Main Dams and Saddle Dams Technical Memorandum

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Acronyms and Abbreviations

ADAS	Automated Data Acquisition System
Authority	Sites Project Authority
bgs	below the ground surface
cfs	cubic feet per second
DWR	California Department of Water Resources, Division of Engineering
GCID	Glenn-Colusa Irrigation District
H:V	Horizontal to Vertical
MAF	million-acre-feet
NMWS	Normal Maximum Water Surface
PMF	Probable Maximum Flood
TM	Technical Memorandum
Reclamation, USBR	U.S. Bureau of Reclamation

1.0 Introduction

1.1 Purpose and Scope

The Sites Project Authority (Authority) is preparing a feasibility-level evaluation for a 1.5-million-acre-foot (MAF) reservoir as a preferred option for the Sites Reservoir Project. This reservoir would be in the same location as the reservoir studied previously by the California Department of Water Resources, Division of Engineering (DWR), and the U.S. Bureau of Reclamation (Reclamation). It would also include constructing similar main dams and saddle dams to form the reservoir.

This Technical Memorandum (TM) provides a description of the dams, their type, locations, sections, foundation objectives, excavations, embankment materials, stability, groundwater/dewatering excavation, and instrumentation, and recommends geotechnical investigations.

1.2 Limitations

The scope of work for this TM was restricted to the development of the feasibility design for the Sites Reservoir Dams. It did not include consideration of other Sites facilities beyond those specifically listed.

The feasibility designs presented in this TM were based on topographic contours that originated from DWR for their 2003 studies. Updated site-specific topographic maps will be prepared for use in preliminary and final phases of design.

AECOM represents that our services were conducted in a manner consistent with the standard of care ordinarily applied as the state of practice in the profession, within the limits prescribed by our client.

This TM is intended for the sole use of the Sites Project Authority. The scope of services performed may not be appropriate to satisfy the needs of other users, and any use or re-use of this document or of the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

2.0 Description of Reservoir and Dams

Water in Sites Reservoir would be impounded by the Golden Gate Dam on Funks Creek, Sites Dam on Stone Corral Creek, and a series of saddle dams and two saddle dikes along the eastern and northern rims of the reservoir. The location of the main and saddle dams and the reservoir are shown on Drawing STS-315-C-2001 (see Section 10 for list drawings attached to this TM).

Two reservoir sizes are under consideration. The 1.5-MAF reservoir alternative would have a Normal Maximum Water Surface (NMWS) elevation of 498 feet, while the 1.3-MAF reservoir would have an NMWS elevation of 482 feet. Preliminary freeboard calculations indicate that the minimum static freeboard (without camber) would be 19 feet, measured above the maximum reservoir storage elevation for 1.5-MAF capacity. Nominal crest would be at elevation 517 feet for all dams for 1.5-MAF capacity, and at elevation 500 feet for 1.3-MAF capacity. Table 2-1 presents a summary of dam heights required to impound Sites Reservoir for the 1.5-MAF capacity and 1.3-MAF capacity. Drawing STS-315-C-2001 shows the main and saddle dam locations for the 1.5-MAF reservoir.

Table 2-1. Dam Heights for 1.5-MAF and 1.3-MAF Sites Reservoir Alternatives

Dam/Dike	1.5-MAF Reservoir Maximum Height Above Streambed (feet)	1.3-MAF Reservoir Maximum Height Above Streambed (feet)
Golden Gate Dam	287	270
Sites Dam	267	250
Saddle Dam 1	27	None
Saddle Dam 2	57	40
Saddle Dam 3	107	90
Saddle Dam 5	77	60
Saddle Dam 6	47	None
Saddle Dam 8A	82	65
Saddle Dam 8B	37	5
Saddle Dike 1	12 [a]	10 (near Saddle Dam 1)
Saddle Dike 2	12 [a]	10 (near Saddle Dam 6)
Saddle Dam 10 [b]	Not required for 1.5-MAF Reservoir	30

[a] Locations of the Saddle Dikes are shown in STS-350-C-2604.
[b] For the1.3-MAF Reservoir, Golden Gate Dam would be reconfigured and Saddle Dam 10 added to close off a topographic saddle in the ridge that is closed in the 1.5-MAF Golden Gate Dam configuration.

Two saddle dikes would be required for the 1.5-MAF reservoir to close off topographic saddles in the ridges near Saddle Dams 8A and 8B. Additional information on the dams is provided in the sections below.

2.1 Golden Gate Dam

Drawings STS-335-C-2601, STS-340-C-2601, STS-345-C-2601, STS-346-C-2602, and STS-347-C-2601 present a plan view of the Golden Gate dam embankment for the 1.5-MAF reservoir. Golden Gate Dam would be on Funks Creek, approximately 1 mile west of Funks Reservoir.

2.2 Sites Dam

Drawings STS-320-C-2601, STS-325-C-2601, STS-330-C-2601, and STS-331-C-2601 present a plan view of the Sites dam embankment for the 1.5-MAF reservoir. Sites Dam would be on Stone Corral Creek approximately 0.25 mile east of the town of Sites, and 8 miles west of the town of Maxwell.

2.3 Saddle Dams

Seven saddle dams are needed at topographic saddle low points along the eastern ridge of the reservoir from Funks Creek north to the northern end of the reservoir. Drawings STS-350-C-2001, and STS-350-C-2601 to STS-350-C-2604, show the plan views of the saddle dam and saddle dike embankments for the 1.5-MAF reservoir.

2.4 Saddle Dikes

Two saddle dikes are needed at topographic saddle low points along the northern end of the reservoir. Drawings STS-350-C-2001 and STS-350-C-2604 show plan views of the saddle dike embankments for the 1.5-MAF reservoir. Saddle dikes are distinguished from dams in that they do not retain water, but raise two saddles that are below the minimum crest elevation of 517 feet, but above elevation 503.8 feet (maximum reservoir elevation during the Probable Maximum Flood [PMF]). A typical Saddle Dike section is presented on Drawing STS- 361-C-3601.

3.0 Feasibility-Level Dam-Type Study

3.1 General

Four options with varying dam types (sections) would be evaluated as part of feasibility-level design. The evaluation would be performed in accordance with the state of practice for dam design with conformance to current dam safety criteria. Site topography, geology, seismicity, and foundation conditions would be considered for feasibility-level design of the dam options. The dam options conform to modern construction practice and incorporate conservative design measures. The four options considered are listed below:

- Option 1A – Earth and Rockfill Dam – original dam type proposed by DWR (2003a).
- Option 1B – Earthfill Dam – uses much less of the more costly rockfill than Option 1A, and does not include upstream filter and transition zones (discussed in Section 4), and may be less costly; however, the dam volume is greater than for Option 1A.
- Option 2 – Hardfill Dam – can include spillway and outlet works within the dam, so may be less costly than Option 1A or 1B. This option includes two potential dam axis options (locations for the dams).
- Option 3 – Concrete gravity dam and spillway structure.

These dam type options would be considered as follows:

- Option 1A and 1B would be considered for the main dams and saddle dams except for Saddle Dam 8B, which includes the spillway structure.
- Option 2 would be considered for the main dams and saddle dams, including Saddle Dam 8B, which includes the spillway structure.
- Option 3 would be considered for Saddle Dam 8B, which includes the spillway structure.

These options are discussed in Section 4 for the embankment dams, and Section 5 for the hardfill and concrete dams.

3.2 Special Considerations – Fault Displacement

Faults have been identified at some of the dam sites. They are discussed in AECOM (2020a), summarized in Table 3-1, and depicted on the drawings. Fault displacement potential would be considered in the selection of the type and in the design of these dams.

