Subject:	**Soil Balance and Reusable Tunnel Material Supplement – Bethany Reservoir Alternative (Final Draft)**
Project feature:	Tunnels and Shafts
Prepared for:	California Department of Water Resources (DWR) / Delta Conveyance Office (DCO)
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1. Purpose

The Delta Conveyance Project (project) would include new intake facilities located along the Sacramento River between the confluences of the American River and Sutter Slough, a tunnel to convey water from the intakes to the southern end of the Delta, and a pumping plant with associated facilities to deliver water to the existing State Water Project (SWP) and potentially the Central Valley Project (CVP) conveyance and distribution systems.

Two tunnel alignments have previously been analyzed, the Central and Eastern corridors, which are now being supplemented to include the Bethany Reservoir Alternative. The subjects of a project-wide soil balance and the properties and reuse opportunities of the reusable tunnel material (RTM) were evaluated for the Central and Eastern corridors as documented in two separate technical memoranda (TMs):

- Soil Balance TM (DCA 2021a) – Assesses the needs and sources for soil across the project.
- Reusable Tunnel Material TM (DCA 2021b) – Evaluates the properties of the RTM and for each project design capacity, calculates the expected quantity of RTM, understands the requirements for processing the RTM, estimates the area required for temporary and permanent storage of RTM, and determines where the RTM will be generated. The TM also describes potential health and environmental considerations associated with the extracting, processing and storing of RTM.

The Bethany Reservoir Alternative alignment is similar to the Eastern corridor alignment from the intake sites along the Sacramento River to the Lower Roberts Island site. From there, the Bethany Reservoir Alternative alignment diverges south from the Eastern Corridor to maintenance shafts on Upper Jones Tract and Union Island, and then terminates a tunnel reception shaft at the Bethany Reservoir Pumping Plant (BRPP) and Surge Basin located on the south side of Byron Highway on Mountain House Road (Attachment 1). The Bethany Reservoir Alternative does not include a Southern Forebay and would instead deliver project water directly to the SWP's existing Bethany Reservoir. The Twin Cities Complex (TCC) and Lower Roberts Island sites were reconfigured for the Bethany Reservoir Alternative, as compared to the Eastern Corridor, to accommodate changes in RTM processing and handling and the use of only two tunnel launch locations for the entire project. Both the TCC and Lower Roberts Island sites would be used as double-launch locations for tunnel boring machines (TBMs) boring in two directions.

The supplemental evaluation of the soil balance and RTM for the Bethany Reservoir Alternative considers a range of tunnel internal diameters (IDs) that would vary between 26 feet and 40 feet, depending on the project design capacity. Based on the range of potential tunnel diameters, the excavated volume of RTM from tunnel construction could vary between 7.2 and 19.2 million cubic yards. As discussed, the Bethany

Reservoir Alternative does not include a Southern Forebay to consume large quantities of suitable RTM, and the surplus stockpiles of material generated as part of the project would generally occur at two permanent locations: (1) TCC and (2) Lower Roberts Island. This differs from the Central and Eastern corridors in that three tunnel launch sites were assumed for those alternatives and a significant quantity of the RTM was used to construct embankments for the Southern Forebay at the south end of the project.

The purpose of this TM is to supplement the previously prepared *Soil Balance TM* and *Reusable Tunnel Material TM* (DCA 2021a; 2021b, respectively) to include additional discussion specific to the Bethany Reservoir Alternative. This supplemental TM is split into two main sections: Section 2 addresses soil balance supplemental information; and Section 3 addresses the RTM supplemental information. This TM provides an overview of the approaches to these items, but additional detail is included in the *Soil Balance TM* and *Reusable Tunnel Material TM* (DCA 2021a; 2021b, respectively).

1.1 Organization

This TM is organized as follows:

- Soil Balance
- Reusable Tunnel Material
- References
- Document History and Quality Assurance

2. Soil Balance

2.1 Background

A project wide assessment and soil balance model (Model) was prepared to understand and improve the balance of the total amount of soil fill material required and produced at the various project construction sites. The Model analyzes soil fill material, including structural and nonstructural fill, topsoil, peat, and specialty materials including filter sand or riprap, as described in the following subsections. The Model does not include other construction materials, such as concrete and asphalt.

An inventory was performed for each construction site to compile fill requirements and soil generation rates and volumes associated with various earthwork activities. The key construction sites considered in the Model for the Bethany Reservoir Alternative include:

- Intakes
- Tunnels, portals, and shafts
- BRPP and Surge Basin
- Aqueduct from the BRPP to Bethany Reservoir
- Bethany Reservoir Discharge Structure
- Pipeline and discharge structure at CVP Project – Delta Mendota Canal (for the 7,500-cubic-foot-per-second cfs project design capacity only)

The schedule for each activity was applied based on the project schedule and the duration of the construction activities (DCA 2021c). The soil balances were analyzed with respect to:

- **Bank Cubic Yards (BCY):** pre-excavation in-situ soil volumes.
- **Loose Cubic Yards (LCY):** bulk material placed or piled after excavation; referred to as "Wet Excavated" in the RTM calculation attachments.

- **Compact Cubic Yards (CCY):** compacted volumes created by the construction equipment activities; referred to as "Dry Compacted" in the RTM calculation attachments.

The volumes of excavated materials were estimated in BCY (the volume of material being excavated). The BCY values were converted to LCY using a bulking factor to assess volumes for transportation and/or storage needs. The CCY values were calculated using compaction factors to calculate fill needs throughout the project. The methods for converting soil volumes for BCY, LCY, and CCY are further discussed in the following sections.

2.2 Methodology and Assumptions

The Model includes a sitewide inventory of the fill needs of each of the project features (such as intakes and shafts), and of the source material generated by each of the project features from earthwork activities. The Model calculates the needs and potential sources of material, including both on-site and import material, on a quarterly basis.

Peat and topsoil would be excavated and stored locally. Excavated peat soil would be placed in stockpiles and covered with five feet of topsoil to limit oxidation of the organic peat material. The quantities of excavated peat and topsoil were estimated for each site based available and the engineering concept drawings and included in the Model as shown for the various construction sites to identify the volume, storage height, and storage area (acres), as well as the expected stockpile duration (for temporary stockpiles) and the locations of permanent stockpiles.

The soil balance generally excludes consideration of fills required for road and railroad construction or modifications (including, road widening, realignment at interchanges), since the majority of these materials are specialty imports that cannot be sourced within the project.

2.2.1 Bulking and Compaction Factors

The bulking and compaction factors used to convert in situ material to compacted volumes for use on-site or loose volumes for stockpiling are consistent with what is presented in the Soil Balance TM (DCA 2021a) and are summarized in Table 2-1.

Table 2-1. Bulking and Compaction Factors

Summary of bulking and compaction factors for different project features

Feature/Material	BCY to LCY (Bulking)	BCY to CCY (Compaction)
Intakes	1.3	0.95
Shafts	1.3	0.9
Levees	1.3	0.9
Logistics (Roads, Park-and-Ride)	1.3	0.9
RTM	1.3	0.99[a]
Clay (Damp) imported from Commercial Sources[b]	1.4	0.9
Gravel (Dry) imported from Commercial Sources[b]	1.15	0.93
Silt imported from Commercial Sources**	1.36	0.83

[a] includes 5% reduction in volume due to drying

[b] Source: Church, Horace K. Excavation Handbook. McGraw-Hill, 1981.

2.2.2 Intake Assumptions

The Model assumptions for the intakes are consistent with those presented in the Soil Balance TM (DCA 2021a). No further discussion of soil balance considerations or findings related to the intakes are included in this supplemental TM.

2.2.3 Shaft Assumptions

The Model assumes that the shaft pads would be constructed with fill provided from within the project. The excavation of shafts would generate excess material that would be permanently stockpiled locally except at launch shafts where shaft excavation soil would be combined with RTM stockpiles. Topsoil stripped from the site or peat excavated from the shaft would be used for re-establishing vegetation at the site for post-construction erosion control.

It was assumed that fill material would be provided from the TCC for construction of the following shaft pads:

- Twin Cities
- New Hope Tract
- Canal Ranch Tract
- Terminous Tract
- King Island

It was assumed that excavated soil from Lower Roberts Island would be used to construct shaft pads at Upper Jones Tract and Union Island.

A shaft pad would not be required at the surge basin reception shaft since natural ground elevations at this site are considerably above the potential flood stage.

Upon stripping of topsoil and peat, soil fill for shaft pads would initially be sourced by excavation of borrow at the TCC or Lower Roberts Island. Onsite borrow areas would eventually be backfilled with RTM from the co-located tunnel launch shaft operations. Based upon the Model input information, maximum borrow excavation depths would be approximately 10 feet at the TCC over 40 acres, and 10 feet at Lower Roberts Island over 26 acres.

The Bethany Reservoir Alternative soil balance did not require changes to the Model inputs or assumptions for shafts at New Hope Tract, Canal Ranch Tract, Terminous Tract, or King Island. No further discussion of soil balance considerations or findings related to these unchanged shafts are included in this supplemental TM.

2.2.4 Levee Assumptions

The Model assumes the Twin Cities Ring Levee would be constructed using excavated soil from the TCC. The Model also assumes modifications to existing levees on Lower Roberts Island would be constructed using excavated materials from Lower Roberts Island.

The approach to RTM processing and management for the Bethany Reservoir Alternative assumes no mechanical or rapid drying is required, since there are no structural reuses of RTM planned for the project. As a result, the size of the TCC was increased to accommodate the larger space requirements associated with the natural “No Drying” approach to RTM management (refer to Section 3), which then requires a larger quantity of locally borrowed fill to construct the ring levee around the enlarged site. The updated quantities are reflected in the TCC soil balance summary tables included later in this section.

No changes were required to the levee repair quantities on Lower Roberts Island for the Bethany Reservoir Alternative.

2.2.5 Bethany Reservoir Pumping Plant and Surge Basin Assumptions

The BRPP and Surge Basin are below grade structures, which only require minimal quantities of fill associated with surface grading and leveling, construction of the access ramp into the interior of the surge basin and backfill behind walls of the pumping plant. As such, these structures will generate significant excess quantities of soil that will be permanently stockpiled locally. Peat soils in the foundation are not anticipated based on known information.

2.2.6 Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structure Assumptions

The Model assumes soil excavated from the Aqueduct cuts, tunnel portals, tunnels, Bethany Reservoir Discharge Structure and associated shafts, and the Jones Discharge and Delta-Mendota Canal (DMC) Control Structures will be reusable as structural fill (excluding topsoil stripping), as needed. A majority of the soil excavated for the Aqueduct and associated tunnels and portals would be reused for production of controlled low-strength material (CLSM), which would be used as backfill around the below grade portion of the Aqueduct pipelines and for soil backfill above the CLSM. The annulus between the shafts at the Bethany Reservoir Discharge Structure and the Aqueduct pipes was also assumed to be backfilled with CLSM. The remaining soil would be consolidated into the permanent stockpiles surrounding the BRPP or on the western side of the DMC (for the 7,500-cfs project design capacity only).

2.2.7 RTM Assumptions

Section 3 describes RTM generation, location, timing, and quantities for the Bethany Reservoir Alternative. These details are imported directly into the Model, with the following assumptions:

- Approximately 20 percent of the RTM volume generated at the tunnel launch shafts at Lower Roberts Island would not be included in the estimate of the height of the above grade permanent stockpile because the stockpiled soil would settle during drying operations.

For the Central and Eastern corridor options, 5 percent of the generated RTM was assumed to be unsuitable for reuse as described in the Soil Balance TM (DCA 2021a). This 5 percent was included in the stockpile volumes. This assumption was relevant to the Central and Eastern corridor options because there was a significant reliance on RTM for the construction of the Southern Forebay embankment and it was appropriate to assume some portion would not be suitable for construction when assessing the project-wide soil balance. For the Bethany Reservoir Alternative, no significant reuse of RTM for structural fill is planned for the Bethany Reservoir Alternative resulting in all of the RTM generated being stockpiled.

2.3 Temporary and Permanent Stockpiles

Peat and topsoil would be excavated and stored at several locations as temporary or permanent stockpiles. Excess excavated soil from construction of the surge basin, BRPP, and Aqueduct would also be stored as permanent stockpiles at the Bethany Complex. “Temporary” stockpiles refer to a period equal to, or less than, the construction period at an individual site, whereas “permanent” stockpiles indicate the stockpile would exist beyond the end of the construction period and would be considered a permanent long-term element of the site.

