Subject:	**Supplementary Tunnel Information – Bethany Reservoir Alternative (Final Draft)**
Project feature:	Tunnels
Prepared for:	California Department of Water Resources (DWR) / Delta Conveyance Office (DCO)
Prepared by:	Delta Conveyance Design and Construction Authority (DCA)
Copies to:	File
Date/Version:	December 23, 2021
Reference no.:	EDM_TS_CE_TMO_Supplementary-Tunnel-Info-Bethany_000991_V02_FD_20211223

1. Introduction

The DWR issued a Notice of Preparation (NOP) pursuant to the California Environmental Quality Act (CEQA) on January 15, 2020 (DWR 2020a). The NOP identified a proposed Delta Conveyance Project (project) to include new intake facilities located along the Sacramento River between Freeport and the confluence of the Sacramento River with Sutter Slough. The new project conveyance facilities would also include a tunnel to convey water from the new intakes to the existing State Water Project (SWP) Harvey O. Banks (Banks) Pumping Plant and related pumping and conveyance facilities in the south Delta.

The NOP described Central and Eastern corridor options to convey water from intakes in the north Delta to the SWP and potentially the Central Valley Project (CVP) pumping plants in the south Delta. Each corridor would use the same intakes and the same Southern Forebay, Banks Pumping Plant, and South Delta Conveyance Facilities, and project alternatives would be sized to convey a range of project design flow rates from 3,000 cubic feet per second (cfs) to 7,500 cfs.

The NOP was circulated to the public, interest groups, and agencies to receive comments. The comments were summarized in a Scoping Report DWR released in July 2020 (DWR 2020b). Some comments were related to concerns about the construction of facilities near roadways and communities near the Clifton Court Forebay (CCF). DWR considered the scoping comments and methods to reduce environmental disturbances at the new Southern Forebay. Based on these considerations, DWR identified the Bethany Reservoir Alternative that would extend from the intakes along the Eastern corridor to Lower Roberts Island; and then continue along a tunnel alignment to a new Bethany Reservoir Pumping Plant (BRPP) to be located south of CCF. The new pumping plant and associated aqueduct would convey the water to a Bethany Reservoir Discharge Structure along the rim of the existing SWP Bethany Reservoir. The BRPP, Surge Basin, Bethany Reservoir Aqueduct, and Bethany Reservoir Discharge Structure are referred to as the Bethany Complex.

1.1 Organization

This technical memorandum (TM) is organized as follows:

- Purpose
- Tunnels and Shafts Overview
- Bethany Complex Tunnels and Shafts
- Tunnel Lining Design
- Ground Settlement and Structure Protection
- Inspection and Maintenance

- Summary
- References
- Document History and Quality Assurance

2. Purpose

This TM provides supplementary tunnel information for the Bethany Reservoir Alternative and the content focuses on information that is different from the Eastern corridor tunnel information. Information contained in this TM is based on the DCA Bethany Reservoir Alternative engineering concept drawings submitted to DCO on January 15, 2021. Where information is the same as the Eastern corridor, this TM refers to prior TMs and the Eastern corridor engineering concept drawings.

3. Tunnels and Shafts Overview

The Bethany Reservoir Alternative would connect the intakes identified for the Central and Eastern corridors in the north to the existing Bethany Reservoir. The tunnel alignment is identical to the Eastern corridor from the intakes to the Lower Roberts Island tunnel launch shaft site. The tunnel alignment then extends from Lower Roberts Island to the south of CCF to a new BRPP and the conveyance system would continue southward to the existing Bethany Reservoir.

The conveyance facilities north of the BRPP would include tunnels plus a series of launch, maintenance and reception shafts with similar attributes to the ones described for the Eastern corridor with some minor differences south of Lower Roberts Island as described in Section 3.1 and as shown on Figure 1.

The conveyance facilities south of the BRPP in the Bethany Complex would include the Bethany Reservoir Aqueduct system composed of two to four parallel pipelines, including associated tunnels and shafts. The number of pipelines, tunnels and shafts for the aqueduct section of the Bethany Reservoir Alternative would be a function of the design flow rate. The Aqueduct would terminate after crossing under the Bethany Reservoir Conservation Easement into a set of vertical shafts that rise to the ground surface at the Bethany Reservoir Discharge Structure as discussed in Section 4.0.

Figure 1. Eastern Corridor and Bethany Reservoir Alternative Shafts and Tunneling Directions

3.1 Shafts – North of Bethany Complex

The proposed tunnel alignment and shaft locations along the Bethany corridor are shown on the Overall Site Map included in Attachment 1. For shaft details regarding conceptual design, and operational and construction requirements north of the Bethany Complex, including the sizing of the various shaft types, refer to the *Shaft Conceptual Design TM* (DCA 2021a). The *Facilities Siting Study – Bethany Alternative TM* (DCA 2021b) discusses methods used to identify and evaluate potential shaft sites, as well as criteria used to evaluate the preferred launch, maintenance, and reception shaft sites for the Bethany Reservoir Alternative. Table 1 summarizes the preliminary tunnel lengths and shaft invert elevations and depths.

