfed agriculture, such as non-irrigated cover crops, can be an adaptation strategy because it builds organic matter in the soil and increases its water storage capacity. This can provide weeks of extra water to cover summer droughts at the height of the growing season, as well as having the ability to grow food without accessory water. However, this measure may be less feasible in low-rainfall areas.

Mitigation

Mitigation strategies result in a reduction of greenhouse gas (GHG) emissions in the effort to reduce contributions to climate change. Mitigation can be accomplished by substituting a high GHG emissions system with a lower GHG emissions system, by creating an emissions sink, or by reducing the use of a high-emissions system. Climate models project that California already faces a certain amount of climate change and sea level rise based on current and past emissions. Climate change mitigation goals are reducing the severity and longevity of those projected climate changes. Crop idling for water transfer and irrigated land retirement are not necessarily mitigation strategies because they could potentially remove a carbon sink, especially if agricultural conservation practices are used on that land. On the other hand, these strategies could be considered mitigation if the land has drainage or runoff issues that require energy-intensive maintenance or remediation, or if the land is heavily amended with nitrogen fertilizer, as both situations result in increased GHG production. The use of transferred water will also determine if it is a mitigation strategy. If the water is used in a manner that is highly energy intensive, then it is no longer a mitigation strategy. Dewvaporation and fog collection typically are energy-intensive processes, so they would only be mitigation strategies if they replaced a water source that requires even higher energy to obtain it. Rainfed agriculture can be a mitigation strategy if it is converted from traditional agriculture and thus reduces the energy use required by traditional irrigation methods. Waterbag transport cannot be considered a mitigation strategy, as it is likely to consume more energy during construction of the bag and related diversion systems, as well as during transportation of the bag by sea, than using an alternate water source.

References

References Cited

California Department of Water Resources. 1981. *Captured Rainfall. Bulletin 213*. Sacramento (CA). Viewed online at: http://www.water.ca.gov/waterdatalibrary/docs/historic/Bulletins/Bulletin_213/Bulletin_213__1981.pdf.

———. 2012. *Catch the Drift: An Innovative Application of Snow Fencing Technology*. Sacramento (CA).

Dower S. 2002. "Clouds on the tap." The Water Wheel, South African Water Bulletin. South African Water Research Commission. Volume 28. Number 4. November/December. Pages 15-17.

Land Retirement Technical Committee. 1999. *Task 3 Land Retirement. Final Report*. Sacramento (CA): The San Joaquin Valley Drainage Implementation Program and the University of California Salinity/Drainage Program. 121 pp. Viewed online at: http://www.water.ca.gov/pubs/groundwater/land_retirement_final_report__san_joaquin_valley_drainage_implementation_program/05-landretirement.pdf. Accessed: Dec., 2009.

Schemenauer RS, Puxbaum H, editors. 2001. *Proceedings. Second International Conference on Fog and Fog Collection*. Second international conference on fog and fog collection. July 15-20. St. John's, Newfoundland Canada. North York , Ontario Canada.536 pp.

University of California Agricultural and Natural Resources. 2012. "Rain-fed winter crops offer multiple benefits at low cost." Oakland (CA): University of California Agricultural and Natural Resources News. [Web site.] Viewed online at: http://ucanr.org/news/?blogpost=6978&blogasset=44547.

U.S. Bureau of Reclamation. 2011. Draft CVPIA Fiscal Year 2012 Annual work plan. Sacramento (CA): U.S. Bureau of Reclamation. Viewed online at: http://www.usbr.gov/mp/cvpia/docs_reports/awp/2012/3408%20h%20LRP.pdf. Accessed: July, 2012.

Additional References

Arizona State University. 2002. *Carrier Gas Enhanced Atmospheric Pressure Desalination. Final Report*. Desalination Research and Development Program Report No. 92. Cooperative Agreement No. 99-FC-81-0186. Sacramento (CA): U.S. Bureau of Reclamation. 57 pp. Viewed online at: http://www.usbr.gov/pmts/water/media/pdfs/report092.pdf.

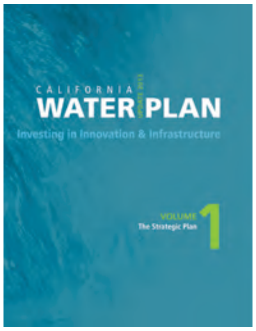
California Department of Water Resources. 2012. DRAFT: Technical Information for Water Transfers in 2012. Sacramento (CA): Viewed online at: http://www.water.ca.gov/watertransfers/docs/TechInfoDoc-WaterTransfers-2012.pdf.

U.S. Bureau of Reclamation. 2007. 3408(h) Land Retirement. The Land Retirement Program. 2009. Sacramento (CA): U.S. Bureau of Reclamation. [Web site.] Viewed online at: http://www.usbr.gov/mp/cvpia/3408h/index.html. Accessed: Dec., 2009.

———. 2008. *San Luis Drainage Feature Re-evaluation Feasibility Report. 2009*. Sacramento (CA): U.S. Bureau of Reclamation. Viewed online at: http://www.usbr.gov/mp/sccao/sld/docs/index.html. Accessed: Dec., 2009.

Navigating Water Plan Update 2013

Update 2013 includes a wide range of information, from a detailed description of California's current and potential future conditions to a "Roadmap For Action" intended to achieve desired benefits and outcomes. The plan is organized in five volumes — the three volumes outlined below; Volume 4, *Reference Guide*; and Volume 5, *Technical Guide*.



VOLUME 1, The Strategic Plan

- Call to action, new features for Update 2013, progress toward implementation.
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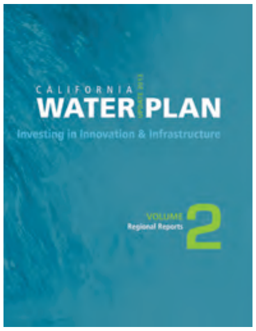
- Comprehensive picture of current water, flood, and environmental conditions.
- Strengthening government alignment and water governance.
- Planning (data, analysis, and public outreach) in the face of uncertainty.
- Framework for financing the California Water Plan.
- Roadmap for Action — Vision, mission, goals, principles, objectives, and actions.



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- Current relationships with other regions and states.
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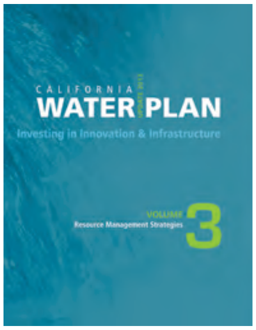

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Integrated water management *is a comprehensive and collaborative approach for managing water to concurrently achieve social, environmental, and economic objectives. In the California Water Plan, these objectives are focused toward improving public safety, fostering environmental stewardship, and supporting economic stability. This integrated approach delivers higher value for investments by considering all interests, providing multiple benefits, and working across jurisdictional boundaries at the appropriate geographic scale. Examples of multiple benefits include improved water quality, better flood management, restored and enhanced ecosystems, and more reliable water supplies.*

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October 2014