Information for the construction sites regarding the anticipated stockpile volume, height, and area, as well as the expected stockpile duration (for temporary stockpiles), and the locations of permanent stockpiles are summarized in Table 2-2 (refer to Section 3.4 for information regarding RTM storage). The stripping quantities and peat quantities for the TCC and Lower Roberts Island launch sites are based on the 6,000-cfs configuration and do not capture the relatively minor differences in shaft excavation quantity or topsoil generated due to stripping for the range of potential project flows, since the material would be completely reused onsite and does not represent a permanent element of the site.

Note, Table 2-2 only includes sites that are new or altered for the Bethany Reservoir Alternative from those described in the Soil Balance TM (DCA 2021a). Refer to that TM for the remaining peat and topsoil stockpile details that were unchanged for the Bethany Reservoir Alternative as compared to the Eastern Corridor (including discussions of the intakes and the shaft pads at New Hope Tract, Canal Ranch Tract, Terminous Tract, and King Island).

The stockpile heights in Table 2-2 include an allowance to account for the effects of stockpile side slopes on the overall size. An allowance of 5% was used for shorter stockpiles (less than approximately 20 feet tall) and an allowance of 10% was used for taller stockpiles (greater than approximately 20 feet tall). The stockpiles on the west side of the DMC (for the 7,500-cfs project design capacity only) will be placed against the existing stockpile slope and as result will not include an additional allowance for side slopes.

Table 2-2. Stockpile Summary-Bethany Alignment

Summarizes the temporary and permanent peat, topsoil, and excavated material stockpiles

Feature	Material	Volume*	Stockpile Duration (years)	Stockpile Area (Acres)	Stockpile Height (ft)
Twin Cities Complex (3000 cfs)	Topsoil	685,828	10	25.0	19
Twin Cities Complex (4500 cfs)	Topsoil	816,387	10	25.0	22
Twin Cities Complex (6000 cfs)	Topsoil	910,767	10	25.0	25
Twin Cities Complex (7500 cfs)	Topsoil	910,767	10	25.0	25
Lower Roberts Island (3000 cfs)	Topsoil	376567	9	24.5	15
	Peat	14,962			6
Lower Roberts Island (4500 cfs)	Topsoil	470251	9	30.6	15
	Peat	14,962			6
Lower Roberts Island (6000 cfs)	Topsoil	537949	9	35	15
	Peat	16,169			7
Lower Roberts Island (7500 cfs)	Topsoil	537949	9	35.0	15
	Peat	17,129			7
Upper Jones Tract (3000 cfs)	Topsoil	12,060	1	1.0	9
	Peat	1,940			
	Excavated Material	21,761	Permanent	3.1	4
Upper Jones Tract (4500 cfs)	Topsoil	12,060	1	1.0	9

Table 2-2. Stockpile Summary-Bethany Alignment

Summarizes the temporary and permanent peat, topsoil, and excavated material stockpiles

Feature	Material	Volume*	Stockpile Duration (years)	Stockpile Area (Acres)	Stockpile Height (ft)
	Peat	2,557			
	Excavated Material	28,686	Permanent	3.1	6
Upper Jones Tract (6000 cfs)	Topsoil	12,060	1	1.0	9
	Peat	3,040			
	Excavated Material	34,102	Permanent	3.1	7
Upper Jones Tract (7500 cfs)	Topsoil	12,060	1	1.0	10
	Peat	3,487			
	Excavated Material	39,117	Permanent	3.1	8
Union Island (3000 cfs)	Topsoil	14,472	2	1.0	10
	Peat	2,120			
	Excavated Material	24,015	Permanent	3.0	5
Union Island (4500 cfs)	Topsoil	14,472	2	1.0	11
	Peat	2,795			
	Excavated Material	31,657	Permanent	3.0	6
Union Island (6000 cfs)	Topsoil	14,472	2	1.0	11
	Peat	33,22			
	Excavated Material	37,634	Permanent	3.0	8
Union Island (7500 cfs)	Topsoil	14,472	2	1.0	11
	Peat	3,811			
	Excavated Material	43,168	Permanent	3.0	9
Bethany Reservoir Pumping Plant and Surge Basin (3,000 cfs)	Topsoil	227,561	7	7.1	22
	Excavated Material	2,389,104	Permanent	61.1	27
Aqueduct and Connection to Bethany Reservoir (3,000 cfs)	Topsoil	133,181	2	4.1	22
Discharge Structure (3,000 cfs)	Topsoil	12,899	3	0.4	22
Bethany Reservoir Pumping Plant and Surge Basin (4,500 cfs)	Topsoil	227,561	7	7.1	22
	Excavated Material	2,680,213	Permanent	61.1	30
Aqueduct and Connection to Bethany Reservoir (4,500 cfs)	Topsoil	141,046	3	4.4	22
Discharge Structure (4,500 cfs)	Topsoil	14,367	4	0.4	22
	Topsoil	228,504	7	7.1	22

Table 2-2. Stockpile Summary-Bethany Alignment

Summarizes the temporary and permanent peat, topsoil, and excavated material stockpiles

Feature	Material	Volume*	Stockpile Duration (years)	Stockpile Area (Acres)	Stockpile Height (ft)
Bethany Reservoir Pumping Plant and Surge Basin (6,000 cfs)	Excavated Material	2,871,816	Permanent	59.3	33
Aqueduct and Connection to Bethany Reservoir (6,000 cfs)	Topsoil	144,716	4	4.5	22
Discharge Structure (6,000 cfs)	Topsoil	14,891	5	0.5	22
Bethany Reservoir Pumping Plant and Surge Basin and CVP Connection East of DMC (7,500 cfs)	Topsoil	268,878	7	7.2	26
	Excavated Material	3,536,502	Permanent	59.3	41
Aqueduct and Connection to Bethany Reservoir (7,500 cfs)	Topsoil	144,716	4	4.5	22
Discharge Structure (7,500 cfs)	Topsoil	14,891	5	0.5	22
CVP Connection West of DMC (7500cfs)	Topsoil	41,947	3	1.0	25
	Excavated Material	372,232	Permanent	9.2	25

Notes:

*Peat and Topsoil are reported in LCY as these stockpiles will not be compacted. Excavated material stockpiles are reported in CCY as these stockpiles will be compacted. Excavated peat soil would be placed in stockpiles and covered with five feet of topsoil to limit oxidation of the organic peat material.

ft = foot (feet)

2.4 Feature Summaries

The Model includes a sitewide inventory for each project feature (such as intakes and shafts) of the fill needs and source material generated from earthwork activities, except for road and railroad fill requirements. Road and railroad fill will generally be specialty base materials that will not be generated onsite and are not included in the Model.

The Model treats all source material (i.e. generated by onsite excavation) as a positive quantity. Conversely, it treats all material needs as a negative quantity. To account for any surplus material (material generated in excess of the identified needs), the Model introduces surplus stockpiles as a “need” that consumes any surplus material not consumed by the other identified needs of the project at that feature; therefore, the surplus stockpiles are treated as a negative quantity.

Results of the soil balance are provided for all project design capacities in the following sections. For each project design capacity there are a series of tables that summarize the fill need volumes, sources, and remnant quantities for each feature.

Note, the following summaries only include sites that are new or altered for the Bethany Reservoir Alternative. Refer to the Soil Balance TM (DCA 2021a) for the soil balance summaries that were unchanged for the Bethany Reservoir Alternative as compared to the Eastern Corridor, which include the intakes and the shaft pads at New Hope Tract, Canal Ranch Tract, Terminous Tract, and King Island.

2.4.1 Bethany Reservoir Alternative with Project Design Capacity of 6,000 cfs

Tables 2-3 to Table 2-8 present the results of the soil balance for each feature and summarize the fill needs and material sources.

Table 2-3. Twin Cities Complex (6,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Twin Cities Shaft-Pad	Onsite	-83,168
Twin Cities Ring Levee	Onsite	-262,859
Restore Topography from Twin Cities Shaft Pad Borrow	Onsite	-92,409
Restore Topography from Twin Cities Ring Levee Borrow	Onsite	-292,065
Restore Topography from New Hope Borrow	Export	-35,386
Restore Topography from Canal Ranch Borrow	Export	-31,922
Restore Topography from Terminous Borrow	Export	-70,233
Restore Topography from King Borrow	Export	-87,176
Sources		**Volume (CCY)[a]**
Twin Cities Shaft Pad Borrow from TCC	Onsite	83,168
Twin Cities Ring Levee Borrow from TCC	Onsite	262,859
Twin Cities Ring Levee Degrade/Stockpile	Onsite	262,859
Twin Cities Shaft Excavation	Onsite	186,308
TCC RTM	Onsite	5,111,861
Material Export/Reuse		**Volume (CCY)[a]**
Stockpile of Twin Cities Levee Degrade	Onsite	-262,859
Surplus RTM Stockpile at Twin Cities	Onsite	-4,688,978

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-4. Lower Roberts Island (6,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Lower Roberts Island Shaft-Pad	Onsite	-212,250
Lower Roberts Island Levee	Onsite	-39,424
Restore Topography from Lower Roberts Island Shaft Pad Borrow	Onsite	-235,833
Restore Topography from Lower Roberts Island Levee Borrow	Onsite	-43,804
Restore Topography from Upper Jones Tract Shaft Pad Borrow	Export	-60,883
Restore Topography from Union Island Shaft Pad Borrow	Export	-55,223
Sources		**Volume (CCY)[a]**

Table 2-4. Lower Roberts Island (6,000-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Lower Roberts Island Shaft Pad Borrow from Lower Roberts Island	Onsite	212,250
Lower Roberts Island Levee Borrow from Lower Roberts Island	Onsite	39,424
Lower Roberts Island Shaft-Excavation	Onsite	178,291
Lower Roberts Island RTM	Onsite	4,680,976
Material Export/Reuse		**Volume (CCY)[a]**
Surplus RTM at Lower Roberts Island	Onsite	-4,463,523

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-5. Upper Jones Tract (6,000-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Upper Jones Tract Shaft-Pad	Onsite	-54,795
Sources		**Volume (CCY)[a]**
Upper Jones Tract Shaft Pad Borrow from Lower Roberts Island	Import	54,795
Upper Jones Tract Shaft-Excavation	Onsite	34,102
Material Export/Reuse		**Volume (CCY)[a]**
Upper Jones Tract Shaft-On Site Stockpile	Onsite	-34,102

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-6. Union Island (6,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Union Island Shaft-Pad	Onsite	-49,701
Sources		**Volume (CCY)[a]**
Union Island Shaft Pad Borrow from Lower Roberts Island	Import	49,701
Union Island Shaft-Excavation	Onsite	37,634
Material Export/Reuse		**Volume (CCY)[a]**
Union Island Shaft-On Site Stockpile	Onsite	-37,634

[a] Note: All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-7. Bethany Reservoir Pumping Plant and Surge Basin (6,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Surge Basin-Access Ramp Free Draining Backfill	Onsite	-10,083
Bethany Pumping Plant-Site Grading	Onsite	-7,121
Sources		**Volume (CCY)[a]**
Surge Basin-Shaft	Onsite	39,399
Surge Basin-Excavation	Onsite	934,835
Surge Basin-Drilled Shafts	Onsite	151,016
Surge Basin-Diaphragm Walls	Onsite	45,810
Bethany Pumping Plant	Onsite	1,270,298
Surge Basin-Access Ramp Free Draining Backfill	Import	10,083
Material Export/Reuse		**Volume (CCY)[a]**
Surge Basin-On Site Stockpile	Onsite	-2,434,237

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-8. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structures 6,000-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir	Onsite	-1,257,486
Sources		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Excavation	Onsite	1,695,064
Material Export/Reuse		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Surplus	Onsite	-437,578

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

2.4.2 Bethany Reservoir Alternative with Project Design Capacity of 3,000 cfs

Tables 2-9 to Table 2-14 provide the results of the soil balance for each feature and summarize the fill needs and material sources.