Table 1 Tunnel Lengths, Shaft Invert Elevations and Depths for Bethany Reservoir Alternative from Intake C-E-3 to BRPP Surge Basin – 6,000-cfs Project Design Capacity

Shaft Location	Shaft Invert Elevation (feet)	Shaft Depth from Ground Level (feet)	Tunnel Length from Upstream Shaft (miles)
Tunnel Reception Shaft at Intake C-E-3	-140	143	Not Applicable
Tunnel Maintenance Shaft at Intake C-E-5	-142	150	2.5
Tunnel Launch Shafts Site on Twin Cities Complex	-150	160	5.7
Tunnel Maintenance Shaft on New Hope Tract	-152	158	4.6
Tunnel Maintenance Shaft on Canal Ranch Tract	-154	157	3.0
Tunnel Reception Shaft on Terminous Tract	-157	153	5.1
Tunnel Maintenance Shaft on King Island	-159	147	3.9
Tunnel Launch Shafts on Lower Roberts Island	-161	150	5.5
Tunnel Maintenance Shaft on Upper Jones Tract	-164	157	5.1
Tunnel Maintenance Shaft on Union Island	-166	160	4.2
Tunnel Reception Shaft at the BRPP Surge Basin	-169	209	5.2
TOTAL TUNNEL LENGTH			44.8

The following lists summarizes the main differences at the shaft sites between the Eastern and Bethany corridors.

- The Twin Cities Complex site would not include rail access and would result in all tunnel segments and construction materials being transported by truck to the site. The site layout was adjusted to reflect this change and there is no rail depot or realignment of Franklin Boulevard. The reusable tunnel material (RTM) storage area and facility layouts within the site were also updated. This is primarily because a rail access is not needed to transport RTM from Twin Cities to the Southern Forebay where the majority of the RTM generated at the Twin Cities Complex would have been used.
- The Lower Roberts Island shaft site would be a double tunnel launch shaft site rather than a tunnel launch\reception shaft site and the excavation direction would occur in both north and south directions instead of a single direction to the north under the Eastern corridor, (Figure 1). The shaft site and RTM storage area would be expanded to accommodate RTM from two tunnel boring machine (TBM) operations. The access roads and railroad alignments would also be adjusted.

- The Union Island tunnel maintenance shaft site would be new site with new access roads as compared to the Eastern corridor. This site will provide a second maintenance shaft in this long tunnel drive that is over 14 Miles.
- The reception shaft at the BRPP Surge Basin would be located within the Bethany Complex.
- The shafts south of New Hope Tract would have higher finished shaft elevations as compared to the Eastern corridor due to higher maximum surge pressures at those locations as discussed *Hydraulic Analysis of Delta Conveyance Options – Bethany Reservoir Alternative TM* (DCA 2021e).

3.2 Tunnel Reaches – North of Bethany Complex

The Bethany Reservoir Alternative tunnel alignment would be approximately 44.8 miles long for a project design capacity of 6,000-cfs from Intake C-E-3 to the Surge Basin reception shaft located adjacent to the BRPP. Based on the tunnel drive configuration, the Bethany Reservoir Alternative would include four separate tunnel reaches as shown on the Overall Site Plan included in Attachment 1 and listed in Table 2.

Table 2 Tunnel Reach Descriptions for a Project Design Capacity of 6,000 cfs

Reach	Start of TBM Drive	Completion of TBM Drive	Length (miles)	Tunneling Direction
1	Twin Cities	Intake No. C-E-3	8.2	North
2	Twin Cities	Terminous Tract	12.7	South
3	Lower Roberts Island	Terminous Tract	9.5	North
4	Lower Roberts Island	Surge Basin Shaft at BRPP	14.6	South

The Bethany Reservoir Alternative alignment would generally follow the same Eastern corridor until Lower Roberts Island and would differ where the corridor changes direction to the Bethany Complex. Since RTM would not be needed for embankment construction for the Bethany Reservoir Alternative, the Lower Roberts Island site could be configured to launch TBMs in both the north and south directions to eliminate the need for an additional tunnel launch shaft near the Bethany Complex. The double launch configuration at Lower Roberts Island was determined to be preferable due to logistical advantages at the Lower Roberts Island site (that is, proximity to major roads and railroads from the adjacent Port of Stockton versus the anticipated logistical challenges associated with a tunnel launch shaft around the CCF).