Table 3-1. Faults with Displacement Potential at Dam Sites

Dam Site	Fault Name/Style	Approximate location	Drawing No.	Fault Displacement Potential (inches)
Golden Gate	GG-1/Strike Slip	Upstream of Dam Options 1A, 1B and 2 – Axis 1 Left Abutment of Option 2 – Axis 2; and Saddle Dams Option 2 – Axis 2	STS-335-C-2601, STS-335-C-3601, STS-335-C-3602, STS-340-C-2601, STS-340-C-3601, STS-345-C-2601, STS-345-C-2602, STS-345-C-3601, STS-347-C-2601	Less than 8 inches
Golden Gate	GG-2/Strike-slip	Right Abutment and Downstream Shell Options 1A, 1B, and 2 – Axis 1 Saddle Dams Option 2 – Axis 2		Less than 8 inches
Sites	S-2/Strike-slip	Right Abutment Options 1A, 1B, and 2	STS-320-C-2601, STS-325-C-2601, STS-330-C-2601, STS-331-C-2601	Less than 8 inches
Saddle Dam 5	LSSD5-4/not evaluated	Middle of dam footprint	STS-350-C-2603	Not evaluated. Needs investigation

4.0 Dam Options 1A and 1B – Embankment Dams

4.1 General Introduction

This section discusses two embankment types, Option 1A-earth and rockfill and Option 1B-earthfill. Essentially they differ in the materials used in the upstream shell, earthfill or rockfill. It is noted that there could be a combination of the two dam types; that is, the upstream shell could be a combination of earthfill and rockfill, as shown for the saddle dams.

4.1.1 <u>Option 1A – Earth and Rockfill Dam</u>

Drawing STS-320-C-3601 provides a typical section for an earth and rockfill dam at Sites. Drawings STS-335-C-3601 and STS-335-C-3602 provide typical sections for an earth and rockfill dam at Golden Gate. Drawing STS-350-C-3601 shows the typical earth and rockfill dam at the saddle dams. The proposed embankment section is a combination of earth and rockfill embankment zones with a central impervious core, and exterior upstream rockfill shell and downstream earthfill shell. As discussed in Section 3.2, Sites, Golden Gate and Saddle Dam 5 have faults that pass through their footprints. These dams would be designed to safely accommodate the potential fault displacement. This could be accomplished by providing widened filter, drain, and transition zones.

The upstream and downstream slopes of the dam embankment for this option are 2.25 Horizontal to 1 Vertical (H:V) and 2H:1V, respectively, for the main dams; and 3.0H:1V and 2.5H:1V for the saddle dams. These slopes were selected based on precedent for this type of dam and a preliminary analysis by DWR that is discussed in Section 4.5. Consistent with typical designs for similar types of dam embankments, the upstream and downstream slopes of the central core were selected to be 0.5H:1V for the main dams, and 1H:1V upstream and vertical downstream for the saddle dams. The dam crests would be 30 feet wide and would include asphalt-paved or gravel maintenance roads.

Upstream of the core (Zone 1), a 30-foot-wide zone of filter and transition materials (Zones 2B-F and 2B-T) are included for filter compatibility between the impervious core and pervious rockfill shell material. Downstream of the core, two 15-foot-wide zones of filter and drain materials (Zones 2A-F and 2A-D) are included for filter compatibility between embankment materials, to provide control of embankment seepage, and to prevent piping of the core material. The downstream embankment section also incorporates a 20-foot-thick blanket drain, composed of filter, drain, and transition (Zones 2A-F, 2A-D and 2A-T), to control foundation seepage and to provide for seepage collection at the downstream toe. Shell materials consist of rockfill (Zone 3) upstream and random materials (Zone 4) downstream. A 4-foot-thick zone of riprap is included for upstream slope protection. A 12-foot-wide rockfill material (Zone 3) is included along the downstream slope of the random shell material (Zone 4) for erosion protection.

Cofferdams are required along Stone Corral and Funks Creeks for Sites Dam and Golden Gate Dam, respectively, as shown in plan on Drawings STS-320-C-2601 and STS-335-C-2601, and in section on Drawings STS-320-C-3601 and STS-335-C-3601. The cofferdams would be incorporated into the upstream toe of the embankment dams and would be constructed of Zone 4 material, likely derived from the excavation of the dam foundations. The crest of the cofferdams is set at elevation 310 feet (5 feet above high water during construction (AECOM, 2020b).

4.1.2 <u>Option 1B – Earthfill Dam</u>

Drawing STS-325-C-3601 provides a typical cross section for an earthfill dam at Sites, and Drawing STS-340-C-3601 provides an earthfill dam section at Golden Gate. Drawing STS-350-C-3602 shows the typical earthfill dam section at the saddle dams. As discussed in Section 3.2 and above for the earth and rockfill option, Sites, Golden Gate, and Saddle Dam 5 have faults that pass through their footprints. These dams would be designed to safely accommodate the potential fault displacement. This could be accomplished by providing widened filter and drain zones, and providing an upstream crack-stopper zone.

The upstream and downstream slopes of the dam embankment for this option are 3.25H:1V and 2.0H:1V, respectively, for the main dams, and 3.25H:1V and 2.5H:1V for the saddle dams. These slopes were selected based on similarly sized earthfill dams. Consistent with typical designs for similar types of dam embankments, the upstream and downstream slopes of the central core were selected to be 0.5H:1V for the main dams, and 1H:1V upstream and vertical downstream for the saddle dams. Like Option 1A, the dam crests would be 30 feet wide, and would include asphalt-paved or gravel maintenance roads.

Downstream of the core, two 15-foot-wide zones of filter and drain materials (Zones 2A-F and 2A-D) are included for filter compatibility between embankment materials, to provide control of embankment seepage, and to prevent piping of the core material. Filter and transition zones are not required between the core and the upstream earthfill shell zones, because there would be filter compatibility between these two zones. The downstream embankment section also incorporates a 20-foot-thick blanket drain, composed of filter, drain, and transition (Zones 2A-F, 2A-D and 2A-T), to control foundation seepage and to provide for seepage collection at the downstream toe. Shell materials consist of random materials (Zone 4). A 4-foot-thick zone of riprap and a 2-foot-thick bedding zone are included for upstream slope protection. A 12-foot-wide rockfill material (Zone 3) is included along the downstream slope for erosion protection.

Cofferdams are required for Sites Dam and Golden Gate Dam, and are shown in plan on Drawings STS-335-C-3601 and STS-335-C-2601, and in section on Drawings STS-325-C-3601 and STS-340-C-3601. The cofferdams would be incorporated into the upstream toe of the embankment dams along Stone Corral and Funks Creeks. The cofferdams would be constructed of Zone 4 material, likely derived from the excavation of the dam foundations. The crest of the cofferdams is set at elevation 310 feet (5 feet above high water during construction [AECOM 2020b]).

4.2 Foundation Objectives

Based on geologic characterization and visual observation of limited drill core photos for Golden Gate and Sites dams, moderately weathered bedrock is judged to be an acceptable foundation for the shell, transition, and drain zones. In addition, slightly weathered to fresh bedrock is judged to be an acceptable foundation for the impervious core zone and chimney filter zones.

For the saddle dams, intensely weathered bedrock is considered a suitable foundation for the shell zones and blanket drain zone. In addition, moderately weathered bedrock is considered to be a suitable foundation for the impervious core zone and chimney filters.

4.3 Foundation Excavation and Dewatering

Bedrock underlying the Golden Gate Dam footprint is predominantly Cortina Formation, while the Sites Dam footprint consists of both Boxer and Cortina Formations (DWR, 2003b). The upstream footprint of the Sites dam would be predominantly founded on Boxer Formation, and the downstream footprint of the dam would be founded on Cortina Formation. At the Sites Dam site, the Boxer Formation is generally characterized as mudstone with sandstone interbeds. The Cortina Formation is generally characterized as sandstone with interbedded mudstone.

To meet the foundation objectives, recent and older alluvium— decomposed and intensely weathered bedrock—would be excavated from the entire footprint of Golden Gate and Sites Dam to obtain a moderately weathered bedrock surface. In addition, moderately weathered bedrock would be excavated from the impervious core footprint down to the top of slightly weathered and/or fresh bedrock surface.

Review of limited geologic information indicates that the average depth to moderately weathered bedrock at Golden Gate and Sites is 15 feet below ground surface (bgs), and the depth to the slightly weathered to fresh bedrock is 40 feet bgs.