Table 2-9. Twin Cities Complex (3,000-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Twin Cities Shaft-Pad	Onsite	-81,312
Twin Cities Ring Levee	Onsite	-230,450
Restore Topography from Twin Cities Shaft Pad Borrow	Onsite	-90,347
Restore Topography from Twin Cities Ring Levee Borrow	Onsite	-256,055
Restore Topography from New Hope Borrow	Export	-30,835
Restore Topography from Canal Ranch Borrow	Export	-27,769
Restore Topography from Terminous Borrow	Export	-63,015
Restore Topography from King Borrow	Export	-77,291
Sources		**Volume (CCY)[a]**
Twin Cities Shaft Pad Borrow from TCC	Onsite	81,312
Twin Cities Ring Levee Borrow from TCC	Onsite	230,450
Twin Cities Ring Levee Degrade/Stockpile	Onsite	230,450
Twin Cities Shaft Excavation	Onsite	172,410
TCC RTM	Onsite	2,366,209
Material Export/Reuse		**Volume (CCY)[a]**
Stockpile of Twin Cities Levee Degrade	Onsite	-230,450
Surplus RTM Stockpile at Twin Cities	Onsite	-1,993,307

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-10. Lower Roberts Island (3,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Lower Roberts Island Shaft-Pad	Onsite	-207,896
Lower Roberts Island Levee	Onsite	-39,424
Restore Topography from Lower Roberts Island Shaft Pad Borrow	Onsite	-230,996
Restore Topography from Lower Roberts Island Levee Borrow	Onsite	-43,804
Restore Topography from Upper Jones Tract Shaft Pad Borrow	Export	-53,585
Restore Topography from Union Island Shaft Pad Borrow	Export	-48,511
Sources		**Volume (CCY)[a]**
Lower Roberts Shaft Pad Borrow from Lower Roberts Island	Onsite	207,896
Lower Roberts Levee Borrow from Lower Roberts Island	Onsite	39,424
Lower Roberts Island Shaft-Excavation	Onsite	164,991
Lower Roberts Island RTM	Onsite	2,468,189
Material Export/Reuse		**Volume (CCY)[a]**
Surplus RTM at Lower Roberts Island	Onsite	-2,256,284

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-11. Upper Jones Tract (3,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Upper Jones Tract Shaft-Pad	Onsite	-48,226
Sources		**Volume (CCY)[a]**
Upper Jones Shaft Pad Borrow from Lower Roberts Island	Import	48,226
Upper Jones Tract Shaft-Excavation	Onsite	21,761
Material Export/Reuse		**Volume (CCY)[a]**
Upper Jones Tract Shaft-On Site Stockpile	Onsite	-21,761

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-12. Union Island (3,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Union Island Shaft-Pad	Onsite	-43,660
Sources		**Volume (CCY)[a]**
Union Island Shaft Pad Borrow from Lower Roberts Island	Import	43,660
Union Island Shaft-Excavation	Onsite	24,015
Material Export/Reuse		**Volume (CCY)[a]**
Union Island Shaft-On Site Stockpile	Onsite	-24,015

[a] Note: All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-13. Bethany Reservoir Pumping Plant and Surge Basin (3,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Surge Basin-Access Ramp Free Draining Backfill	Onsite	-10,083
Bethany Pumping Plant-Site Grading	Onsite	-7,121
Sources		**Volume (CCY)[a]**
Surge Basin-Shaft	Onsite	39,399
Surge Basin-Excavation	Onsite	934,835
Surge Basin-Drilled Shafts	Onsite	151,016
Surge Basin-Diaphragm Walls	Onsite	45,810
Bethany Pumping Plant	Onsite	948,122
Surge Basin-Access Ramp Free Draining Backfill	Import	10,083
Material Export/Reuse		**Volume (CCY)[a]**
Surge Basin-On Site Stockpile	Onsite	-2,112,061

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-14. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structures (3,000-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Bethany Pump Station to Bethany Reservoir	Onsite	-593,662
Sources		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Excavation	Onsite	870,705
Material Export/Reuse		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Surplus	Onsite	-277,043

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

2.4.3 Bethany Reservoir Alternative with Project Design Capacity of 4,500 cfs

Tables 2-15 to Table 2-20 provide the results of the soil balance for each feature and summarize the fill needs and material sources.

Table 2-15. Twin Cities Complex (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Twin Cities Shaft-Pad	Onsite	-81,312
Twin Cities Ring Levee	Onsite	-238,740
Restore Topography from Twin Cities Shaft Pad Borrow	Onsite	-90,347
Restore Topography from Twin Cities Ring Levee Borrow	Onsite	-265,267
Restore Topography from New Hope Borrow	Export	-33,474

Table 2-15. Twin Cities Complex (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Restore Topography from Canal Ranch Borrow	Export	-30,177
Restore Topography from Terminous Borrow	Export	-67,214
Restore Topography from King Borrow	Export	-83,034
Sources		**Volume (CCY)[a]**
Twin Cities Shaft Pad Borrow from TCC	Onsite	81,312
Twin Cities Ring Levee Borrow from TCC	Onsite	238,740
Twin Cities Ring Levee Degrade/Stockpile	Onsite	238,740
Twin Cities Shaft Excavation	Onsite	172,410
TCC RTM	Onsite	3,807,778
Material Export/Reuse		**Volume (CCY)[a]**
Stockpile of Twin Cities Levee Degrade	Onsite	-238,740
Surplus RTM Stockpile at Twin Cities	Onsite	-3,410,675

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-16. Lower Roberts Island (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Lower Roberts Island Shaft-Pad	Onsite	-207,896
Lower Roberts Island Levee	Onsite	-39,424
Restore Topography from Lower Roberts Island Shaft Pad Borrow	Onsite	-230,996
Restore Topography from Lower Roberts Island Levee Borrow	Onsite	-43,804
Restore Topography from Upper Jones Shaft Pad Borrow	Export	-57,822
Restore Topography from Union Island Shaft Pad Borrow	Export	-52,407
Sources		**Volume (CCY)[a]**
Lower Roberts Island Shaft Pad Borrow from Lower Roberts Island	Onsite	207,896
Lower Roberts Island Levee Borrow from Lower Roberts Island	Onsite	39,424
Lower Roberts Island Shaft-Excavation	Onsite	164,991
Lower Roberts Island RTM	Onsite	3,486,816
Material Export/Reuse		**Volume (CCY)[a]**
Surplus RTM at Lower Roberts Island	Onsite	-3,266,778

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-17. Upper Jones Tract (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Upper Jones Tract Shaft-Pad	Onsite	-52,040
Sources		**Volume (CCY)[a]**
Upper Jones Tract Shaft Pad Borrow from Lower Roberts Island	Import	52,040
Upper Jones Tract Shaft-Excavation	Onsite	28,686
Material Export/Reuse		**Volume (CCY)[a]**
Upper Jones Tract Shaft-On Site Stockpile	Onsite	-28,686

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-18. Union Island (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Union Island Shaft-Pad	Onsite	-47,166
Sources		**Volume (CCY)[a]**
Union Island Shaft Pad Borrow from Lower Roberts Island	Import	47,166
Union Island Shaft-Excavation	Onsite	31,657
Material Export/Reuse		**Volume (CCY)[a]**
Union Island Shaft-On Site Stockpile	Onsite	-31,657

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-19. Bethany Reservoir Pumping Plant and Surge Basin (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[1a]
Surge Basin-Access Ramp Free Draining Backfill	Onsite	-10,083
Bethany Pumping Plant-Site Grading	Onsite	-7,121
Sources		**Volume (CCY)[a]**
Surge Basin-Shaft	Onsite	39,399
Surge Basin-Excavation	Onsite	934,835
Surge Basin-Drilled Shafts	Onsite	151,016
Surge Basin-Diaphragm Walls	Onsite	45,810
Bethany Pumping Plant	Onsite	1,147,473
Surge Basin-Access Ramp Free Draining Backfill	Import	10,083
Material Export/Reuse		**Volume (CCY)[a]**
Surge Basin-On Site Stockpile	Onsite	-2,311,412

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-20. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structures (4,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Bethany Pump Station to Bethany Reservoir	Onsite	-914,742
Sources		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Excavation	Onsite	1,283,544
Material Export/Reuse		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Surplus	Onsite	-368,802

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

2.4.4 Bethany Reservoir Alternative with Project Design Capacity of 7,500 cfs

Tables 2-21 to Table 2-26 provide the results of the soil balance for each feature and summarize the fill needs and material sources.

Table 2-21. Twin Cities Complex (7,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Twin Cities Shaft-Pad	Onsite	-85,044
Twin Cities Ring Levee	Onsite	-262,859
Restore Topography from Twin Cities Shaft Pad Borrow	Onsite	-94,493
Restore Topography from Twin Cities Ring Levee Borrow	Onsite	-292,065
Restore Topography from New Hope Borrow	Export	-37,067
Restore Topography from Canal Ranch Borrow	Export	-33,457
Restore Topography from Terminous Borrow	Export	-72,874
Restore Topography from King Borrow	Export	-90,805
Sources		**Volume (CCY)[a]**
Twin Cities Shaft Pad Borrow from TCC	Onsite	85,044
Twin Cities Ring Levee Borrow from TCC	Onsite	262,859
Twin Cities Ring Levee Degrade/Stockpile	Onsite	262,859
Twin Cities Shaft Excavation	Onsite	200,746
TCC RTM	Onsite	7,169,540
Sources		**Volume (CCY)[a]**
Stockpile of Twin Cities Levee Degrade	Onsite	-262,859
Surplus RTM Stockpile at Twin Cities	Onsite	-6,749,524

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-22. Lower Roberts Island (7,500-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Lower Roberts Island Shaft-Pad	Onsite	-216,648
Lower Roberts Island Levee	Onsite	-39,424
Restore Topography from Lower Roberts Island Shaft Pad Borrow	Onsite	-240,720
Restore Topography from Lower Roberts Island Levee Borrow	Onsite	-43,804
Restore Topography from Upper Jones Tract Shaft Pad Borrow	Export	-63,570
Restore Topography from Union Island Shaft Pad Borrow	Export	-57,696
Sources		**Volume (CCY)[a]**
Lower Roberts Island Shaft Pad Borrow from Lower Roberts Island	Onsite	216,648
Lower Roberts Island Levee Borrow from Lower Roberts Island	Onsite	39,424
Lower Roberts Island Shaft-Excavation	Onsite	188,887
Lower Roberts Islance RTM	Onsite	5,962,662
Material Export/Reuse		**Volume (CCY)[a]**
Surplus RTM at Lower Roberts Island	Onsite	-5,745,759

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-23. Upper Jones Tract (7,500-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Upper Jones Tract Shaft-Pad	Onsite	-57,213
Sources		**Volume (CCY)[a]**
Upper Jones Tract Shaft Pad Borrow from Lower Roberts Island	Import	57,213
Upper Jones Tract Shaft-Excavation	Onsite	39,117
Material Export/Reuse		**Volume (CCY)[a]**
Upper Jones Tract Shaft-On Site Stockpile	Onsite	-39,117

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-24. Union Island (7,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Union Island Shaft-Pad	Onsite	-51,926
Sources		**Volume (CCY)[a]**
Union Island Shaft Pad Borrow from Lower Roberts Island	Import	51,926
Union Island Shaft-Excavation	Onsite	43,168
Material Export/Reuse		**Volume (CCY)[a]**
Union Island Shaft-On Site Stockpile	Onsite	-43,168

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-25. Bethany Reservoir Pumping Plant and Surge Basin (7,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Surge Basin-Access Ramp Free Draining Backfill	Onsite	-10,083
Bethany Pumping Plant-Site Grading	Onsite	-7,121
Sources		**Volume (CCY)[a]**
Surge Basin-Shaft	Onsite	39,399
Surge Basin-Excavation	Onsite	1,216,000
Surge Basin-Drilled Shafts	Onsite	199,903
Surge Basin-Diaphragm Walls	Onsite	52,288
Bethany Pumping Plant	Onsite	1,475,818
Surge Basin-Access Ramp Free Draining Backfill	Import	10,083
Material Export/Reuse		**Volume (CCY)[a]**
Surge Basin-On Site Stockpile	Onsite	-2,976,287

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

Table 2-26. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structure (7,500-cfs Project Design Capacity)

Needs		Volume (CCY)[a]
Bethany Pump Station to Bethany Reservoir	Onsite	-1,257,486
Bethany Pump Station to DMC-East Side of DMC	Onsite	-429,016
Bethany Pump Station to DMC-West Side of DMC	Onsite	-284,709
Sources		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Excavation	Onsite	1,695,064

Table 2-26. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structure (7,500-cfs Project Design Capacity)

Needs		**Volume (CCY)[a]**
Bethany Pump Station to DMC Excavation-East Side of DMC	Onsite	551,653
Bethany Pump Station to DMC Excavation-West Side DMC	Onsite	656,940
Material Export/Reuse		**Volume (CCY)[a]**
Bethany Pump Station to Bethany Reservoir Surplus	Onsite	-437,578
Bethany Pump Station to DMC Surplus-East Side of DMC	Onsite	-122,637
Bethany Pump Station to DMC Surplus-West Side of DMC	Onsite	-372,232

[a] All source materials are treated as positive quantities and all material needs and surplus are treated as negative quantities.