The *Tunnel Excavation and Drive Assessment TM* (DCA 2021c) discusses the considerations involved to determine feasible tunnel excavation and drive lengths for the Delta Conveyance tunnels. All tunnels slope "downhill" at 0.01 percent from north to south, and tunnel inverts range from 140 to 145 feet below mean sea level (msl) for the North Tunnel and from 145 to 164 feet below msl for the Main Tunnel. Identical to the Central and Eastern corridors, the proposed vertical alignment of the Main Tunnel for the Bethany Reservoir Alternative would conform to a Port of Stockton restriction at the undercrossing of the San Joaquin River and Stockton Deep Water Ship Channel.

3.3 Tunnel Construction Methods

Since most of the Bethany tunnel alignment would overlap with the Eastern corridor, ground conditions at-tunnel depths are expected to be the same, and would consist of clays, silts, silty and clayey sands, and clean sands. Based on the expected ground and groundwater conditions, pressurized-face TBMs would also be required to excavate the North and Main Tunnels for the Bethany Reservoir Alternative. Further details about the use of TBMs for tunnel construction are presented in the *Tunnel Excavation Drive Assessment TM* (DCA 2021c).

4. Bethany Complex Tunnels and Shafts

The Bethany Reservoir Aqueduct (Aqueduct) would convey water from the new BRPP to the Bethany Reservoir. The Aqueduct would consist of multiple large-diameter pipelines, pressurized by the BRPP. The pipelines would be 180-inch-diameter, welded steel pipe, operating at working pressures up to about 100 pounds per square inch (psi) and pressures under surge conditions of up to about 180 psi. The number of pipelines would be a function of the design flow rate. The Aqueduct would range from two to four parallel pipelines and each pipeline in the Aqueduct system would carry up to 1,500 cfs.

The Aqueduct pipelines would mostly be constructed by cut-and-cover methods. However, two tunnel crossings within the aqueduct reach would be needed one of which will carry the pipelines under an existing surface feature and the other a conservation easement. Specifically, the Aqueduct would be tunneled under the existing C.W. “Bill” Jones (Jones) Pumping Plant discharge penstocks and under the existing Bethany Reservoir Conservation Easement. The Aqueduct pipelines to the Bethany Reservoir would terminate after crossing under the Conservation Easement in a set of vertical shafts that daylight at the Bethany Reservoir Discharge Structure. Details for pipe installation inside the tunnel and shafts can be found in the *Conceptual Development of Aqueduct and Discharge Structure TM* (DCA 2021d). Attachment 2 provides the general locations of the tunneled sections.

4.1 Jones Penstocks Tunnel Crossing

4.1.1 Geometry

Tunneling under the Jones Penstocks would require the excavation of cuts to establish tunnel portals on each side of the crossing. All the major tunneling operations would be performed from the eastern portal and the excavation would end at the portal on the western side of the Jones Penstock crossing. Four tunnels would be required for the 6,000-cfs option, and each tunnel would be approximately 200 feet long and have an excavated diameter of about 20 feet. The Aqueduct pipelines would be assembled outside the tunnels and jacked into place. The annulus between the pipe and tunnel would be backfilled with grout.

4.1.2 Excavation and Initial Ground Support Methods

The tunnel underneath the Jones Penstocks could be constructed in alluvial soils, which may be highly permeable and have a high groundwater inflow potential. The tunnel is considered too short to use a TBM; however, based on the expected ground conditions, a digger shield with an excavator arm mounted inside would appear to be the most suitable excavation method. Digger shields are used mainly to excavate soft ground tunnels with short lengths. To support unstable portions of the face, digger shields can be outfitted with breast tables or breasting doors to provide face support while continuing excavation in other areas of the face. The breasting typically consists of several hydraulically actuated doors or louvers that are pushed into the face. As with all tunnel shields, the shield is advanced forward by pushing off an initial support system consisting of segmental lining or steel ribs and lagging. The initial support is assembled in the tail of the shield. Pre-excavation ground modification (including but not limited to dewatering and/or permeation grouting) would also likely be needed to improve the stability of the ground along the alignment of the new tunnel. Such ground modifications in advance of the tunneling would also reduce the water inflow rates at the tunnel face.

4.2 Conservation Easement Tunnel Crossing

4.2.1 Geometry

A construction portal would be used on the north end of the Conservation Easement Tunnel for access to complete the following tasks:

- Excavate the tunnels.
- Remove the excavated material from the tunnel.
- Provide ventilation.
- Install the tunnel temporary support
- Install the final welded steel pipe and grout the annulus.
- Provide access for work crews during construction and maintenance crews during operations.

For the 6,000-cfs project design capacity, each of four tunnels would connect into a 55-foot-diameter shaft on the Bethany Reservoir side of the tunnels (southern end). These shafts would extend the steel pipe tunnel lining to the bottom of the Bethany Reservoir Discharge Structure. Each tunnel crossing underneath the Bethany Reservoir Conservation Easement would have an excavated diameter of approximately 20 feet in a horseshoe shape and a length of 3,060 feet, and would be constructed with a 0.6 percent upward gradient from the portal to the shaft (refer to the Bethany Reservoir Alternative engineering concept drawings submitted to DCO on January 15, 2021).