Bedrock underlying the saddle dam footprints is predominantly mudstone with siltstone, sandstone, and a conglomerate of the Boxer Formation (DWR, 2003b). To meet the foundation objectives, colluvium and decomposed bedrock would be excavated from the entire footprint of the saddle dams to obtain an intensely weathered bedrock surface. In addition, intensely weathered bedrock would be excavated from the impervious core footprint to obtain a moderately weathered bedrock surface. A minimum bottom core trench width of 20 feet is incorporated into the saddle dam foundation design. The average depth to intensely weathered bedrock for the saddle dams is estimated at 12 feet bgs, and average depth to moderately weathered bedrock is 25 feet. In addition, the average depth to slightly weathered bedrock for the saddle dams is 35 feet.

Review of the limited geotechnical information performed near the dams indicate that groundwater is present at the main and saddle dam sites, and dewatering would be required during excavations (DWR, 2003b). For Golden Gate Dam, the groundwater is approximately 13 feet to 25 feet bgs along the dam channel area, and about 40 feet to 75 feet bgs along the dam abutments. For Sites Dam, the groundwater is approximately 10 feet to 20 feet along the dam channel area; and for the most part, reflects the groundwater elevation associated with the creek channel. The depth to water at the abutments averaged about 80 feet bgs. For the saddle dams, the groundwater depth is shallow (less than 10 feet) along the channel areas, and varies between 20 feet to 90 feet along the abutments.

4.4 Embankment Materials

Selection of the embankment materials was based on the available on-site materials identified and evaluated as part of the materials investigation program. Drawing STS-315-C-2002 shows the locations of potential borrow areas. A summary of the materials designated for use in specific embankment zones is provided below.

Zone 1: Core material would be composed of low- to medium-plasticity clays, with lesser amounts of high-plasticity clays and clayey sands. The impervious material would be obtained from designated borrow areas on the floor of the reservoir upstream of the dams. It is intended that haul distances would be less than 1 mile. Impervious material processing beyond normal disking and moisture conditioning in the designated borrow areas is not anticipated. Suitable materials could also be derived from other mandatory facility excavations depending on schedule and economics of hauling.

Zone 2: Filter, drain, and transition materials would consist of suitable fresh rock or alluvial materials processed to various sizes to meet filter compatibility and permeability requirements. It is assumed that fresh Venado Sandstone of the Cortina Formation would not be suitable for use in these zones, and these embankment materials would need to be imported from the closest currently known off-site sand and gravel source. Transition materials may be able to be processed for on-site Venado Sandstone. One off-site source is an old, abandoned channel on Stony Creek between Orland and Willows, approximately 30 to 35 road miles north of the Golden Gate Dam site (see Drawing STS-315-C-2002, Borrow Areas and Quarries). Another potential source of materials is Butte Sand and Gravel, which is approximately 40 miles east-southeast of the reservoir site, also shown on Drawing STS-315-C-2002. For any off-site source, permitting issues and production capacities would need to be resolved.

Zone 3: Shell material would consist of processed clean rockfill with a maximum rock size of 30 inches. The shell material would be obtained from fresh Venado Sandstone of the Cortina Formation from one or more quarries developed in the eastern ridge of the reservoir near the dam site. Haul distances (one way) could be up to 1 mile. Quarry operations would require drilling and blasting with selective mining to remove mudstones, weathered sandstone, and other unsuitable materials to produce fresh Venado Sandstone with the required gradation. Suitable materials can also come from mandatory facility excavations, including the dam foundation excavation.

Zone 4: Random material would be composed of material unsuitable for use as clean rockfill. This material would consist of weathered sandstone, mudstone, and slopewash obtained from excavation of the dam foundations, appurtenant structures, and the rockfill quarry. Haul distances would be less than 1 mile, and processing would typically not be required, except to remove oversize material.

4.5 Stability

DWR performed feasibility-level stability evaluations for the earth and rockfill dam embankment (Option 1A) with upstream and downstream slopes of 2.25H:1V and 2H:1V (DWR, 2003a). The analysis was performed for the 1.8-MAF reservoir, with a nominal crest at elevation 540 feet. Factors of safety were estimated for pool and partial pool conditions with seepage, and for a rapid drawdown condition. The safety factors between 1.5 and 2.2 were found to exceed customary allowable safety factors for large dams as recommended in federal and state standards. The analyses were based on very limited site-specific information, and used strength values based on similar materials and experience.

DWR performed simplified seismic stability analysis using a range of peak ground acceleration (PGA) values of 0.5 g, 0.7 g, and 0.9 g. The maximum reported earthquake-induced displacements using the Newmark and Makdisi-Seed Sliding Block approaches for the PGA of 0.9 g are as follows:

- Golden Gate Dam: 2.1 feet
- Large Saddle Dams: 1.2 feet
- Small Saddle Dams: <1 foot

Considering the dam height and 20 feet of freeboard without camber, AECOM agrees with DWR's assessment that these displacements are considered to be acceptable.

Displacements for Sites Dam was not reported by DWR. However, because Sites Dam has a similar cross-section to Golden Gate, and has a lower maximum height than Golden Gate, the earthquake-induced displacements for Sites Dam would be similar to those for Golden Gate Dam. Seismically induced reservoir seiches were also evaluated by DWR. Wave heights would be significantly less than the reservoir freeboard at full pool, even allowing for crest deformations.

In summary, based on DWR's simplified analyses, the potential earthquake-induced displacements of the dams (Option 1A) for the Sites Reservoir indicate acceptable seismic performance. This assessment would need to be confirmed by conducting further field investigations and laboratory testing of foundation and borrow materials (Section 9), confirming design ground motion parameters, and performing comprehensive seismic deformation analyses.

Stability analyses have not been performed for the earthfill dam option (Option 1B). The earthflll dam upstream slope was selected based on precedent for this type of dam and size.

4.6 Foundation Seepage Control

4.6.1 Golden Gate and Sites Dams

A review of water pressure test data from DWR drill holes in the Golden Gate and Sites Dam foundation indicates that the slightly weathered to fresh bedrock, is—overall—fairly impermeable. However, because water pressure test data indicated that some areas of higher hydraulic conductivity occur in the upper portion of the dam foundation, consolidation and curtain grouting were included in the dam design to reduce seepage through the dam foundation. Curtain grouting would be used to reduce seepage quantities and seepage pressures though the dam foundations. Near-surface joints and discontinuities can be more open, and are more likely to be filled with weathering products than deeper discontinuities. To address this, consolidation grouting would be used to further reduce the potential for development of seepage paths through discontinuities in the near-surface rock.

The grout program would consist of a two-row grout curtain, with one row of consolidation holes upstream and one row downstream of the curtain holes. The rows would parallel the dam centerline, and be spaced 10 feet apart. In addition, a 40-foot-wide by 3-foot-thick concrete grout cap was included to mitigate surface leakage of grout during grouting of the upper stage.

Each row of consolidation and curtain grout holes would consist of mandatory primary and secondary holes spaced at 10-foot centers. In addition, it was assumed that tertiary holes (between the primary and secondary holes) would be required over half the length of the dam to meet grout closure criteria. Consistent with dam foundation grouting practices, the drilling depth of consolidation holes was estimated to be one-quarter the height of the dam, with a minimum depth of 50 feet. In addition, the drilling depth of curtain holes was estimated to be one-half the height of the dam, with a minimum depth of 100 feet.

Drawings STS-330-C-5601 and STS-345-C-5601 show profiles of Sites and Golden Gate illustrating the consolidation and curtain grouting.

4.6.2 Saddle Dams

For saddle dams, curtain grouting was included in the design of the saddle dams to reduce seepage through the dam foundations. Foundation grouting would consist of a two-row vertical grout curtain spaced 10 feet apart parallel to the dam centerline. Each row of curtain grout holes would consist of mandatory, primary, and secondary holes spaced at 10-foot centers; and tertiary holes split-spaced between the primary and secondary holes. Consistent with dam foundation grouting practices, the drilling depth of curtain holes was estimated to be one-half the dam height, or a minimum depth of 30 feet. In addition to the grouting program described here, additional grouting and/or treatment of special features, such as the Salt Lake fault (see Drawing STS-350-C-2601), would likely be required. This additional grouting and/or treatment would be examined further once additional geologic information is available.