3. Reusable Tunnel Material

This section supplements the *Reusable Tunnel Material TM* (DCA 2021b) for the Bethany Reservoir Alternative and provides a brief description of the assumptions and approach used to develop the conclusions. Additional details are included in the *Reusable Tunnel Material TM* (DCA 2021b). Attachment 2 provides a table of inputs and assumptions applied to the investigation. The RTM generation quantities, locations, and schedule described in this section were used in the project wide soil balance discussed in Section 2, which also accounts for surface borrow, shaft excavation quantities, and settlement of RTM stockpiles into the foundation.

Discussions of anticipated geotechnical and geological conditions relative to RTM along the Bethany Reservoir Alternative tunnel alignment are unchanged from the Central and Eastern corridor discussions. As such, refer to the *Reusable Tunnel Material TM* (DCA 2021b) for further discussion about the anticipated geotechnical and geological conditions.

Discussions of the preliminary engineering and environmental properties of the RTM, including effects to health, environment, and ecology for the Bethany Reservoir Alternative tunnel alignment are unchanged from the Central and Eastern corridor discussions. As such, refer to the *Reusable Tunnel Material TM* (DCA 2021b) for further discussion about the preliminary engineering and environmental properties of the RTM.

Note, information included in this supplemental TM is considered preliminary and will be subject to change as the project develops.

3.1 Tunneling

Information regarding tunnel shaft materials and TBM tunneling operations for the Bethany Reservoir Alternative tunnel alignment are unchanged from the Central/Eastern corridor discussions. As such, refer to the Reusable Tunnel Material TM (DCA 2021b) for that information. Information regarding RTM at the various project design capacities, tunnel diameters, tunnel lengths, and associated excavation quantities for the Bethany Reservoir Alternative are summarized below.

3.1.1 Tunnel Diameter

The tunnel diameter is directly related to the project design capacity. For the Bethany Reservoir Alternative, the tunnel diameters developed as part of the project hydraulic analyses (DCA, 2021e) at the four project design capacities under consideration are shown in Table 3-1.

Table 3-1. Tunnel Internal Diameters by Project Design Capacities

Item	Project Design Capacity = 3,000 cfs	Project Design Capacity = 4,500 cfs	Project Design Capacity = 6,000 cfs	Project Design Capacity = 7,500 cfs
Tunnel Diameter (ft)	26	31	36	40

The required external diameter of the tunnel lining is a function of the required thickness of the tunnel lining which is directly related to the internal diameter. These have been determined based on experience with similar diameter tunnel projects in similar ground conditions and are shown for each tunnel diameter in Table 3-2 and explained in further detail in the *Tunnel Lining Sizing Evaluation TM* (DCA 2021d). In addition to the tunnel lining thickness, the TBM shield thickness and radial overcut, in reference to the tunnel lining radius, needs to be accounted for to determine the excavated volume. These are also shown in Table 3-2.

For this TM, the four possible tunnel diameters (Table 3-1) have been considered and a resulting range of RTM volumes was developed. Table 3-2 presents the assumptions and resulting cutterhead/excavated area for each of the four internal tunnel diameters.

Table 3-2. Tunnel Lining and TBM Dimensions and Resulting Excavated Area

Tunnel lining internal diameter (ft)	26.0	31.0	36.0	40.0
Project Design Capacity (cfs)	3,000	4,500	6,000	7,500
Lining thickness (in)	14.0	16.0	18.0	24.0
Tunnel lining external diameter (ft)	28.3	33.7	39.0	44.0
TBM tail can thickness (in)	2.5	3.0	3.5	4.0
Cutterhead offset (in)	2.5	3.0	3.5	4.0
TBM cutterhead (excavated) diameter (ft)	29.2	34.7	40.2	45.3
TBM cutterhead (excavated) area (yd^2)	74	105	141	179

Notes:
cfs = cubic feet per second
in = inch(es)
yd^2 = square yard(s)

3.1.2 Bethany Reservoir Alternative

The Bethany Reservoir Alternative alignment includes two tunnel sections that vary, depending on the project design capacity: (1) a northern section between the intakes and the TCC varies in length and diameter, and (2) a main tunnel between the TCC and the Surge Basin reception shaft that varies only in diameter.

3.1.2.1 Northern Section

The length of the northern tunnel between the intakes and TCC varies, depending on the intakes used, which is directly related to the project flow rates as follows:

- 3,000 cfs – Intake 5, Tunnel length = 5.6 miles
- 4,500 cfs – Intakes 3 and 5, Tunnel length = 8.2 miles
- 6,000 cfs – Intakes 3 and 5, Tunnel length = 8.2 miles
- 7,500 cfs – Intakes 2, 3, and 5, Tunnel length = 10.3 miles

3.1.2.2 Main Section

The main section of the Bethany Reservoir Alternative tunnel alignment would extend from the TCC along an easterly route through New Hope Tract, Canal Ranch Tract, Brack Tract, Terminous Tract, King Island, and Rindge Tract to Lower Roberts Island, where the corridor would turn southwest through Lower Roberts Island, Lower and Upper Jones Tracts, Victoria Island, Kings Island, Union Island, and Coney Island to the Surge Basin reception shaft. The tunnel in this section is referred to as the main tunnel of the Bethany Reservoir Alternative and has a total length of 36.6 miles for all project design capacities.

3.1.3 Shafts

Along the tunnel sections, there are a number of shafts. Three different types of shafts would be constructed as part of the project, each serving a different purpose to support tunneling activities:

- Launch shafts – At these shafts, the TBM would be lowered into the ground and begin excavation. All of the RTM associated with a tunnel drive would be extracted and brought to the surface at the respective launch site.
- Reception shafts – At these shafts, the TBMs would complete excavation and be extracted from the ground.
- Maintenance shafts – These shafts are located between the launch and reception shafts that the TBMs would pass through. These provide an opportunity to inspect and carry out maintenance and repairs to the cutterhead at the front of the TBM as well as the main bearing and other components that would otherwise be difficult to access during excavation.

Attachment 1 shows the configuration of the various shafts for the Bethany Reservoir Alternative. Table 3-3 summarizes each tunnel drive for the longest tunnel drive, which would occur for the 7,500 cfs project design capacity (40-ft-inside-diamter tunnel), listing the shaft name, shaft type, tunnel section, tunnel drive direction (indicated by an arrow) and tunnel drive length. The table omits the maintenance shafts for simplicity.

Table 3-3. Details for Bethany Corridor (7,500 cfs Project Design Capacity).

Structure	Shaft Type and Tunnel Drive Direction	Drive Length
Intake No. 2 Shaft	Reception	
Northern Tunnels	↑	10.3 mi
Twin Cities Shaft	Launch	
Main Tunnels	↓	12.7 mi
Terminous Tract Shaft	Reception	

Table 3-3. Details for Bethany Corridor (7,500 cfs Project Design Capacity).

Structure	Shaft Type and Tunnel Drive Direction	Drive Length
Main Tunnels	↑	9.5 mi
Lower Roberts Island Shaft	Launch	
Main Tunnels	↓	14.4 mi
Surge Basin Shaft	Reception	
Total		46.9 mi

Notes:
mi = mile(s)

3.2 Reusable Tunnel Material Volumes

RTM would be generated at the TBM launch shafts. The volume of RTM generated at each of these shafts would be a function of the tunnel diameter and length. The tunnel diameter would vary with project design capacity, as summarized in Table 3-1.

The wet excavated volumes of RTM that would be generated and need to be processed at each launch shaft for each project design capacity would be as shown in Table 3-4.

Table 3-4. Wet Excavated RTM Volume Generated at Each Shaft for Each Option

Shaft	3,000 cfs Project Design Capacity (M yd^3)	4,500 cfs Project Design Capacity (M yd^3)	6,000 cfs Project Design Capacity (M yd^3)	7,500 cfs Project Design Capacity (M yd^3)
Twin Cities	3.1	5.0	6.7	9.4
Lower Roberts Island	4.1	5.7	7.7	9.8
Total	7.2	10.7	14.4	19.2

Notes:
M = million(s)

As Table 3-4 shows, depending on the tunnel diameter, the volume of RTM to be processed ranges from 7.2 to 19.2 M yd^3. The calculations of these volumes are included in Attachment 4.

3.3 Reusable Tunnel Material Processing

All of the RTM would be tested for contaminated and hazardous materials as it was excavated and before further processing. This section describes the process for testing, spreading, and drying the RTM excavated by an earth-pressure balance TBM. For a slurry TBM, the excavated material would be pre-processed in the slurry separation plant, so the post-processing requirement would be less.

3.3.1 Natural Drying

The Natural Drying process was selected for the Bethany Reservoir Alternative since the RTM would not be used as fill elsewhere on the project and it provides a reasonable method to manage and stockpile the

RTM at the launch shaft sites. The process for testing, spreading, and drying the RTM would follow the flowchart shown on Figure 3-1 and described here.

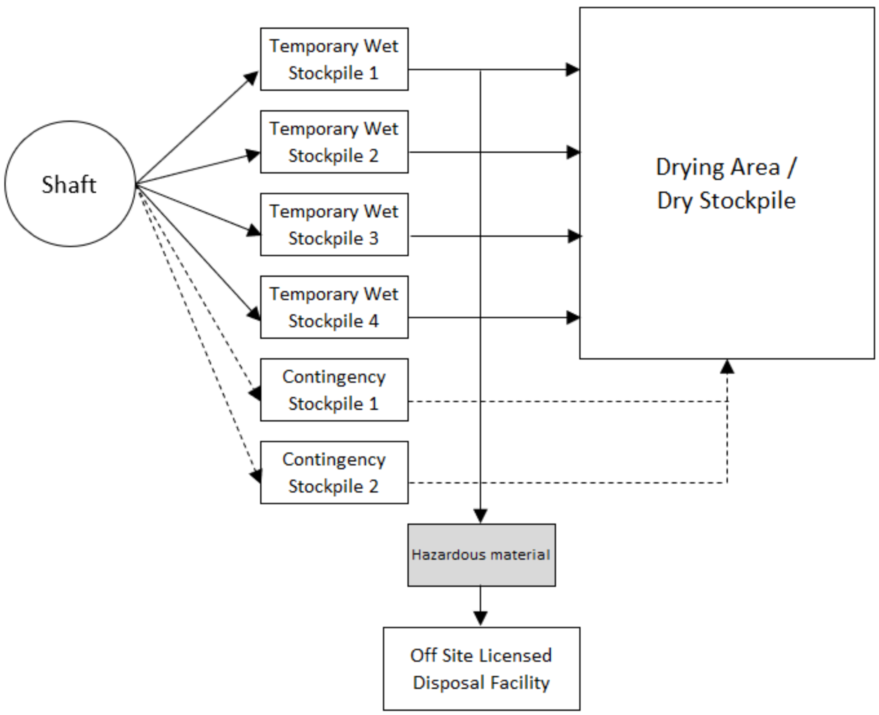


Figure 3-1. Natural Drying Flowchart

The excavated material would be transferred from the shaft by conveyor to a temporary wet stockpile area, where bulldozers would pile it up to a maximum of 10 feet high. The temporary wet stockpiles would be designed to accommodate about 1 weeks' worth of RTM at peak excavation rate. Once a week's worth (or other amount to be determined by the contractor) of RTM was placed in the temporary wet stockpile area, it would be isolated while samples collected for this material are tested for hazardous materials. Meanwhile, stockpiling would continue in a second and subsequent temporary wet stockpile areas. Stockpiling would occur whenever a TBM advances and hence is expected to be a 20 hour/day operation. Leachate or runoff from the temporary wet stockpiles would be collected and tested before being used or released.