Based on common tunneling practice, a minimum tunnel spacing of one tunnel diameter would be maintained between each of the tunnels at the portal locations. It is well understood as the distance from the tunnel opening increases, the influence of the opening upon the stresses in the rock decreases. Based on basic rock mechanic principles at r =3a (where a = radius, r = distance to stresses at a point) the ratio of induced to applied stress is very close to unity (Hoek, 1980). This means that one tunnel diameter spacing is large enough to allow adequate clearance so that stresses generated by the first tunnel excavation would not affect the structural stability of the adjacent tunnel.

The one tunnel diameter spacing also allows adequate room at the portal to allow equipment access without creating conflicts and enables concurrent tunnel excavation sequences to reduce the potential likelihood of any construction impacts from occurring. At the southern end of the tunnel alignments the spacing between the tunnels increases to 50 feet at the connection to the Bethany Discharge Structure shafts to accommodate conservative riser shaft dimensions. The spacing of the tunnels could be refined in future design phases, if needed, once additional geotechnical information becomes available and the riser shaft design is further developed. Tunnel Excavation and Initial Ground Support Methods

The tunnels underneath the conservation area would encounter highly variable ground conditions, ranging from recent alluvial deposits to sedimentary rocks consisting of interbedded shales, sandstones, and siltstones with occasional hard calcareous boulder concretions within the sandstone beds. It is expected that majority of the alignment would be excavated beneath the groundwater table, and groundwater pressures would be expected to increase for the last 500 feet of the tunnel excavation due to proximity to the reservoir.

Several tunnel excavation methods are feasible to excavate the tunnels underneath the conservation easement:

- A crawler-mounted roadheader could be used to excavate the tunnels in weak to moderately strong rocks. The advantages of roadheader include flexibility to adjust to variable ground support requirements and good access to the tunnel face for installation of initial support. Roadheaders also provide the ability to increase the tunnel section in localized areas where heavier supports are needed. Roadheaders are generally a very economical method for excavating sedimentary rock and have been used on another nearby project in similar ground conditions.

- A TBM is feasible; however, the short lengths of each tunnel, the variability of ground conditions and the logistical challenges associated with retrieving the TBM at the end of each drive and relaunching the TBM make it unlikely that a TBM would be considered as a preferred excavation method. Depending on the ground conditions, a larger-diameter starter tunnel could be needed for the first few hundred feet of tunnel before the TBMs would be launched. Alternatively, if the ground conditions are favorable, the TBM could be launched from the portal with the trailing gear attached for a more efficient operation.
- Drill-and -blast excavation methods are considered feasible for the portion of tunnels excavated in the sedimentary deposits. Drill-and-blast methods would require controlled, smooth-wall blasting techniques to minimize overbreak and prevent excessive loosening, damage, or deterioration of the rock mass bordering the excavation. However, due to the rock formation's low compressive strength, mechanized excavation methods should be used in lieu of blasting methods to the greatest extent practicable so that higher production rates can be achieved under safer working conditions.

Rock reinforcement is considered to be a feasible and cost-effective initial support method for tunnel excavation in the sedimentary rock, except where weathered or highly fractured rock is encountered. In weathered rock or highly fractured rock, sections of the tunnel steel ribs (or lattice girders) and shotcrete would be needed for initial support (refer to the DCA Bethany Reservoir Alternative engineering concept drawings, January 15, 2021). Face support measures could also be necessary in the weaker ground. Depending on the excavation method used, examples of face support could include breasting tables or plates, forepoling, and shotcrete with or without fiberglass rock dowels. Similar to the Jones Penstock tunnel crossing, ground improvements would also be needed in certain sections to improve the tunnel's stability.

Within 200 feet of areas that are likely to contain high accumulations of water, probe holes would be drilled and maintained so at least 20 feet of tested ground would remain in place beyond the face at all times in accordance with California Division of Occupational Safety and Health (Cal OSHA) Tunnel Safety Orders (CCR 2018). To reduce and control water inflows into the tunnel excavation, one or two probe holes could be continuously drilled ahead of the face and pre-excavation grouting would be performed only when a specified water inflow criterion was exceeded. Probe holes are typically drilled 120 feet ahead of the tunnel face at a 45-degree angle relative to the face, to intersect potentially water-producing features that could trend parallel to the tunnel axis. If a predetermined water inflow criteria were exceeded, additional grout holes would be drilled to initiate grouting operations. Once the water inflow criteria were satisfied, tunnel excavation could resume for no more than 100 feet and repeat the probing and grouting cycle.