5.0 Dam Option 2 – Hardfill Dams

5.1 Hardfill Dam Sections

Drawings STS-330-C-3601, STS-345-C-3601, and STS-350-C-3603 provide typical sections for hardfill dams at Sites, Golden Gate, and Saddle dams. The sections show a hardfill dam with a crest width of 30 feet, and 0.8H:1V upstream and downstream slopes with concrete facings. The hardfill dam footprint for Sites Dam is shown on Drawings STS-330-C-2601 and STS-331-C-2601. The hardfill dam footprints for Golden Gate Dam are shown on Drawings STS-345-C-2601 and STS-345-C-2602. Two potential locations (Axis 1 and Axis 2) for the hardfill dam are shown. Axis 1 is at the same location as the other Golden Gates dam options (Drawing STS-345-C-2601). Another potential dam location (Axis 2) was developed approximately 700 feet upstream of Axis 1. This axis location would reduce the volume of hardfill and moves it off of Fault GG-2 (Drawing STS-345-C-2601). However, Axis 2 would locate the dam over Fault GG-1. Axis 2 would also require a saddle dam approximately 1,500 feet south, as shown on Drawing STS-345-C-2602. Two saddle dam location options are considered. Both were selected to be earthfill dams. The footprints are shown on Drawing STS-345-C-2602.

A potentially significant benefit of the hardfill dam is to incorporate the inlet/outlet (I/O) structure on the upstream face of the dam, run the I/O conduits through the dam itself, and include the spillway over the dam. These concepts are shown on Drawing STS-345-C-3601. This concept would eliminate the need for a separate I/O tower and tunnels for the conduits, resulting in potential cost savings.

As discussed in Section 3.2, Sites, Golden Gate, and Saddle Dam 5 have faults that pass through their footprints. These dams would be designed to safely accommodate the potential fault displacement. This could be accomplished by providing a flexible geomembrane liner anchored to the upstream face of the hardfill dam.

Hardfill is “low strength concrete” (uses imported cement and fly ash), built by earth-moving methods (like roller-compacted concrete), and has steeper slopes than embankment dam types. As mentioned above, hardfill dams includes spillway and outlet works in the dam, so they may be less costly than the embankment dam options. Foundation stability and deformation considerations, however, would be important in the design of this dam type.

Cofferdams may be required for Sites Dam and Golden Gate Dam, and are shown in plan on Drawings STS-330-C-2601 and STS-345-C-2601, and in section on Drawings STS-330-C-3601 and STS-345-C-3601. The cofferdams would be upstream of the foundation excavations along Stone Corral and Funks Creeks. The cofferdams would be constructed of Zone 4 material, likely derived from the excavation of the dam foundations. The crest of the cofferdams is set at elevation 310 feet (5 feet above high water during construction).

Diversion of Funks and Stone Corral creek flows through the Golden Gate and Sites dam sites could be accomplished by constructing a diversion structure (box culvert) in the creek channels. The hardfill dam would be placed on top of the culvert. When diversion is no longer necessary at the completion of dam construction, the culvert would be plugged with concrete or converted into a low-level outlet works.

5.2 Foundation Objectives

Based on geologic characterization and observation of limited drill core photos, slightly weathered to fresh bedrock is considered suitable foundation for Golden Gate and Sites dams. For the saddle dams, slightly weathered bedrock is judged to be a suitable foundation for the hardfill dam type. Rock coring and dilatometer testing would be needed to evaluate the foundation rock strength and deformability.

5.3 Foundation Excavation and Dewatering

The description of foundation excavation and dewatering requirements in this section is similar to that described for the embankment dam types in Section 4.3, but tailored to the hardfill dam.

Bedrock underlying the Golden Gate Dam footprint is predominantly Cortina Formation, while the Sites Dam footprint consists of both Boxer and Cortina Formations. The upstream footprint of the Sites dam would be predominantly founded on Boxer Formation, and the downstream footprint of the dam would be founded on Cortina Formation. At the Sites Dam site, the Boxer Formation is generally characterized as mudstone with sandstone interbeds. The Cortina Formation is generally characterized as sandstone with interbedded mudstone.

To meet the foundation objectives for the hardfill dam, recent and older alluvium— decomposed intensely and moderately weathered bedrock—would be excavated from the entire footprint of Golden Gate and Sites Dam to obtain a slightly weathered bedrock surface. Review of limited geologic information indicates that the average depth to slightly weathered to fresh bedrock is 40 feet bgs.

Bedrock underlying the saddle dam footprints is predominantly mudstone with siltstone, sandstone, and a conglomerate of the Boxer Formation. To meet the foundation objectives, colluvium—decomposed, intensely, and moderately weathered bedrock—would be excavated from the entire footprint of the saddle dams to obtain a slightly weathered bedrock surface. The average depth to slightly weathered bedrock for saddle dams is 35 feet.

Review of the limited geotechnical information performed near the dams indicate that groundwater is present at the site, and dewatering would be required during excavations. For Golden Gate Dam, the groundwater is approximately 13 feet to 25 feet bgs along the dam channel area, and about 40 feet to 75 feet bgs along the dam abutments. For Sites Dam, the groundwater is approximately 10 feet to 20 feet along the dam channel area; and for the most part, reflects the groundwater elevation associated with the creek channel. The depth to water at the abutments averaged about 80 feet bgs. For saddle dams, the groundwater depth is shallow (less than 10 feet bgs) along the channel areas, and varies between 20 feet to 90 feet bgs along the abutments.

5.4 Dam Materials

Hardfill is a mixture of sand, gravel, water, cement, fly ash, and admixtures that would be combined in an on-site batch plant; placed in dump trucks; dumped; and spread and compacted in lifts in a manner similar to that used for roller-compacted cement or soil cement. Alternatively, a conveyor belt may be used to transport the hardfill mix to the dam sites. The sand and gravel can be produced from the on-site fresh Venado Sandstone of the Cortina Formation. The sand and gravel would be quarried, and crushed and graded using an on-site rock processing plant. Trial mixes would be needed during design to evaluate the strength and deformation properties. During design, samples of the fresh Venado Sandstone can be taken to an existing rock processing plant for a test crushing and screening to use in a trial mix. This could be part of a test quarry during design.

5.5 Stability

Stability analyses have not been performed for this option. However, the side slopes of 0.8H:1V were selected for the hardfill section based on a precedent review of these types of dams (ICOLD, 2017).

5.6 Foundation Seepage Control

As indicated on the sections, the hardfill dam has a two-row grout curtain, consolidation grouting, and drainage gallery upstream of the dam axis. The actual depth of the grout curtain would be evaluated based on the geotechnical exploration data. The description of the grout curtain is similar to that described in Section 4.6 for the embankment dam types. In addition, consolidation grouting would be needed in fractured areas of the dam foundation.

6.0 Dam Option 3 – Concrete Gravity Spillway Structure

6.1 Spillway Location and Crest Options

The preferred location for a flood control spillway is around the northern perimeter of the reservoir. At this location, the ridges are low and the elevation drop between the water level in the reservoir and the topography downstream is smallest compared with other locations along the eastern ridge forming the reservoir. This leads to more efficient spillway designs, with minimum spillway chute sections and minimum energy dissipation requirements downstream.

The preferred location for the spillways would be at one of the saddle dam locations. Options would include incorporating the spillway structure in the abutment of one of the larger earthen saddle dams (like Saddle Dam 3 or Saddle Dam 5). Another option would be to locate the spillway at a small saddle dam location and use a concrete gravity dam with integral spillway section. In reviewing the various location options, Saddle Dam 8B was selected for the feasibility study as the location for a concrete gravity dam and spillway. Considerations for this selection included the short length of dam required, more favorable topography, and direct connection to the reservoir without significant channel excavations or hillside cutting.