Once the test results have been received, the temporary wet stockpile can be emptied with the use of bulldozers pushing the RTM into central conveyor pits. It is anticipated that it would take 2 weeks to empty a full wet stockpile area based on a 10 hour working day and as such, a total of four temporary wet stockpile areas would be required, with one being filled, one being held for test results, and two being emptied at any one time. A further two contingency stockpiles of the same size are also recommended to accommodate unforeseen delays.

If the test results suggested a sample was hazardous, all of the RTM from that stockpile would be removed from site and taken to a licensed disposal facility. If the test results deemed the sample as nonhazardous, the RTM would be transferred by wheel loader, conveyor, or another method to be determined by the contractor, to a specific cell within the drying area. During the wet season, the RTM would be piled up within the drying cell until the dry season or a suitable stretch of dry weather occurs. At the beginning of the dry season, the RTM piles and any subsequent RTM generated would be spread out by bulldozers within its respective cell to a depth ideally of no more than 18 inches and allowed to dry for at least

3 weeks, with no additional effort applied to accelerate the drying process, since the soil would not be needed on a scheduled basis for transport and use for structural fill as part of the project. This duration was calculated based on an average volume of water that would need to be extracted of 1.65 gallons per cubic foot and an evaporation rate of 0.21 inch per day over a given area, estimated from the California Irrigation Management Information System data for the period of April 2019 until March 2020. The drying time calculation can be found in Attachment 4. At the end of the third week, a compactor would roll over the RTM to compact it in place, preparing the ground for the next lift. Each cell would be designed to hold 1 weeks' worth of RTM at 18 inches high. The wet season is conservatively estimated to last 7 months of the year; as such, a total of 37 cells would be required, with 15 of those being used twice within the dry season of an annual cycle. The process would continue as tunnel excavation advanced up to a final height specific to each location and project design capacity.

3.3.2 Processing Area and Equipment

The total area required for processing and storage of RTM varies by site and tunnel diameter associated with the project design capacity. Similarly, the equipment used in the processing, as well as the power requirement and cost of that equipment, is directly related to the excavation rate and tunnel diameter.

Tables 3-5 and 3-6 show, for each TBM launch site and tunnel diameter associated with the project design capacity, the area allocated to process and the area for the temporary stockpile of all the RTM associated with a single tunnel drive at that site.

At the Twin Cities Complex Site, for the 3,000 cfs, 4,500cfs and 6,000cfs project design capacities, the temporary storage area is based on that required to spread the RTM 18 inches high. For the 7,500 cfs project design capacity at Twin Cities, the same area required for the 6,000 cfs project design capacity would be used, due to site constraints, with an increased annual lift as required.

Table 3-5. RTM Processing, Temporary RTM Stockpiling Areas and Annual Lifts at Twin Cities Complex per Tunnel Drive for a Range of Project Design Capacities

	3,000 cfs Project Design Capacity	4,500 cfs Project Design Capacity	6,000 cfs Project Design Capacity	7,500 cfs Project Design Capacity
Temporary Wet Storage Area (acres)	9	12	14	16
Temporary Stockpile Area (acres)	129	168	196	196
Temporary Stockpile Annual Lift (in)	18	18	18	21

At Lower Roberts Island tunnel launch shaft site, the temporary storage area is based on that required for the natural drying process with an annual lift of 18 inches up to a maximum area of 196 acres per tunnel drive as dictated by site constraints beyond which the annual lift will increase as required.

Table 3-6. RTM Processing, Temporary RTM Stockpiling Areas and Annual Lifts at Lower Roberts Island Site per Tunnel Drive for a Range of Project Design Capacities

	3,000 cfs Project Design Capacity	4,500 cfs Project Design Capacity	6,000 cfs Project Design Capacity	7,500 cfs Project Design Capacity
Temporary Wet Storage Area (acres)	9	12	14	16
Temporary Stockpile Area (acres)	129	168	196	196
Temporary Stockpile Annual Lift (in)	18	18	18.5	21

Table 3-7 shows the estimated earth-moving equipment required, and the estimated range of hours, power, and cost per tunnel drive for each project design capacity. The quantity, power, and cost vary according to tunnel diameter and assumed excavation rate, because they are directly related to the time required to process the RTM. Operating costs include rental, fuel and maintenance and repair. Costs are estimated in 2020 dollars and do not account for escalation.

Table 3-7. Earth-moving Equipment Required Per Tunnel Drive for Range of Project Design Capacities

Equipment, Hours, Power and Cost	3,000 cfs Project Design Capacity	4,500 cfs Project Design Capacity	6,000 cfs Project Design Capacity	7,500 cfs Project Design Capacity
Bulldozers	12	12	12	12
Wheel Loaders	1	2	2	2
Compactor	1	1	1	1
Capital Cost	$2.6M	$2.8M	$2.8M	$2.8M
Annual Working Hours	10,000	13,000	15,200	17,400
Power Requirements (MWh/yr)	2,000	2,600	3,000	3,500
Annual Operating Cost	$1.1M	$1.4M	$1.6M	$1.8M

Notes:

MWh/yr = megawatt-hour(s) per year

Detailed calculations to show the areas and equipment requirements for each of project design capacity are included in Attachment 4.

3.3.3 Site Preparation

Each of the RTM processing areas would have the sites sufficiently prepared for all loading and operations that are expected. Temporary stockpiles are expected to be concrete structures with walls on three sides at least 3 feet above the designed stockpile height. They are also expected to have two centrally located conveyor pits into which the RTM can be pushed by bulldozer, as well as underground channels for the conveyors to transport the RTM away from the temporary stockpiles to the next processing or loading area. Drainage should be incorporated into the floor design of the temporary stockpiles to catch runoff and leachate for testing, treatment (if required), and disposal.

3.4 Reusable Tunnel Material Storage

For the Bethany Reservoir Alternative, the area required for the long-term storage of RTM depends on the area required for drying and how much borrow material is planned to be excavated at each site, which would need to be replaced. The quantities described here were developed in conjunction with the projectwide soil balance, which considers onsite borrow, other onsite material sources, and fill needs across the project.

At both the TCC and Lower Roberts Island, a borrow pit is anticipated to be excavated. It is assumed that at each site, the surplus RTM from both tunnel drives would be stockpiled on one combined permanent storage site after tunneling was complete and the borrow pit was filled. The permanent storage stockpiles would be filled to a maximum height of 15 feet with area varying by site and project design capacity. Table 3-8 shows the areas of the permanent stockpile for each project design capacity.

Table 3-8. Areas of Permanent Stockpiles for Each Site and Each Project Design Capacity

	3,000 cfs Project Design Capacity	4,500 cfs Project Design Capacity	6,000 cfs Project Design Capacity	7,500 cfs Project Design Capacity
Twin Cities Complex (acres)	95	157	214	303
Lower Roberts Island (acres)	93	137	189	245

Note: Assumes 15 foot fill height.

These areas include a 5 percent allowance for working space and vehicle maneuvering; the RTM would be placed with side slopes similar to the soil's natural angle of repose or as recommended by the project geotechnical engineers. For simplicity, side slopes are not accounted for in the calculations directly and would only have a negligible effect on volume and area calculations for such large quantities with comparatively small heights. Any difference in volume resulting from side slopes is more than accounted for in the 5 percent allowance for working space and vehicle maneuvering. Areas designated for the permanent storage of RTM that were not previous prepared would be stripped of topsoil prior to placement of the RTM. Stripped topsoil would be stockpiled and re-spread over these areas after the RTM was placed and the stockpiles would be planted with erosion control grasses.

3.4.1 Settlement

A preliminary settlement analysis would be conducted at each proposed storage site to understand the potential impacts, which would depend on the site-specific geotechnical conditions. Additional geotechnical analyses would be performed upon the completion of supplemental site-specific geotechnical exploration and testing. Furthermore, at Lower Roberts Island, RTM stored permanently is expected to sink by as much as 20 percent and become unusable for future use, although this is likely to take a number of years and have negligible effect outside of the stockpile footprint. When such settlements occur, the height of the stockpiles would be reduced approximately the same amount as the settlements.

4. References

Church, Horace. 1981. Excavation Handbook. McGraw-Hill.

Delta Conveyance Design and Construction Authority (DCA). 2021a. *Soil Balance Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021b. *Reusable Tunnel Material (RTM) Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021c. *Preliminary Construction Schedules for Bethany Reservoir Alternative*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021d. *Tunnel Lining Sizing Evaluation Technical Memorandum*. Final Draft.

Delta Conveyance Design and Construction Authority (DCA). 2021e. *Hydraulic Analysis of Delta Conveyance Options*. Final Draft.

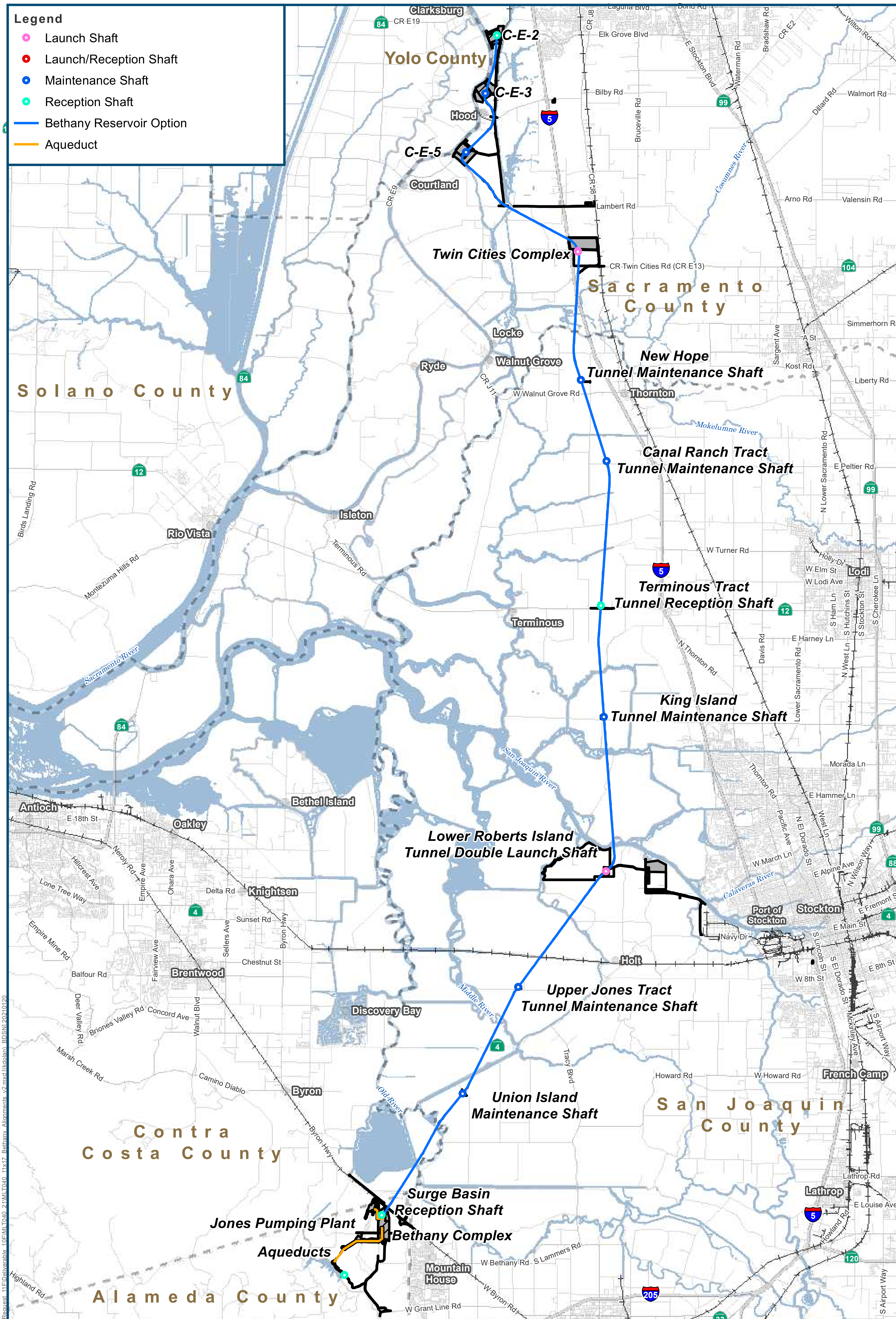
5. Document History and Quality Assurance

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**
Shaun Firth / EDM RTM Task Force Lead Matt Weil / EDM Geotechnical Engineer	Michael Conant/ EDM Levees and Forebay Lead	Gwen Buchholz / DCA Environmental Consultant Phil Ryan / EDM Design Manager	Terry Krause / EDM Project Manager

This interim document is considered preliminary and was prepared under the responsible charge of Matthew Weil, California Geotechnical Engineering License GE3093.