4.3 Bethany Reservoir Discharge Structure Shafts

4.3.1 Geometry

The four shafts (project design capacity of 6,000-cfs) located at the Bethany Reservoir Discharge Structure would have an excavated diameter of approximately 55 feet and a depth of approximately 115 feet. Each shaft would intersect a 20-foot-diameter (horseshoe shaped) tunnel that would cross beneath the Conservation Easement, as described in Section 4.2. The shafts would connect to the base of the Reservoir

Discharge Structure that would be constructed after the shafts were completed. Shaft diameter would be dictated by the size of the steel pipe elbow that needs to be lowered into the bottom of the shaft and connected to the steel pipe in the tunnel. After the elbow is installed, a 180-inch diameter steel pipe would be used to connect to the bottom of the discharge structure. The annular space between the elbow and pipe would be filled with concrete near the shaft base and controlled low-strength material (CLSM) would be used for the vertical shaft backfill. The shaft diameter could be reduced during final design.

4.3.2 Shaft Excavation and Initial Ground Support Methods

The shafts would be constructed from the base of an excavation for the reservoir discharge structure. This excavation would be against the hillside at the back of the structure and could be protected by a cofferdam placed in the reservoir to form a work area from which to construct the shafts. The upper portion of the shaft would be excavated in recent alluvium consisting of fat clay and sandy clay with lenses of sand and gravel. Beneath the alluvium, the shaft excavation would encounter sedimentary rock deposits consisting of shale and sandstones with varying degrees of weathering. The groundwater table could be high due to the proximity of the Bethany Reservoir, which could result in groundwater heads of approximately 100 feet at the shaft invert.

Key issues in the selection of shaft excavation and support methods include the shaft depth, stability of the soil/rock formation, and groundwater level. Feasible shaft excavation methods could include roadheader/backhoe, drill-and-blast, and slurry diaphragm wall excavation with hydro-mill.

Based on limited geotechnical information, in poorer ground conditions the shaft excavation could be supported using steel ring beams with either liner plates, shotcrete, or timber lagging. Where the rock was less weathered and fractured, rock reinforcement consisting of pattern bolting and reinforced shotcrete could be used. Using a roadheader/backhoe combination appears to be the most feasible excavation method for the expected ground conditions. The excavation method and support of the shaft would be confirmed in the future once results from the geotechnical exploration program became available.

Given the proximity of the shafts to the reservoir, there is the potential for large water inflows if open joints are present within the rock mass. To minimize the potential for large water inflows, pre-excavation grouting and or curtain grouting could be performed at the shaft. Such grouting programs are conducted from the surface at the periphery of the shaft prior to shaft excavation.

5. Tunnel Lining Design

The Bethany tunnels north of the BRPP would be excavated at a depth ranging from 105 to 170 feet below ground surface (bgs) at the tunnel crown (top of the tunnel) for the 36-foot-inside-diameter tunnel, based on the invert tunnel elevations shown in the Bethany Reservoir Engineering Concept Drawings. Along the alignment, the groundwater level ranges from 5 to 10 feet below ground surface (bgs), and the groundwater at any location is assumed to be connected vertically within a single aquifer. The external hydrostatic pressure on the tunnel ranges between 3.0 bar (43.3 psi) at the tunnel crown to 6.0 bar (86.6 psi) at the tunnel invert (bottom of the tunnel) for the 36-foot-inside-diameter tunnel. Hydraulic models were run to evaluate the hydraulic grade line (HGL) on the entire system, which includes the intakes, tunnel, and pumping plant, as described in a separate *Hydraulic Analysis of Delta Conveyance Options – Bethany Reservoir Alternative TM* (DCA 2021e). Results from the hydraulic models indicate a maximum surge pressure elevation of approximately 36 feet would be reached for a 36-foot-inside-diameter tunnel with a design flow capacity equal to 6,000 cfs and a tunnel flow velocity of 6 feet per second (fps). Results from the model indicate the maximum surge pressure occurs at the Union Island maintenance shaft. When soil confinement is neglected, the external pressure is equivalent to full hydrostatic head, which would result in a maximum differential water pressure of approximately 22 psi in tension. Since the maximum differential water pressure would be less than the maximum 25 psi computed for the Central corridor, the preliminary conceptual design consisting of an 18-inch thick precast gasketed segmental lining (6,000 psi concrete) could also be adopted for the Bethany Main Tunnels. Refer to the *Conceptual Tunnel Lining Evaluation TM* (DCA 2021f) for details.

6. Ground Settlement and Structure Protection

The *Tunneling Effects Assessment TM* (DCA 2021g) provides preliminary assessments of potential effects of underground construction at critical crossings along the proposed alignment from Intake No. 3 to Lower Roberts Island. Several additional locations requiring a ground settlement assessment have been identified between Lower Roberts Island and the BRPP, and are discussed in this section.