The spillway crest for the 1.5-MAF Reservoir could be set at elevation 498.0 feet, corresponding to the NMWS elevation. When PMF routing is superimposed on the full reservoir, a portion of the inflow would pass over the spillway and flow down the Hunters Creek drainage. The estimated peak spillway discharge is approximately 3,900 cubic feet per second (cfs), with a maximum flood water surface reaching elevation 503.3 feet. It is likely that flood easements would be required for some distance down Hunters Creek to the point where the spillway discharge produces no increased hydraulic impacts beyond the no-project condition. With and without project conditions would have to be studied to evaluate the extent of flood easements required. In addition, a spillway release during the wet season could adversely affect existing creek conveyance facility infrastructure at the Glenn-Colusa Irrigation District (GCID) and Tehama-Colusa Canals, Interstate 5, and other crossings.

To avoid flood easements and potential impacts to existing infrastructure, the crest of the spillway could be raised to elevation 504.0 feet so that the PMF runoff to the reservoir is fully stored, and there would be no spillway releases. The reservoir water surface for full storage of the PMF is estimated to reach elevation 503.8 feet. Raising the spillway crest level from 498.0 feet to 504.0 feet would not significantly impact the cost of the spillway structure. Figures 6-1 and 6-2 show the two spillway sections with crest elevations at 504.0 feet and 498.0 feet, respectively.

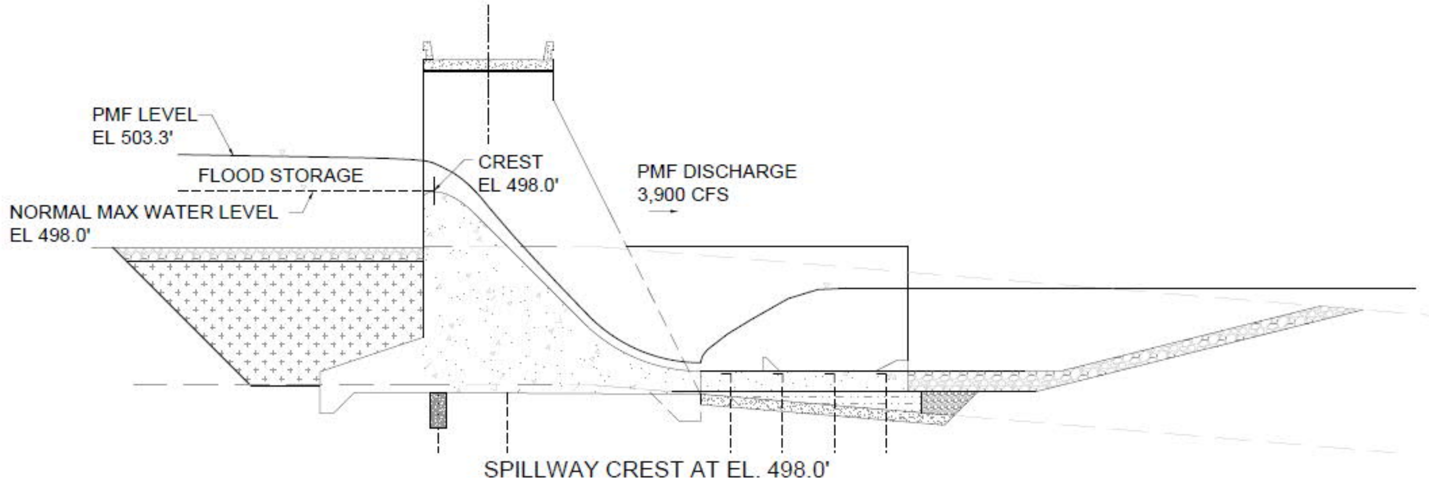

Figure 6-1. Spillway Crest Elevation 498 feet

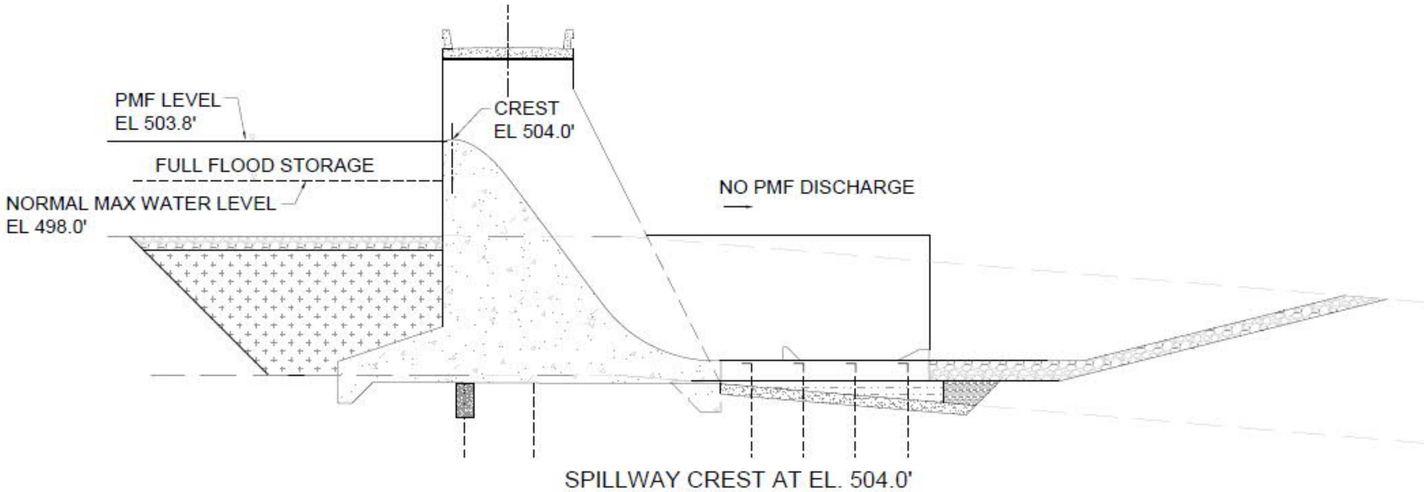

Figure 6-2. Spillway Crest Elevation 504 feet

The peak overflow during probable maximum flood routing would be approximately 3,900 cfs, which also corresponds to the combined maximum pumping capacity for the Terminal Regulating Reservoir and Funks pumping plants for the 1.5-MAF Reservoir option. If the spillway crest is raised to elevation 504.0 feet to fully store the probable maximum flood runoff as described above, there is no sizing criteria for the spillway. It is unrealistic that two canal operators (Tehama-Colusa Canal Authority and GCID) would over-pump at the same time, and over-pump together continuously for more than 10 days to produce spillway flows due to the large incremental storage capacity in the reservor at the levels involved.

Considering the low probability of an over-pumping event, the off-stream location of the reservoir with small natural drainage area, and stringent reservoir operating criteria that would be in place, the spillway with crest at elevation 504 feet is recommended. It is recommended to have a preliminary consultation with California Department of Water Resources, Division of Safety of Dams to discuss the criteria for the size of the spillway. The current drawings show a crest at elevation 504.0 feet to store the PMF without spilling, and sufficient capacity to pass full over-pumping in the unlikely event that over-pumping occurred for more than 10 days.

6.2 Concrete Gravity Dam Sections

Drawings STS-360-C-4601 and STS-360-C-5601 show the plan, section, and profile views of the concrete spillway structure for Saddle 8B. The structure consists of a gravity concrete section with 16-foot crest width, a vertical upstream face, and 0.5H:1V downstream face. The crest of the dam section is elevation 517 feet, and the crest of the spillway is elevation 504.0 feet. The spillway section includes a reinforced-concrete slab with dowels into rock. A riprap-lined basin would be located further downstream. There is a bridge over the spillway with a center supporting pier.

6.3 Foundation Objectives

Based on geologic characterization and visual observation of photos of limited drill core for the saddle dams, slightly weathered bedrock is judged to be a suitable foundation. At Saddle 8B, the depth to slightly weathered rock is assumed to be 20 feet. Coring and dilatometer testing would be needed to evaluate the foundation rock.