Attachment 1
Corridor Map



DCA DELTA CONVEYANCE DESIGN & CONSTRUCTION AUTHORITY

For Illustration Purposes Only

N

0 1.5 3 Miles

Bethany Reservior Option

Data Source: DCA, DWR

Attachment 2
Table of Inputs and Assumptions

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Assumptions and Inputs

Input		Value	Unit
Tunnel Lining Dimensions			
3,000 cfs	Tunnel lining ID	26.00	ft
	Tunnels lining thickness	14.00	in
4,500 cfs	Tunnel lining ID	31.00	ft
	Tunnels lining thickness	16.00	in
6,000 cfs	Tunnel lining ID	36.00	ft
	Tunnels lining thickness	18.00	in
7,500 cfs	Tunnel lining ID	40.00	ft
	Tunnels lining thickness	24.00	in
TBM Dimensions			
3,000 cfs	TBM tailcan thickness	2.50	in
	Cutterhead offset	2.50	in
4,500 cfs	TBM tailcan thickness	3.00	in
	Cutterhead offset	3.00	in
6,000 cfs	TBM tailcan thickness	3.50	in
	Cutterhead offset	3.50	in
7,500 cfs	TBM tailcan thickness	4.00	in
	Cutterhead offset	4.00	in
Tunnel Excavation Rates			
Start up advance rate (All Options)		30.00	ft / day
3,000 cfs	Tunnels average advance rate	50.00	ft / day
4,500 cfs	Tunnels average advance rate	46.00	ft / day
6,000 cfs	Tunnels average advance rate	40.00	ft / day
7,500 cfs	Tunnels average advance rate	36.00	ft / day
Est. percentage of excavation at peak rate (All Options)		16.67	%
TBM Utilization			
Tunnelling hours per day		20	hours
Tunnelling days per week		5	days / wk
Tunnelling weeks per year		51	wks / yr
Geotechnical Factors			
Unit weight of in-situ RTM		120.00	lb/ft3
Unit weight of wet excavated RTM		99.70	lb/ft3
Unit weight of dry excavated RTM		95.00	lb/ft3
Bulking factor		1.30	
Volume loss during drying		5.00	%
Volume of water extracted during drying		1.65	gal/ft3
Compaction factor		0.80	
Storing RTM			
Temporary stockpile working space/buffer		50.00	%
Temporary working space / buffer		20.00	%
Permanent working space / buffer		5.00	%
Max. height of temporary short term wet stockpiles		10.00	
Max. height of drying stockpile at Twin Cities		15.00	ft
Max. height of drying stockpile at Lower Roberts Island		15.00	ft

Attachment 3
Determination of Geotechnical Factors

Please see Attachment 3 in *Reusable Tunnel Material (RTM) Technical Memorandum* (Volume 1, Attachment B, DCA, 2021b).

Attachment 4.1
RTM Calculations – 3,000 cfs, 26-foot-ID Tunnel

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor
Northern tunnels ID	26.0 ft	5 days	51 wks	74 yd2				74 yd2			
Main tunnels ID	26.0 ft	5 days	51 wks	74 yd2	1.30	5.00 %	0.80	74 yd2	1.30	5.00 %	0.80
Southern tunnels ID	26.0 ft	5 days	51 wks	74 yd2				74 yd2			

			Drive Options				RTM Volume / Tunnel Length				RTM Volume / Shaft				RTM Volume / Tunnel Drive	
Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	In-Situ RTM Volume / Tunnel Length	Wet Excavated RTM Volume / Tunnel Length	Dry Excavated RTM Volume / Tunnel Length	Dry Compacted RTM Volume / Tunnel Length	Wet In-situ RTM Volume / Shaft	Wet Excavated RTM Volume / Shaft	Dry Excavated RTM Volume / Shaft	Dry Compacted RTM Volume / Shaft	Dry Compacted RTM Volume / Tunnel Drive	Ave. Quarterly Excavated Dry Compacted RTM Volume / Tunnel Drive
BETHANY		0.000 mi					- yd3	- yd3	- yd3	- yd3						
		0.000 mi		5.640 mi	2.4 yrs		- yd3	- yd3	- yd3	- yd3					728,064 yd3	74,647 yd3
	Intake No. 5 Shaft		R													
	Northern Tunnel	5.640 mi	↑				736,907 yd3	957,979 yd3	910,080 yd3	728,064 yd3						
	Twin Cities Shaft		L			2					2,394,948 yd3	3,113,432 yd3	2,957,761 yd3	2,366,209 yd3		
	Main Tunnel	4.580 mi	↓				598,410 yd3	777,933 yd3	739,037 yd3	591,229 yd3						
	New Hope Shaft		M													
	Main Tunnel	3.000 mi	↓	12.690 mi	5.4 yrs		391,972 yd3	509,563 yd3	484,085 yd3	387,268 yd3					1,638,144 yd3	76,227 yd3
	Canal Ranch		M													
	Main Tunnel	5.110 mi	↓				667,659 yd3	867,956 yd3	824,559 yd3	659,647 yd3						
	Terminous Tract Shaft		R													
	Main Tunnel	3.940 mi	↑				514,790 yd3	669,227 yd3	635,765 yd3	508,612 yd3						
	King Island Shaft		M	9.500 mi	4.1 yrs										1,226,349 yd3	74,355 yd3
	Main Tunnel	5.560 mi	↑				726,455 yd3	944,391 yd3	897,171 yd3	717,737 yd3						
	Lower Roberts Island Shaft		L			2					3,122,709 yd3	4,059,522 yd3	3,856,546 yd3	3,085,237 yd3		
	Southern Tunnels	5.130 mi	↓				670,272 yd3	871,353 yd3	827,786 yd3	662,229 yd3						
	Upper Jones Tract Shaft		M													
	Southern Tunnels	4.240 mi	↓	14.400 mi	5.8 yrs		553,987 yd3	720,183 yd3	684,174 yd3	547,339 yd3					1,858,887 yd3	79,785 yd3
	Union Island Shaft		M													
	Southern Tunnels	5.030 mi	↓				657,206 yd3	854,368 yd3	811,650 yd3	649,320 yd3						
	Surge Basin Shaft		R													
	Total	42.23 mi	2	42.23 mi		4	5,517,657 yd3	7,172,954 yd3	6,814,307 yd3	5,451,445 yd3	5,517,657 yd3	7,172,954 yd3	6,814,307 yd3	5,451,445 yd3	5,451,445 yd3	305,014 yd3

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year
Northern tunnels ID	26.0 ft	5 days	51 wks
Main tunnels ID	26.0 ft	5 days	51 wks
Southern tunnels ID	26.0 ft	5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's
BETHANY		0.000 mi				
		0.000 mi		5.640 mi	2.4 yrs	
	Intake No. 5 Shaft		R			
	Northern Tunnel	5.640 mi	↑			
	Twin Cities Shaft		L			2
	Main Tunnel	4.580 mi	↓			
	New Hope Shaft		M			
	Main Tunnel	3.000 mi	↓	12.690 mi	5.4 yrs	
	Canal Ranch		M			
	Main Tunnel	5.110 mi	↓			
	Terminous Tract Shaft		R			
	Main Tunnel	3.940 mi	↑			
	King Island Shaft		M	9.500 mi	4.1 yrs	
	Main Tunnel	5.560 mi	↑			
	Lower Roberts Island Shaft		L			2
	Southern Tunnels	5.130 mi	↓			
	Upper Jones Tract Shaft		M			
	Southern Tunnels	4.240 mi	↓	14.400 mi	5.8 yrs	
	Union Island Shaft		M			
	Southern Tunnels	5.030 mi	↓			
	Surge Basin Shaft		R			
	Total	42.23 mi	2	42.23 mi		4

Quarterly Dry Compacted RTM Volume Generated by Tunnel Drive (m yd3)

Start	HIDE	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
17	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Quarterly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.23	0.23	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.15	0.23	0.46	0.69	1.00	1.30	1.61	1.91	2.22	2.52	2.83

Start	HIDE	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
20	0	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly		0.29	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.15	0.08	0.08	0.08	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		3.11	3.34	3.57	3.80	4.03	4.26	4.49	4.72	4.95	5.11	5.19	5.27	5.35	5.43	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter
Northern tunnels ID	26.0 ft
Main tunnels ID	26.0 ft
Southern tunnels ID	26.0 ft

Tunnelling days / week	Tunnelling weeks / year
5 days	51 wks
5 days	51 wks
5 days	51 wks

Option	Element	Tunnel Length	Drive Options: Tunnel Drive	Drive Options: Drive Length	Drive Options: Drive Duration	TBM's	Start
BETHANY		0.000 mi					
		0.000 mi		5.640 mi	2.4 yrs		20
	Intake No. 5 Shaft		R				
	Northern Tunnel	5.640 mi	↑				
	Twin Cities Shaft		L			2	
	Main Tunnel	4.580 mi	↓				
	New Hope Shaft		M				
	Main Tunnel	3.000 mi	↓	12.690 mi	5.4 yrs		17
	Canal Ranch		M				
	Main Tunnel	5.110 mi	↓				
	Terminous Tract Shaft		R				
	Main Tunnel	3.940 mi	↑				
	King Island Shaft		M	9.500 mi	4.1 yrs		22
	Main Tunnel	5.560 mi	↑				
	Lower Roberts Island Shaft		L			2	
	Southern Tunnels	5.130 mi	↓				
	Upper Jones Tract Shaft		M				
	Southern Tunnels	4.240 mi	↓	14.400 mi	5.8 yrs		20
	Union Island Shaft		M				
	Southern Tunnels	5.030 mi	↓				
	Surge Basin Shaft		R				
	Total	42.23 mi	2	42.23 mi		4	

Quarterly Dry Compacted RTM Volume Generated at Each Shaft (m yd3)

	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Twin Cities Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Lower Roberts Island Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.08	0.23	0.23	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.15	0.23	0.46	0.69	1.00	1.30	1.61	1.91	2.22	2.52	2.83

	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Twin Cities Shaft	0.13	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Roberts Island Shaft	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.08	0.08	0.08	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly	0.29	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.15	0.08	0.08	0.08	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	3.11	3.34	3.57	3.80	4.03	4.26	4.49	4.72	4.95	5.11	5.19	5.27	5.35	5.43	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Stockpiles**

Maximum allowable stockpile heights

Max. permanent stockpile height at Twin Cities	15	ft	above grade
Max. permanent stockpile height at Lower Roberts	15	ft	above grade
Contingency	5	%	

Temporary stockpiles (All RTM)

Bethany	Vol. of RTM to stockpile (yd3)	Area of temp. stockpile (acres)	Height of temp. stockpile (ft)	Resulting individual lift (in)
Twin Cities North	600,639	129	2.9	18.0
Twin Cities South	1,351,438	129	6.5	18.0
Lower Roberts North	1,099,295	129	5.3	18.0
Lower Roberts South	1,666,300	129	8.0	18.0

Temporary stockpile notes

Twin Cities
- < 7,500 cfs, area based on drying method
- 7,500 cfs uses same area as for 6,000 cfs

Lower Roberts
- Area based on drying method
- Max. available area 193 acres / tunnel drive
- See 'No Drying Annual Process' sheet.