6.1 Canals

The main tunnel would cross underneath several canals located between Lower Roberts Island and the BRPP, including the West Canal, Victoria Canal\North Canal. The Victoria Canal\North Canal, at approximately Station 2170+00, has the least amount of ground cover. The ground level adjacent to this canal is at approximately Elevation -8 feet and this would result in approximately 134 feet of cover between the tunnel springline and the foundation.

6.2 Overhead High-voltage Electrical Transmission Line

The main tunnel would cross a high-voltage electrical transmission line near Station 2380+20 just east of the CCF. The foundation type and depth are not known now, nor are the specific locations relative to the tunnel corridor. For this TM, it was conservatively assumed that the towers are located adjacent to the tunnel and supported on deep foundations extending 50 feet bgs. The ground surface elevation in this area is approximately Elevation 0 feet. Therefore, based on this assumption it is calculated that the base of the deep foundations is at Elevation -50 feet. The tunnel excavation crown would be located at approximately Elevation -125 feet; therefore, there would be approximately 95 feet of soil between the tunnel springline and the base of the foundation.

The *Tunneling Effects Assessment TM* (DCA 2021g) provides the methodology to estimate ground settlement. Table 3 summarizes the maximum ground settlement and trough widths that could potentially be expected assuming that no mitigation measures are implemented.

Table 3. Maximum Ground Settlement and Trough Width

Structure and Station	Volume Loss (percent)	Depth to Springline (feet)	Maximum Settlement (inches)	Settlement Trough Width (feet)
Victoria Canal\North Canal (Station 2170+00)	0.25	134	0.22	144
Victoria Canal\North Canal (Station 2170+00)	0.50	134	0.44	213
Electrical Trans. Lines (Station 2380+20)	0.25	95	0.31	129
Electrical Trans. Lines (Station 2380+20)	0.50	95	0.63	171

These settlement data are based on limited geotechnical information and conceptual engineering-level data. Once the tunnel corridor, diameter, and invert elevations were established and site-specific geotechnical conditions were determined at the key project locations, this information would be updated to reflect ground conditions encountered during the future geotechnical investigation program.

In addition, an allowable settlement criterion would need to be established for each structure identified. Also, if the calculated maximum settlements are not acceptable for a given structure/feature, then mitigation measures will be taken in advance of tunneling to reduce such settlements to acceptable levels.

6.3 Jones Penstocks Tunnel Crossing

The current plans show the tunnel underneath the Jones Penstocks with a ground cover of approximately of 20 feet. Based on the expected ground and groundwater conditions and excavation method, structure protection measures would need to be implemented to reduce potential impacts to the penstocks. In addition to instrumentation and monitoring, it is envisaged that ground improvement combined with under pinning could be required to protect the penstocks while the tunnels are being excavated. The response of the penstocks should be evaluated in subsequent design phases using numerical methods to determine the extent of the protective measures deemed necessary. As-built drawings and material properties for the penstocks, along with results from future geotechnical investigations, would also be needed to perform a detailed evaluation of this crossing.

7. Inspection and Maintenance

The *Tunnel Inspection and Maintenance Considerations TM* (DCA 2021h) provides an overview of how the Delta Conveyance tunnels are accessed for inspection and maintenance.

8. Summary

The following list summarizes the main tunnel and shaft features that differ along the Bethany Reservoir Alternative alignment from the Eastern corridor:

- The Twin Cities Complex site no longer includes rail access for materials delivery and export of RTM to Southern Forebay.
- Tunnel Reach 4 the southernmost Main Tunnel drive would be in the north to south direction for the Bethany Reservoir Alternative alignment versus south to north direction for the Eastern corridor.
- The Lower Roberts Island shaft site would be a double-tunnel launch shaft site, rather than a tunnel\reception shaft site for the Eastern corridor. The double-tunnel launch shaft site would have one tunnel launched north to Terminous Tract reception shaft and one tunnel launched south towards the Surge Basin reception shaft located at the BRPP.
- The Upper Jones Tract maintenance shaft site would be in a different location on the island, compared to the Eastern corridor. The Upper Jones Tract maintenance shaft would provide access for maintenance between the Lower Roberts Island launch shaft and the Union Island maintenance shaft.
- The Union Island maintenance shaft would provide an access location for maintenance between the Upper Jones Tract maintenance shaft and the Surge Basin reception shaft located at the BRPP.
- The Surge Basin shaft at BRPP would serve as a reception shaft and would also be the terminus for the Bethany Main Tunnel alignment.

- The Bethany Reservoir Aqueduct would consist of two to four 180-inch-diameter pipelines with two locations that would be tunneled with as many as four parallel tunnel barrels per location. The Aqueduct tunnels would require combinations of tunnel launch/reception portals and tunnel discharge riser shafts.

9. References

California Code of Regulations (CCR). 2018. Title 8, Subchapter 20. Tunnel Safety Orders Article 9 Emergency Plan and Precautions

California Department of Water Resources (DWR). 2020a. Notice of Preparation of Environmental Impact Report for the Delta Conveyance Project.