6.4 Foundation Excavation and Dewatering

As stated above for Saddle 8B, the depth to foundation is estimated to be approximately 20 feet. The depth to groundwater varies, and perched water has been observed to be as shallow as a few feet in the low points of the saddles. It is likely that some dewatering would be required, and could be accomplished by sumps in the excavation.

6.5 Dam Materials

The dam and spillway would be concrete founded on slightly weathered rock. Sand and gravel for concrete aggregates would be imported from off-site commercial sources described above. Zone 1 clay backfill would fill the foundation excavation upstream of the structure; and Controlled Low-Strength Material fill, imported drainage material, and Venado Sandstone riprap would be used downstream of the spillway.

6.6 Stability

Stability analyses have not been done for this option. The section was selected based on precedent for this type of structure.

6.7 Foundation Seepage Control

As indicated on the drawings, seepage control would consist of a two-row grout curtain. The upstream row includes a concrete grout cap. Downstream beneath the spillway slab is a drainage blanket to reduce potential uplift of the slab.

7.0 Reservoir Rim

7.1 East Ridge Stability

Much of the reservoir's eastern rim is impounded by relatively high, steep ridges trending north-south. The stability of this natural ridge would be considered under a future reservoir level.

Generally, the ridge on the eastern side of the reservoir is composed of upper Cretaceous marine sedimentary rocks of the Cortina and Boxer Formations. The rock characterized by these formations is interbedded sandstone and mudstone that strike generally north and dip steeply to the east. Exploratory drilling by DWR found generally good-quality rock at depth, with light to moderate weathering and fracturing.

The potential for reservoir pressures west of the ridge to affect stability of the east-facing slope of the ridge was appraised at the feasibility level by reviewing the topography and the geometry of the rock structure.

Based on review of the topography around the eastern side of the reservoir, the critical locations for seepage and stability (steepest slopes and narrowest ridge) appear to be at the right and left abutments of the Golden Gate Dam site. Topography and geology at these locations are shown on the plates from the 2003 DWR geology report. The sedimentary geology that composes the ridge has an average dip of 63 degrees parallel to the slope. The bedding dips steeper than the slope; therefore, joint-controlled failures are not likely to be a significant factor in the stability of the east-facing slope. The mapped attitudes vary in dip, but the mapped features dip steeper than the average ridge slope of about 31 degrees.

Future geotechnical analyses would be needed to further evaluate the geotechnical conditions and stability of selected portions of the reservoir ridge.

7.2 Reservoir Eastern Rim Grouting

The eastern reservoir rim narrows in locations from Golden Gate Dam north through the location of the northernmost saddle dam. Potential through-seepage could occur in these narrow ridge areas at maximum reservoir water level, depending on the depth to fresh rock. Additional geotechnical investigations would be needed to further evaluate seepage conditions. A practical method to address rim seepage would be to:

- Extend the embankment foundation grouting for Golden Gate Dam and the saddle dams along the ridge through narrow areas of concern.
- Add ridge grouting in areas of concern between dams (narrow sections of the ridge).

8.0 Instrumentation

Instrumentation would be installed in the dam embankment, or in the hardfill dam and foundation, downstream of the dam, and in the abutments. The objectives of instrumenting the dam include developing physical data for comparison to assumptions made for the design analyses; anticipated behavior based during the studies; and monitoring of dam performance during construction, first filling of the reservoir, and long-term operation of the project. The selection of the type and location of instrumentation would be based on measurement of specific engineering parameters that need to be monitored, including deformation, seepage flows, piezometric levels (or uplift in the hardfill dam), pore-water pressure, and seismic response.

Instrumentation data would initially be used to evaluate the behavior of the dam during construction, and whether constructed conditions are consistent with the design assumptions. During long-term operation of the project, instrumentation data would be used to monitor the performance of the dam. As data are compiled, trends under normal operation would be established, and the significance of variations under unusual events or loads, such as earthquakes, could be evaluated.

Primary considerations in the selection of the types of instrumentation are the reliability and accuracy needed to meet the objectives presented above. In addition, the instrumentation would be selected to minimize disruption to construction operations to the fullest practical extent.

Selection of instrumentation would be coordinated with the Authority for development of the automated data acquisition system (ADAS). Requirements for instrumentation would emphasize the performance and durability of each instrumentation system, as well as the need for low maintenance. Table 8-1 lists the types and purpose of instrumentation for installation at the dam.

Table 8-1. Summary of Instrumentation

Type	Purpose
Vibrating Wire Piezometer	Piezometric level; or uplift below the hardfill dam
Open Standpipe Piezometer	Piezometric level
Inclinometer	Lateral deformation
Survey Monument	Three-dimensional surface deformation
Seepage V-notch Weir	Seepage rate
Strong Motion Accelerograph	Earthquake acceleration time history
Reservoir Level Device	Reservoir level change
Thermocouples	Hardfill temperature to confirm heat rise is within design expectations during construction

The monitoring frequency of the instrumentation systems would be developed as part of future design studies, and would be part of an instrumentation monitoring plan. Those studies would be coordinated with the Authority so that the monitoring requirements can be integrated into project operation.

Performance monitoring instrumentation would be included in the design of the dam. Data from the reservoir-level sensor, piezometers, and V-notch weirs would be transmitted by radio from the remote terminal units to the ADAS central recording hub, where the data would be logged and processed according to programming. Strong motion recordings from the accelerographs can be downloaded using direct cable connection, or uploaded over cell or radio networks independent of the ADAS. The piezometer data can also be recorded manually at read-out terminals. V-notch weir and reservoir-level data can be visually recorded from staff gauges.

9.0 Geotechnical Investigations

9.1 Previous Investigations

DWR performed a study that included detailed geologic surface mapping and exploration drill holes at both the Sites and Golden Gate dam sites and the saddle dam locations (DWR 2003b). DWR performed field work between 1998 and 2001. Borehole exploration consisted of drilling 45 core holes totaling 9,513 feet, and about 16 auger holes totaling 267 feet, as summarized in Table 9-1. Reclamation performed a geotechnical investigation in 1980 that included geologic surface mapping and exploration drill holes at Sites, Golden Gate, and saddle dams (DWR 2003b). A summary of the Reclamation drilling is presented in Table 9-1. Both Reclamation and the DWR excavated test pits in the proposed Sites Reservoir as part of a construction materials investigation.

Table 9-1. Summary of Existing Investigations at Sites Reservoir

Dam	No. of Boreholes			
	DWR 1998 to 2001		USBR 1980	
	No. of Boreholes	Borehole Name	No. of Boreholes	Borehole Name
Golden Gate	11	RC-1, LC-1, LA-1, RA-1, GGC-RC1, GGC-RC2, GGC-LA1, GGC-RA1, AUG-4 TO AUG-6	3	DH-201, DH-204, DH-205
Sites	7	LC-1 to LC-4, AUG-1 TO AUG-3	3	DH-301 TO DH-303
Saddle Dam 1	0	–	1	DH-100
Saddle Dam 2	0	–	1	DH-101
Saddle Dam 3	9	SSD3-1 TO SSD3-6, AUG-1 TO AUG-3	2	DH-102, DH-103
Saddle Dam 5	4	SSD5-1 TO SSD5-4	2	DH-105, DH-106
Saddle Dam 6	1	SSD6-1	1	DH-107
Saddle Dam 8	4	SSD8-1 TO SSD8-3, SSD8-5	2	DH-110, DH-111

9.2 Recommended Geotechnical Investigations for Design

9.2.1 Dam Foundations

The objective of the dam foundation exploration is to evaluate:

- Excavation methods
- Excavated material use for dam construction
- Dewatering requirements for foundation excavation
- Confirmation of fault locations and fault rupture potential
- Foundation deformability, hydraulic conductivity and strength
- Foundation treatment
- Foundation grouting/cutoff requirements

The investigations for the dams should consist of geologic mapping, geophysics, borings, test pits, test excavations, and fault trenching. In situ testing should include downhole geophysics (suspension and televiewer), packer testing, and dilatometer. Piezometers would be installed at select locations to get an understanding of groundwater depth. Laboratory testing would include point load and unconfined compression on rock and index testing of soils. Geologic logging would include observations of degree of weathering and the orientation and description of shears, joints, and fractures.