Permanent stockpiles (Surplus RTM)

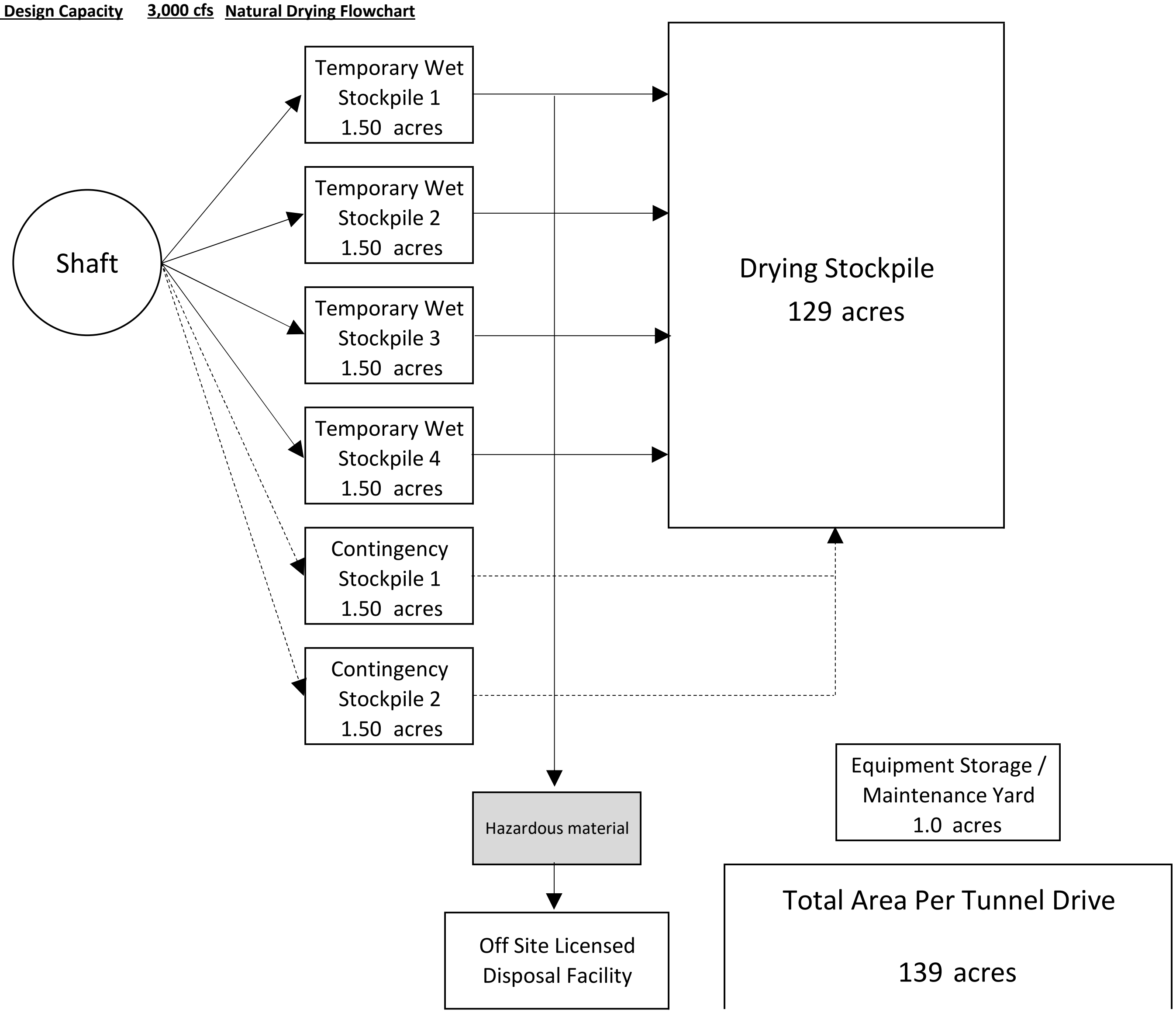
		Based on max. height	
Bethany	Vol. of RTM to stockpile (yd3)	Area of perm. stockpile (acres)	Height of perm. stockpile (acres)
Twin Cities	2,182,526	95	15
Lower Roberts	2,148,548	93	15

Permanent stockpile notes

Both sites consolidated into one stockpile
Area calculated based on 15ft height
At TC volume includes ring levee degradation
Surplus volumes account for filling borrow pit

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity 3,000 cfs Natural Drying Flowchart



CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Natural Drying Annual Process**

Drying stockpile height per lift	18	in
Drying stockpile contingency	5	%
Tunnelling days / week	5	days / week
Tunnelling weeks / year	51	weeks / year
Wet season	7	months / year
Wet season	30	weeks / year
Number of drying cells	37	

Per Tunnel	Cell >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		
Drive	Area→	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5		
Season	Week↓																																						Spreading	Compacting
Wet	1	Hold	Hold	Hold	Fill		< wet season begins with 3 full cells from previous drying season																																0	0
Wet	2	Hold	Hold	Hold	Hold	Fill																																	0	0
Wet	3	Hold	Hold	Hold	Hold	Hold	Fill																																0	0
Wet	4	Hold	Hold	Hold	Hold	Hold	Hold	Fill																															0	0
Wet	5	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																														0	0
Wet	6	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																													0	0
Wet	7	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																												0	0
Wet	8	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																											0	0
Wet	9	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																										0	0
Wet	10	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																									0	0
Wet	11	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																								0	0
Wet	12	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																							0	0
Wet	13	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																						0	0
Wet	14	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																					0	0
Wet	15	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																				0	0
Wet	16	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																			0	0
Wet	17	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																		0	0
Wet	18	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																	0	0
Wet	19	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																0	0
Wet	20	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill															0	0
Wet	21	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill														0	0
Wet	22	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill													0	0
Wet	23	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill												0	0
Wet	24	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill											0	0
Wet	25	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill										0	0
Wet	26	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill									0	0
Wet	27	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill								0	0
Wet	28	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill							0	0
Wet	29	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill						0	0
Wet	30	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill					0	0
Dry	31	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill + Spread				3	0
Dry	32	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Fill + Spread			3	0
Dry	33	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Fill + Spread		3	0
Dry	34	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Fill + Spread	3	3
Dry	35	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	3	3
Dry	36	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	3	3
Dry	37	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	3	3
Dry	38	Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold					Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold					3	3
Dry	39		Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold						Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold					3	3
Dry	40			Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold							Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold					3	3
Dry	41				Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold								Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold					3	3
Dry	42					Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold									Dry + Compact	Dry	Dry	Spread	Hold	Hold					3	3
Dry	43						Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold										Dry + Compact	Dry	Dry	Spread	Hold					3	3
Dry	44							Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold											Dry + Compact	Dry	Dry	Spread					3	3
Dry	45								Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold												Dry + Compact	Dry	Dry					2	3
Dry	46									Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold													Dry + Compact	Dry					2	3
Dry	47										Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold														Dry + Compact					2	3
Dry	48											Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold																			2	2
Dry	49												Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread																			2	2
Dry	50	Fill												Dry + Compact	Dry	Dry		Dry + Compact	Dry	Dry																			0	2
Dry	51	Hold	Fill												Dry + Compact	Dry			Dry + Compact	Dry																			0	2
Dry	52	Hold	Hold	Fill												Dry + Compact				Dry + Compact																			0	2

Permanent stockpile per site

Shaft site	Total vol. of RTM (yd3)	Stockpile area (acres)	Final height of stockpile (ft)	Equivalent annual lift (in)
Twin Cities	2,182,526	258	5.2	24
Lower Roberts	2,148,548	258	5.2	24

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Natural Drying Areas**

Excavation Rates per tunnel drive

Tunnel lining ID	26	ft
TBM cutterhead area	668	ft2
TBM advance rate (ave.)	50	ft / day
TBM advance rate (peak)	100	ft / day
Daily in-situ rate of excavation per tunnel (ave.)	1,237	yd3 / day
Daily in-situ rate of excavation per tunnel (peak)	2,475	yd3 / day
Bulking factor	1.30	
Daily excavated volume per tunnel (ave.)	1,608	yd3 / day
Daily excavated volume per tunnel (peak)	3,217	yd3 / day
Estimated duration of peak excavation	21	days
Volume loss due to drying	5	%
Equivalent daily dry excavated volume per tunnel (ave.)	1,528	yd3 / day
Equivalent daily dry excavated volume per tunnel (peak.)	3,056	yd3 / day

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Temporary Wet Stockpile Area per tunnel drive

No. of days storage	5	days	assuming 5 days of peak excavation in a 7 day cycle
Volume of RTM to stockpile at peak excavation rate	16,085	yd3	per stockpile
Height of stockpile	10	ft	short term
Contingency	50	%	includes allowance for conveyor pits
Area required at peak excavation rate	1.50	acres	per stockpile = 255 x 255 ft or equivalent
No. of temporary stockpiles	6.0		
Total area of temporary stockpiles	9.0	acres	

Equipment Storage / Maintenance Yard per tunnel drive

Area required for equipment storage / maintenance yard	1.0	acres

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Drying Stockpile

Contingency	5	%

Natural Drying Area Summary

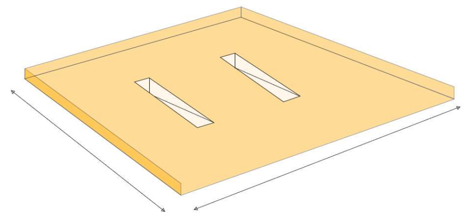
Alignment	Site	Tunnel Drive	Compacted RTM to store above grade	Temporary Wet Stockpile 10 ft high	Equipment / Maintenance Yard	Dry Stockpile (height varies)	Total RTM Area	Total RTM Area
Bethany	Twin Cities	North	0.6 m yd3	9.0 acres	1 acres	129 acres	139 acres	278 acres
		South	1.4 m yd3	9.0 acres	1 acres	129 acres	139 acres	
	Lower Roberts Island	North	1.1 m yd3	9.0 acres	1 acres	129 acres	139 acres	278 acres
		South	1.7 m yd3	9.0 acres	1 acres	129 acres	139 acres	

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Natural Drying Equipment**

Temporary Wet Stockpile Filling per tunnel drive

Volume of RTM to stockpile at peak excavation rate	16,085	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for filling temporary stockpile	5	days	
Working hours per day	20	hours	
Average cycle time per shove	5	mins	
Efficiency	80	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	23.0	hours / day	
Total hours at average excavation rate per day	11.5	hours / day	
Total hours for operation per year	2,932	hours / year	



Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Temporary Wet Stockpile Emptying per tunnel drive

Assume two conveyor pits in the centre of the temporary stockpile each to be loaded from both sides.

Volume of RTM to stockpile at peak excavation rate	16,085	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for emptying temporary stockpile	10	days	
Working hours per day	10	hours	
Average cycle time per shove	5	mins	
Efficiency	81	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	22.8	hours / day	
Total hours at average excavation rate per day	11.4	hours / day	2 stockpiles emptied at any one time
Total hours for operation per year	2,910	hours / year	

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Moving per tunnel drive

Daily excavated volume per tunnel (peak)	1,608	yd3 / day	to be moved per day
Wheel Loader capacity	19.50	yd3 / wheel loader	
Working hours per day	10	hours	
Average cycle time	5	mins	
Efficiency	81	%	
Number of wheel loaders	1	wheel loaders	
Total hours at peak excavation rate per day	8.5	hours / day	
Total hours at average excavation rate per day	4.2	hours / day	
Total hours for operation per year	1,082	hours / year	

Example: Caterpillar, 990K, Capacity = 19.5yd3 (see equipment schedule for details)

Drying Area / Dry Stockpile Spreading per tunnel drive

Volume of RTM to be spread per cell (ave.)	8,042	yd3 / cell
Bulldozer capacity	14.50	yd3 / bulldozer
Working hours per week	50	hours / week / cell
Average cycle time per shove	5	mins
Efficiency	81	%
Number of bulldozers required	2	bulldozers / cell
Max. number of cells to spread in one week	3	cells
Number of bulldozers required	6	bulldozers
Total hours per cell (ave.)	57.1	hours / cell
Number of cells to spread per year	52	cells / year
Total hours for operation per year	2,967	hours / year

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Compacting   per tunnel drive

Roller width	84	in	
Roller width	2.33	yd	
Area per cell	3.5	acres	per site (ie. two tunnel drives)
Area per cell	16,889	yd2	
Speed	6.8	mph	
Speed	11,968	yd/hr	
Area/hr	27,925	yd2/hr	
Working hours per day	10	hours	
Efficiency	50	%	
No. of passes	2	passes	
Time to compact one cell	2.4	hrs	
Max. number of cells to compact in one week	3	cells / week	
Number of compactors required	1	compactors	
Number of cells to compact per year	52	cells / year	
Total hours for operation per year	126	hours / year	

Example: Caterpillar, CS54B, Capacity = 84in roller at 6.8mph (see equipment schedule for details)