California Department of Water Resources (DWR). 2020b. Delta Conveyance Project Scoping Summary Report. July.

Delta Conveyance Design and Construction Authority (DCA). 2021a. *Shaft Conceptual Design, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021b. *Facilities Siting Study – Bethany Alternative Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021c. *Tunnel Excavation Drive Assessment, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021d. *Conceptual Development of Aqueduct and Discharge Structure, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021e. Hydraulic Analysis of Delta Conveyance Options – Bethany Reservoir Alternative Technical Memorandum. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021e. *Hydraulic Analysis of Delta Conveyance Options – Bethany Reservoir Alternative, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021f. *Conceptual Tunnel Lining Evaluation, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021g. *Tunneling Effects Assessment, Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021h. *Tunnel Inspection and Maintenance Considerations Technical Memorandum*. Final Draft.

Hoek, E., and Brown, E.T. (1980). *Underground Excavations in Rock*. Institution for Mining and Metallurgy, London, 10-106.

10. Document History and Quality Assurance

Reviewers listed have completed an internal quality review check and approval process for deliverable documents that is consistent with procedures and directives identified by the Engineering Design Manager (EDM) and the DCA.

Approval Names and Roles			
Prepared by	Internal Quality Control review by	Consistency review by	Approved for submission by
Steve Dubnewych / EDM Tunnels Lead	Robert Marshall / EDM QC Reviewer	Gwen Buchholz / DCA Environmental Liaison Phil Ryan / EDM Design Manager	Terry Krause / EDM Project Manager

This interim document is considered preliminary and was prepared under the responsible charge of Steve Dubnewych, California Professional Engineering License C66922.

Attachment 1
Overall Site Map Single Tunnel Bethany Reservoir

NOTES:

1. SITE PLAN FOR AQUEDUCT SECTION FROM BETHANY RESERVOIR PUMPING PLANT TO THE BETHANY RESERVOIR NOT SHOWN. SEE BETHANY RESERVOIR AQUEDUCT DRAWINGS FOR DETAILS.

PLAN
1"=7000'

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

TUNNELS AND SHAFTS

REV	DATE	DESCRIPTION	SUB.	APPD
	12/23/2021	FINAL DRAFT BASELINE DRAWINGS		

DESIGNED: MARTIN ELLIS
DRAWN: RUSSELL TORADO
CHECKED: STEVE DUBNEWYCH
APPROVAL RECOMMENDED
APPROVAL BY

DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

ENGINEERING PROJECT REPORT
DELTA CONVEYANCE PROJECT
SINGLE TUNNEL - BETHANY RESERVOIR ALTERNATIVE

OVERALL SITE MAP

PROJECT NO. W8X97000
SHEET NO. STB-G-0010TN
REV SEQUENCE NO.