9.2.2 Dam Borrow

The objective of the exploration is to evaluate:

- Excavation methods
- Borrow excavation slopes
- Dewatering for borrow excavations
- Volume of materials generated from excavation
- Material types generated by excavation
- Requirements for processing of materials
- Properties of materials when placed and compacted in the dams
- Evaluation of rock for riprap and aggregates
- Evaluation of types and volumes of materials generated from required excavations from dams, structures, and tunnels.
- Confirmation that the volume of materials available is at least 1.5 times the volume required.

The investigation for the borrow areas should consist of geologic mapping, geophysics, borings, test pits, test excavations, test blasting and test fills. In situ testing would include downhole geophysics (suspension and televiewer) and rippability studies. Laboratory testing would include point load and unconfined compression on rock and index testing of soils. Laboratory testing would also include testing on remolded samples for compaction, strength, permeability, compressibility, and erosion potential. Test fills would be performed on rockfill and random fill materials. Geologic logging would include observations of degree of weathering and the orientation and description of shears, joints, and fractures.

9.2.3 Reservoir Rim

The objective of the exploration is to evaluate seepage and stability. The exploration for the reservoir rim would consist of geologic mapping, geophysics, borings, and test pits. In situ testing would include downhole geophysics (televiewer) and packer testing. Laboratory testing would include point load and unconfined compression on rock. Lab testing may include testing of remolded joint/shear material for strength evaluation. Geologic logging would include observations of degree of weathering, and the orientation and description of shears, joints, and fractures.

10.0 Plan Sheets

Table 10-1 lists the dam drawings that are presented under separate submittal.

Table 10-1. List of Dam Drawings

Drawing No.	Main Title	Subtitle
STS-315-C-2001	General	Main Dams and Saddle Dams – Location Plan
STS-315-C-2002	General	Offsite Borrow Areas and Quarries – Location Plan
STS-315-C-2003	General	Haul Routes, Borrow, Disposal, Stockpile, Staging, and Rock Processing Areas
STS-315-C-2004	General	Haul Routes, Borrow, Disposal, Stockpile, Staging, and Rock Processing Areas (Expanded View)
STS-320-C-2601	Sites Dam	Plan – Earth and Rockfill Dam (Option 1A)
STS-320-C-3601	Sites Dam	Section A – Earth and Rockfill Dam (Option 1A)
STS-325-C-2601	Sites Dam	Plan – Earthfill Dam (Option 1B)
STS-325-C-3601	Sites Dam	Section A – Earthfill Dam (Option 1B)
STS-330-C-2601	Sites Dam	Plan – Hardfill Dam (Option 2)
STS-330-C-3601	Sites Dam	Section A – Hardfill Dam (Option 2)
STS-330-C-5601	Sites Dam	Grouting Detail
STS-331-C-2601	Sites Dam	Plan – Comparison of Dam Type Footprints
STS-335-C-2601	Golden Gate Dam	Plan – Earth and Rockfill Dam (Option 1A)
STS-335-C-3601	Golden Gate Dam	Section A – Earth and Rockfill Dam (Option 1A)
STS-335-C-3602	Golden Gate Dam	Section B – Earth and Rockfill Dam (Option 1A)
STS-340-C-2601	Golden Gate Dam	Plan – Earthfill Dam (Option 1B)
STS-340-C-3601	Golden Gate Dam	Section A – Earthfill Dam (Option 1B)
STS-345-C-2601	Golden Gate Dam	Plan – Hardfill Dam (Option 2 – Axis 1)
STS-345-C-2602	Golden Gate Dam	Plan – Hardfill Dam (Option 2 – Axis 2)
STS-345-C-3601	Golden Gate Dam	Section A – Hardfill Dam (Option 2)
STS-345-C-5601	Golden Gate Dam	Grouting Detail
STS-347-C-2601	Golden Gate Dam	Plan – Comparison of Dam Type Footprints
STS-350-C-2001	Saddle Dams and Dikes	Location Plan

STS-350-C-2601	Saddle Dams 1 and 2	Plan – Options 1A, 1B, 2
STS-350-C-2602	Saddle Dam 3	Plan – Options 1A, 1B, 2
STS-350-C-2603	Saddle Dams 5 and 6	Plan – Options 1A, 1B, 2
STS-350-C-2604	Saddle Dams 8A & 8B/Saddle Dikes 1 and 2	Plan – Saddle Dams (Options 1A, 1B, 2, 3) and Saddle Dikes
STS-350-C-3601	Saddle Dams – 1, 2, 3, 5, 6, 8A	Typical Section – Earth and Rockfill Dam (Option 1A)
STS-350-C-3602	Saddle Dams – 1, 2, 3, 5, 6, 8A	Typical Section – Earthfill Dam (Option 1B)
STS-350-C-3603	Saddle Dams – 1, 2, 3, 5, 6, 8A, 8B	Typical Section – Hardfill Dam (Option 2)
STS-351-C-3601	Saddle Dikes	Typical Section – Saddle Dike
STS-360-C-4601	Saddle Dam 8B	Plan and Sections – Concrete Gravity Dam and Spillway Structure (Option 3)
STS-360-C-5601	Saddle Dam 8B	Profiles – Concrete Gravity Spillway Structure (Option 3)
STS-361-C-4601	Emergency Release Structure (ERS-1)	Plan and Profile
STS-361-C-4602	Emergency Release Structure (ERS-2)	Plan and Profile

11.0 Estimated Quantities and Disturbance Areas

The estimated dam construction quantities and disturbance areas due to dam construction for Option 1A are summarized in Appendix A. These quantities and areas are likely to change as the work is advanced.

12.0 References

AECOM (2020a). Geology and Seismicity Technical Memorandum – Sites Reservoir, Service Area HR Task Order No. 1, Task HR2.91. August.

AECOM (2020b). Creek Diversions Technical Memorandum –Sites Reservoir, Service Area HR Task Order No. 1, Task HR2.95. August.

Department of Water Resources (DWR) (2003a). Sites Reservoir Engineering Feasibility Study, Golden Gate, Sites, and Saddle Dams. February.

Department of Water Resources (DWR) (2003b). Geologic Feasibility Report, Sites Reservoir Project, Appendix to Engineering Feasibility Report, Project Geology Report No. 94-30-02. July.

International Commission on Large Dams (ICOLD) (2017). Technical Committee on Cemented Material Dams, The 2nd Workshop on Cemented Material Dams (CMDs), Prague. July 3.

Appendix A

Estimated Quantities and Disturbance Areas

Calculated by: RN
Reviewed by: MS
Date: August, 2020

TABLE A-1 - ESTIMATED QUANTITIES FOR 1.5 MAF RESERVOIR CAPACITY - OPTION 1A (EARTH AND ROCKFILL)

			Footprint Areas (acres)			Dam Embankment Volume											Excavation Volume (CY)
Dam	Length, ft	Maximum Height, ft	Total Area	Area within Reservoir	Area outside Reservoir	Zone 1 (Core), CY	Zone 2A (Filter), Tons	Zone 2A (Drain), Tons	Zone 2A (Transition), Tons	Zone 2B (Filter), Tons	Zone 2B (Transition), Tons	Zone 3 (Rockfill), CY	Zone 4 (Random), CY	Riprap, CY	Cement (Tons)	Concrete Aggregate, CY	Foundation Excavation (CY)
Golden Gate	2,200	287	38	17	21	2,400,000	660,000	730,000	98,000	410,000	430,000	2,600,000	2,200,000	98,000	30,000	88,000	1,600,000
Sites	780	267	18	9	8	710,000	220,000	270,000	39,000	135,000	145,000	1,050,000	660,000	40,000	9,500	28,000	570,000
Saddle Dam 1	310	27	2	1	1	20,000	7,300	6,600	1,500	-	-	17,000	16,000	3,100	1,100	3,300	25,000
Saddle Dam 2	240	57	2	1	1	20,000	7,300	6,600	1,500	-	-	17,000	16,000	4,400	1,150	3,500	25,000
Saddle Dam 3	3,400	107	33	11	22	900,000	290,000	290,000	84,000	-	-	610,000	1,600,000	130,000	19,500	59,000	670,000
Saddle Dam 5	1,900	77	18	6	12	310,000	110,000	115,000	33,000	-	-	190,000	470,000	47,000	1,950	4,600	260,000
Saddle Dam 6	360	47	3	1	2	30,000	13,000	13,000	3,700	-	-	15,000	34,000	4,500	8,000	25,000	32,000
Saddle Dam 8A	1,300	82	13	4	9	360,000	130,000	135,000	37,000	-	-	175,000	530,000	43,000	2,400	6,500	280,000
Saddle Dam 8B (Spillway)	470	37	2	1	1	20,000	-	540	-	-	-	-	-	2,400	-	19,500	40,000
Saddle Dike 1	120	12	1	-	1	-	-	-	-	-	-	-	3,900	-	-	-	3,300
Saddle Dike 2	200	12	1	-	1	-	-	-	-	-	-	-	6,300	-	-	-	5,400
Rim Grouting	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,200	-	-
Emergency Release Structure, ERS -1	-	-	4	-	4	-	-	170	-	-	-	-	63,000	4,500	-	2,000	81,000
Emergency Release Structure, ERS -2	-	-	3	-	3	59,000	-	190	-	-	-	-	-	4,200	-	2,000	77,000
Total Quantities						4,800,000	1,450,000	1,550,000	300,000	550,000	580,000	4,700,000	5,600,000	380,000	75,000	241,000	3,700,000

Assumptions:

1. The quantities are approximate and will change as the project moves forward.

2. Cement quantities include cement for grouting and concrete (grout cap, dental and backfill concrete).

3. Concrete aggregate volumes include structural, backfill, dental and grout cap.

Calculated by: RN
Reviewed by: MS
Date: August, 2020

TABLE A-2 - ESTIMATED BORROW, STOCKPILE, DISPOSAL,STAGING, PROCESSING AND HAUL ROAD AREAS FOR 1.5 MAF RESERVOIR CAPACITY

	Golden Gate			Sites Dam			Saddle Dams 1 and 2			Saddle Dam 3			Saddle Dams 5, 6, 8A, 8B, Saddle Dikes 1 and 2, ERS 1 and 2			
	ID #	Required Volume, CY	Footprint Area (acres)	ID #	Required Volume, CY	Footprint Area (acres)	ID #	Required Volume, CY	Footprint Area (acres)	ID #	Required Volume, CY	Footprint Area (acres)	ID #	Required Volume, CY	Footprint Area (acres)	Total (acres)
Total Dam Footprint/Construction Area, acres	-	-	76	-	-	36	-	-	7	-	-	66	-	-	89	274
Dam Footprint/Construction Area Inside Reservoir, acres	-	-	34	-	-	19	-	-	3	-	-	21	-	-	24	101
Dam Footprint/Construction Area Outside Reservoir, acres	-	-	42	-	-	17	-	-	5	-	-	45			65	173
Borrow Areas (permanent)																
Impervious Area (Zone 1) Inside Reservoir	GG-Z1 Borrow	4,800,000	150	Sites-Z1 Borrow	1,420,000	44	SD 1, 2-Z1 Borrow	80,000	3	SD3-Z1 Borrow	1,800,000	56	SD5,6,8-Z1 Borrow	1,558,000	48	300
Rockfill (Zone 3) and Riprap Inside Reservoir	GG- Z3 Quarry 1		37	-		-	-		-	SD3,5,6,8A-Z3 Quarry 1		51	SD3,5,6,8A-Z3 Quarry 1		60	150
Rockfill (Zone 3) and Riprap Outside Reservoir	GG- Z3 Quarry 2	10,800,000	300	Sites- Z3 Quarry	4,360,000	135	SD1,2,3-Z3 Quarry 2	166,000	5	SD1,2,3-Z3 Quarry 2	2,960,000	41	-	1,942,400	-	480
Random (Zone 4) - Inside Reservoir	GG- Z3 Quarry 1		10	-		-	-		-	SD3,5,6,8A-Z3 Quarry 1		10	SD3,5,6,8A-Z3 Quarry 1		20	40
Random (Zone 4) - Outside Reservoir	GG- Z3 Quarry 2	4,400,000	125	Sites- Z3 Quarry	1,320,000	41	SD1,2,3-Z3 Quarry 2	64,000	2	SD1,2,3-Z3 Quarry 2 GG- Z3 Quarry 2	3,200,000	20 69	GG- Z3 Quarry 2	2,088,400	45	300
Other Areas (temporary/permanent)																
Stockpile Area Inside the Reservoir (temporary)	GG-Stockpile	-	41	Sites-Stockpile	-	19	SD1,2-Stockpile	-	13	SD3-Stockpile	-	32	SD5,6,8A-Stockpile	-	40	145
Disposal Areas Inside the Reservoir (permanent)	GG-Disposal Area	-	132	Sites-Disposal Area	-	32	-	-	-	-	-	-	-	-	-	164
Staging Areas Inside the Reservoir (temporary)	GG-Staging	-	56	Sites-Staging	-	33	SD1,2-Staging	-	5	SD3,5-Staging	-	23	SD 6,8A Staging SD3,5-Staging	- -	5 23	145
Rock Processing Area Inside Reservoir (permanent)	GG-Rock Processing 1	-	14	-	-	-	-	-	-	SD3,5,6,8A-Rock Processing	-	7	SD3,5,6,8A-Rock Processing	-	7	29
Rock Processing Area Outside Reservoir (temporary)	GG-Rock Processing 2	-	49	Sites-Rock Processing	-	30	SD1,2,3-Rock Processing	-	10	SD1,2,3-Rock Processing	-	10	-	-	-	99
Haul Routes Inside Reservoir (permanent)	-	-	12	-	-	22	-	-	35	-	-	51	-	-	45	166
Haul Routes Outside Reservoir (temporary)	-	-	25	-	-	15	-	-	31	-	-	12	-	-	22	104
															Total Area (acres)	2,400
Offsite Borrow																
Offsite Borrow (Zone 2) (Tons)	-	2,800,000	-	-	970,000	-	-	50,000	-	-	800,000	-	-	700,000	-	5,320,000
Cement (Tons)	-	36,000	-	-	11,500	-	-	2,700	-	-	23,000	-	-	16,000	-	89,000
Concrete Aggregate (CY)	-	105,000	-	-	34,000	-	-	8,200	-	-	71,000	-	-	72,000	-	290,000

Assumptions:

1. Plan view showing the locations of the areas presented above is provided in STS-315-C-2003 and STS-315-C-2004.
2. Dam Footprint areas are doubled to account for the dam construction disturbance area.
3. Required volume of borrow is doubled from the estimated volume for all Zones, except for Zone 2, concrete and Zone 3 volumes. The Zone 2 and concrete volumes are off site borrow materials and the numbers are increased by 20 percent. The required volume for Zone 3 is increased by 4 times.
4. Disturbance areas inside the reservoir are considered permanent.
5. Zone1 borrow is approximately 25 feet deep and yields 20 feet of Zone 1, remainder to disposal.
6. Zone 3 borrow yields 20 feet of Zone 3, remainder Zone 4 and to disposal.
7. Haul routes assumed to be 50 feet wide and length of the haul routes are doubled.
8. Areas within the reservoir having elevations lower than 290' are considered disposal areas.
9. Refer to technical memorandum HR.2.92; Sheets STS-320-C-2601 , STS-320-C-3601 for Sites Dam Option 1A; Sheets STS-335 C-2601, STS-335-C-3601 for Golden Gate Option 1A; Sheets STS-350-C-2601 TO STS-350-C-2604 , STS-350-C-3601, STS-351-C-3601, STS-360-C-4601 for Saddle Dams 1,2,3,5,6,8A Option 1A, Saddle Dam 8B Option 3 and Saddle Dikes.