STB-G-0010TN_W8X97000.dgn

PLOT DATE:11/12/2021 PLOT TIME:2:23:06 PM

Attachment 2
Bethany Reservoir Aqueduct Site Plan

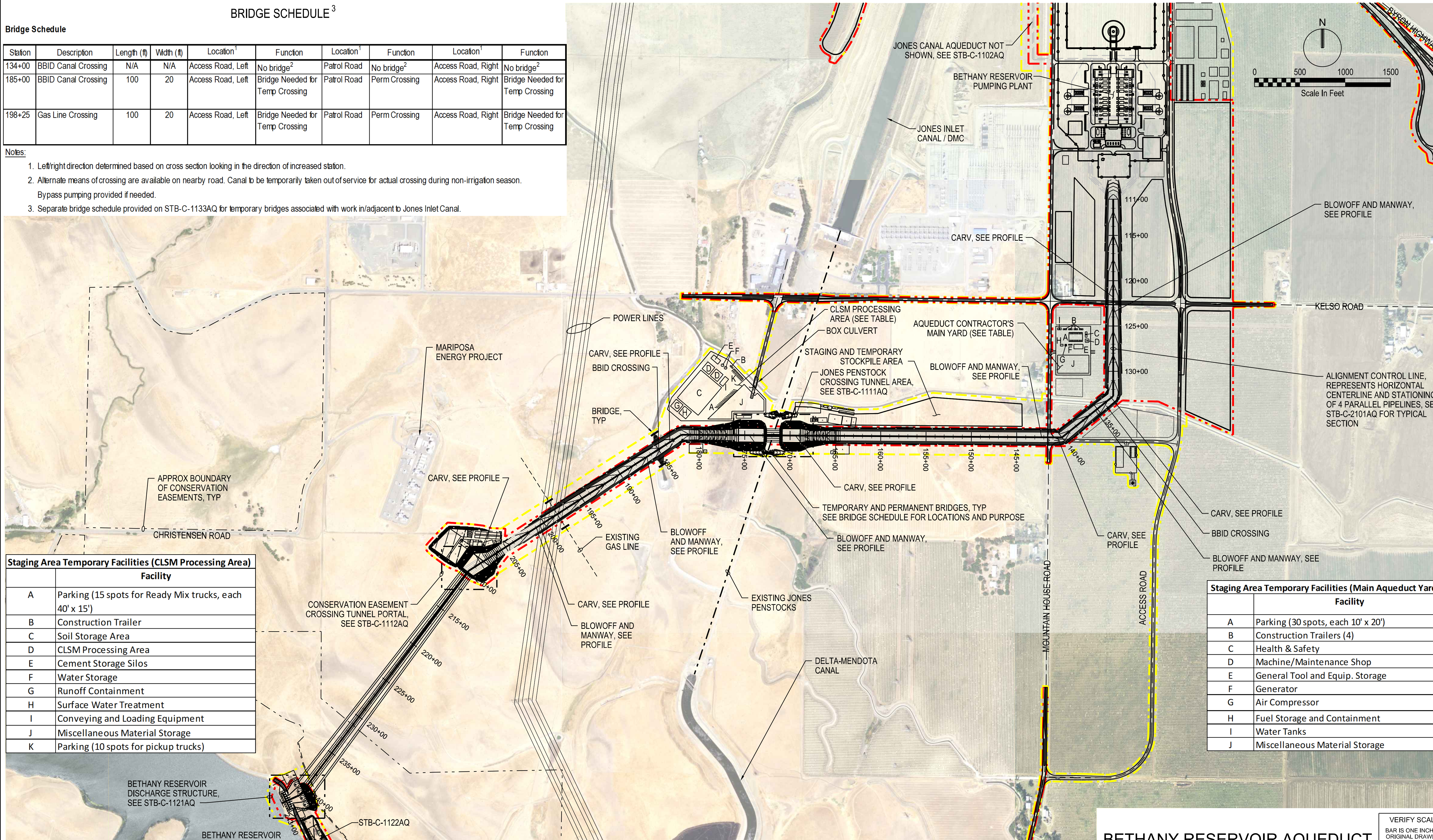
BRIDGE SCHEDULE [3]

Bridge Schedule

Station	Description	Length (ft)	Width (ft)	Location[1]	Function	Location[1]	Function	Location[1]	Function
134+00	BBID Canal Crossing	N/A	N/A	Access Road, Left	No bridge[2]	Patrol Road	No bridge[2]	Access Road, Right	No bridge[2]
185+00	BBID Canal Crossing	100	20	Access Road, Left	Bridge Needed for Temp Crossing	Patrol Road	Perm Crossing	Access Road, Right	Bridge Needed for Temp Crossing
198+25	Gas Line Crossing	100	20	Access Road, Left	Bridge Needed for Temp Crossing	Patrol Road	Perm Crossing	Access Road, Right	Bridge Needed for Temp Crossing

Notes:

1. Left/right direction determined based on cross section looking in the direction of increased station.
2. Alternate means of crossing are available on nearby road. Canal to be temporarily taken out of service for actual crossing during non-irrigation season. Bypass pumping provided if needed.
3. Separate bridge schedule provided on STB-C-1133AQ for temporary bridges associated with work in/adjacent to Jones Inlet Canal.



Staging Area Temporary Facilities (CLSM Processing Area)

	Facility
A	Parking (15 spots for Ready Mix trucks, each 40' x 15')
B	Construction Trailer
C	Soil Storage Area
D	CLSM Processing Area
E	Cement Storage Silos
F	Water Storage
G	Runoff Containment
H	Surface Water Treatment
I	Conveying and Loading Equipment
J	Miscellaneous Material Storage
K	Parking (10 spots for pickup trucks)

Staging Area Temporary Facilities (Main Aqueduct Yard)

	Facility
A	Parking (30 spots, each 10' x 20')
B	Construction Trailers (4)
C	Health & Safety
D	Machine/Maintenance Shop
E	General Tool and Equip. Storage
F	Generator
G	Air Compressor
H	Fuel Storage and Containment
I	Water Tanks
J	Miscellaneous Material Storage

BETHANY RESERVOIR AQUEDUCT

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"

REV	DATE	DESCRIPTION	SUB.	APPD

DESIGNED | APPROVAL RECOMMENDED
DRAWN | APPROVAL BY
CHECKED

DCA
DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

ENGINEERING PROJECT REPORT
DELTA CONVEYANCE PROJECT
SINGLE TUNNEL - BETHANY RESERVOIR ALTERNATIVE

BETHANY RESERVOIR AQUEDUCT
SITE PLAN A

PROJECT NO. W8X97000
SHEET NO. STB-C-1101AQ
REV | SEQUENCE NO.

STB-C-1101AQ_W8X97000.dgn

PLOT DATE:2021\01\08 PLOT TIME:10:50:03 AM