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Natural Drying Equipment Schedule**

Working Hours / Year

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule (per tunnel drive)

Operation	Equipment	Manufacturer	Model	Power	Power	Hours / Year / Operation	Hourly Operating Cost	Capital Cost	Average Excavation Rate: Total Hours / Year	Average Excavation Rate: Total Power / Year	Average Excavation Rate: Total Annual Operating Cost	Peak Excavation Rate: Quantity	Peak Excavation Rate: Total Capital Cost
Temporary Wet Stockpiles Filling	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	2932 hrs	$ 105	$ 196,000	2932 hrs	474 MWh	$ 307,849	2	$ 392,000
Temporary Wet Stockpiles Testing													
Temporary Wet Stockpiles Emptying	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	2910 hrs	$ 105	$ 196,000	2910 hrs	471 MWh	$ 305,568	4	$ 784,000
Drying Stockpile Moving	Wheel Loaders	Caterpillar	990K	699 hp	521 kW	1082 hrs	$ 120	$ 180,000	1082 hrs	564 MWh	$ 129,839	1	$ 180,000
Drying Stockpile Spreading	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	2967 hrs	$ 105	$ 196,000	2967 hrs	480 MWh	$ 311,560	6	$ 1,176,000
Drying Stockpile Compacting	Compactor	Caterpillar	CS54B	131 hp	98 kW	126 hrs	$ 55	$ 73,100	126 hrs	12 MWh	$ 6,919	1	$ 73,100

Equipment utilization 14%

	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Total Electrical	- hrs	- MWh	$ -	0	$ -
Total Gas/Diesel	10,017 hrs	2,002 MWh	$ 1,061,734	14	$ 2,605,100
Total	10,017 hrs	2,002 MWh	$ 1,061,734	14	$ 2,605,100

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **3,000 cfs** **Equipment Schedule Summary**

Working Hours

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule

No Drying - (per tunnel drive)			Annual usage		
Operation	Equipment	Power	Quantity required	Total Hours / Year	Notes
Temporary Wet Stockpiles Filling	Bulldozers	217 hp	2	2,932 hrs	Day and night shift, 12mths/yr
Temporary Wet Stockpiles Testing		hp		hrs	No activity
Temporary Wet Stockpiles Emptying	Bulldozers	217 hp	4	2,910 hrs	Day shift only, 12mths/yr
Drying Stockpile Moving	Wheel Loaders	699 hp	1	1,082 hrs	Day shift only, 12mths/yr
Drying Stockpile Spreading	Bulldozers	217 hp	6	2,967 hrs	Day shift only, 12mths/yr
Drying Stockpile Compacting	Compactor	131 hp	1	126 hrs	Two passes over each drying cell / yr

Total Electrical	0	- hrs
Total Gas/Diesel	14	10,017 hrs
Total	14	10,017 hrs

Attachment 4.2
RTM Calculations – 4,500 cfs, 31-foot-ID Tunnel

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor
Northern tunnels ID	31.0 ft	5 days	51 wks	105 yd2				105 yd2			
Main tunnels ID	31.0 ft	5 days	51 wks	105 yd2	1.30	5.00 %	0.80	105 yd2	1.30	5.00 %	0.80
Southern tunnels ID	31.0 ft	5 days	51 wks	105 yd2				105 yd2			

Option	Element	Tunnel Length	Drive Options: Tunnel Drive	Drive Length	Drive Duration	TBM's	RTM Volume / Tunnel Length: In-Situ RTM Volume / Tunnel Length	Wet Excavated RTM Volume / Tunnel Length	Dry Excavated RTM Volume / Tunnel Length	Dry Compacted RTM Volume / Tunnel Length
		0.000 mi					- yd3	- yd3	- yd3	- yd3
	Intake No. 3 Shaft		R							
	Northern Tunnel	2.550 mi	↑	8.190 mi	3.9 yrs		470,679 yd3	611,882 yd3	581,287.99 yd3	465,030 yd3
	Intake No. 5 Shaft		M							
	Northern Tunnel	5.640 mi	↑				1,041,030 yd3	1,353,339 yd3	1,285,672 yd3	1,028,538 yd3
	Twin Cities Shaft		L			2				
	Main Tunnel	4.580 mi	↓				845,376 yd3	1,098,988 yd3	1,044,039 yd3	835,231 yd3
	New Hope Shaft		M							
	Main Tunnel	3.000 mi	↓	12.690 mi	5.9 yrs		553,739 yd3	719,861 yd3	683,868 yd3	547,095 yd3
BETHANY	Canal Ranch		M							
	Main Tunnel	5.110 mi	↓				943,203 yd3	1,226,164 yd3	1,164,856 yd3	931,884 yd3
	Terminous Tract Shaft		R							
	Main Tunnel	3.940 mi	↑				727,244 yd3	945,418 yd3	898,147 yd3	718,518 yd3
	King Island Shaft		M	9.500 mi	4.5 yrs					
	Main Tunnel	5.560 mi	↑				1,026,264 yd3	1,334,143 yd3	1,267,436 yd3	1,013,949 yd3
	Lower Roberts Island Shaft		L			2				
	Southern Tunnels	5.130 mi	↓				946,894 yd3	1,230,963 yd3	1,169,415 yd3	935,532 yd3
	Upper Jones Tract Shaft		M							
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.4 yrs		782,618 yd3	1,017,404 yd3	966,534 yd3	773,227 yd3
	Union Island Shaft		M							
	Southern Tunnels	5.030 mi	↓				928,436 yd3	1,206,967 yd3	1,146,619 yd3	917,295 yd3
	Surge Basin Shaft		R							
	Total	44.78 mi	2	44.78 mi		4	8,265,484 yd3	10,745,129 yd3	10,207,873 yd3	8,166,298 yd3

Element	RTM Volume / Shaft: Wet In-situ RTM Volume / Shaft	Wet Excavated RTM Volume / Shaft	Dry Excavated RTM Volume / Shaft	Dry Compacted RTM Volume / Shaft	RTM Volume / Tunnel Drive: Dry Compacted RTM Volume / Tunnel Drive	Ave. Quarterly Excavated Dry Compacted RTM Volume / Tunnel Drive
Intake No. 3 Shaft						
Northern Tunnel					1,493,568 yd3	95,373 yd3
Intake No. 5 Shaft						
Northern Tunnel						
Twin Cities Shaft	3,854,027 yd3	5,010,235 yd3	4,759,723 yd3	3,807,778 yd3		
Main Tunnel						
New Hope Shaft						
Main Tunnel					2,314,210 yd3	97,629 yd3
Canal Ranch						
Main Tunnel						
Terminous Tract Shaft						
Main Tunnel						
King Island Shaft					1,732,466 yd3	95,579 yd3
Main Tunnel						
Lower Roberts Island Shaft	4,411,458 yd3	5,734,895 yd3	5,448,150 yd3	4,358,520 yd3		
Southern Tunnels						
Upper Jones Tract Shaft						
Southern Tunnels					2,626,054 yd3	101,926 yd3
Union Island Shaft						
Southern Tunnels						
Surge Basin Shaft						
Total	8,265,484 yd3	10,745,129 yd3	10,207,873 yd3	8,166,298 yd3	8,166,298 yd3	390,507 yd3

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year
Northern tunnels ID	31.0 ft	5 days	51 wks
Main tunnels ID	31.0 ft	5 days	51 wks
Southern tunnels ID	31.0 ft	5 days	51 wks

Option	Element	Tunnel Length	Drive Options: Tunnel Drive	Drive Length	Drive Duration	TBM's
BETHANY		0.000 mi				
	Intake No. 3 Shaft		R			
	Northern Tunnel	2.550 mi	↑	8.190 mi	3.9 yrs	
	Intake No. 5 Shaft		M			
	Northern Tunnel	5.640 mi	↑			
	Twin Cities Shaft		L			2
	Main Tunnel	4.580 mi	↓			
	New Hope Shaft		M			
	Main Tunnel	3.000 mi	↓	12.690 mi	5.9 yrs	
	Canal Ranch		M			
	Main Tunnel	5.110 mi	↓			
	Terminous Tract Shaft		R			
	Main Tunnel	3.940 mi	↑			
	King Island Shaft		M	9.500 mi	4.5 yrs	
	Main Tunnel	5.560 mi	↑			
	Lower Roberts Island Shaft		L			2
	Southern Tunnels	5.130 mi	↓			
	Upper Jones Tract Shaft		M			
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.4 yrs	
	Union Island Shaft		M			
	Southern Tunnels	5.030 mi	↓			
	Surge Basin Shaft		R			
	Total	44.78 mi	2	44.78 mi		4

Quarterly Dry Compacted RTM Volume Generated by Tunnel Drive (m yd3)

Start	HIDE	Y1				Y2				Y3				Y4				Y5				Y6				Y7				Y8				Y9				Y10				Y11				Y12				Y13				Y14			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.29	0.29	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.36	0.30	0.30	0.30	0.30	0.18	0.10	0.10	0.10	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.29	0.59	0.88	1.27	1.66	2.05	2.44	2.84	3.23	3.62	4.01	4.40	4.79	5.18	5.57	5.96	6.32	6.61	6.91	7.20	7.50	7.68	7.78	7.88	7.99	8.09	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter
Northern tunnels ID	31.0 ft
Main tunnels ID	31.0 ft
Southern tunnels ID	31.0 ft

Tunnelling days / week	Tunnelling weeks / year
5 days	51 wks
5 days	51 wks
5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	Start
BETHANY		0.000 mi					
	Intake No. 3 Shaft		R				
	Northern Tunnel	2.550 mi	↑	8.190 mi	3.9 yrs		20
	Intake No. 5 Shaft		M				
	Northern Tunnel	5.640 mi	↑				
	Twin Cities Shaft		L			2	
	Main Tunnel	4.580 mi	↓				
	New Hope Shaft		M				
	Main Tunnel	3.000 mi	↓	12.690 mi	5.9 yrs		17
	Canal Ranch		M				
	Main Tunnel	5.110 mi	↓				
	Terminous Tract Shaft		R				
	Main Tunnel	3.940 mi	↑				
	King Island Shaft		M	9.500 mi	4.5 yrs		22
	Main Tunnel	5.560 mi	↑				
	Lower Roberts Island Shaft		L			2	
	Southern Tunnels	5.130 mi	↓				
	Upper Jones Tract Shaft		M				
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.4 yrs		20
	Union Island Shaft		M				
	Southern Tunnels	5.030 mi	↓				
	Surge Basin Shaft		R				
	Total	44.78 mi	2	44.78 mi		4	

Quarterly Dry Compacted RTM Volume Generated at Each Shaft (m yd3)

	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Twin Cities Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Lower Roberts Island Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	0.10	0.29	0.29	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.20	0.29	0.59	0.88	1.27	1.66	2.05	2.44	2.84	3.23	3.62

	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Twin Cities Shaft	0.19	0.19	0.19	0.19	0.19	0.19	0.16	0.10	0.10	0.10	0.10	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Roberts Island Shaft	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.11	0.10	0.10	0.10	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly	0.39	0.39	0.39	0.39	0.39	0.39	0.36	0.30	0.30	0.30	0.30	0.18	0.10	0.10	0.10	0.10	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	4.01	4.40	4.79	5.18	5.57	5.96	6.32	6.61	6.91	7.20	7.50	7.68	7.78	7.88	7.99	8.09	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17	8.17

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **Stockpiles**

Maximum allowable stockpile heights

Max. permanent stockpile height at Twin Cities	15	ft	above grade
Max. permanent stockpile height at Lower Roberts	15	ft	above grade
Contingency	5	%	

Temporary stockpiles (All RTM)

Bethany	Vol. of RTM to stockpile (yd3)	Area of temp. stockpile (acres)	Height of temp. stockpile (ft)	Resulting individual lift (in)
Twin Cities North	1,327,515	168	4.9	18.0
Twin Cities South	2,056,919	168	7.6	18.0
Lower Roberts North	1,605,412	168	5.9	18.0
Lower Roberts South	2,433,467	168	9.0	18.0

Temporary stockpile notes

Twin Cities
- < 7,500 cfs, area based on drying method
- 7,500 cfs uses same area as for 6,000 cfs

Lower Roberts
- Area based on drying method
- Max. available area 193 acres / tunnel drive
- See 'No Drying Annual Process' sheet.

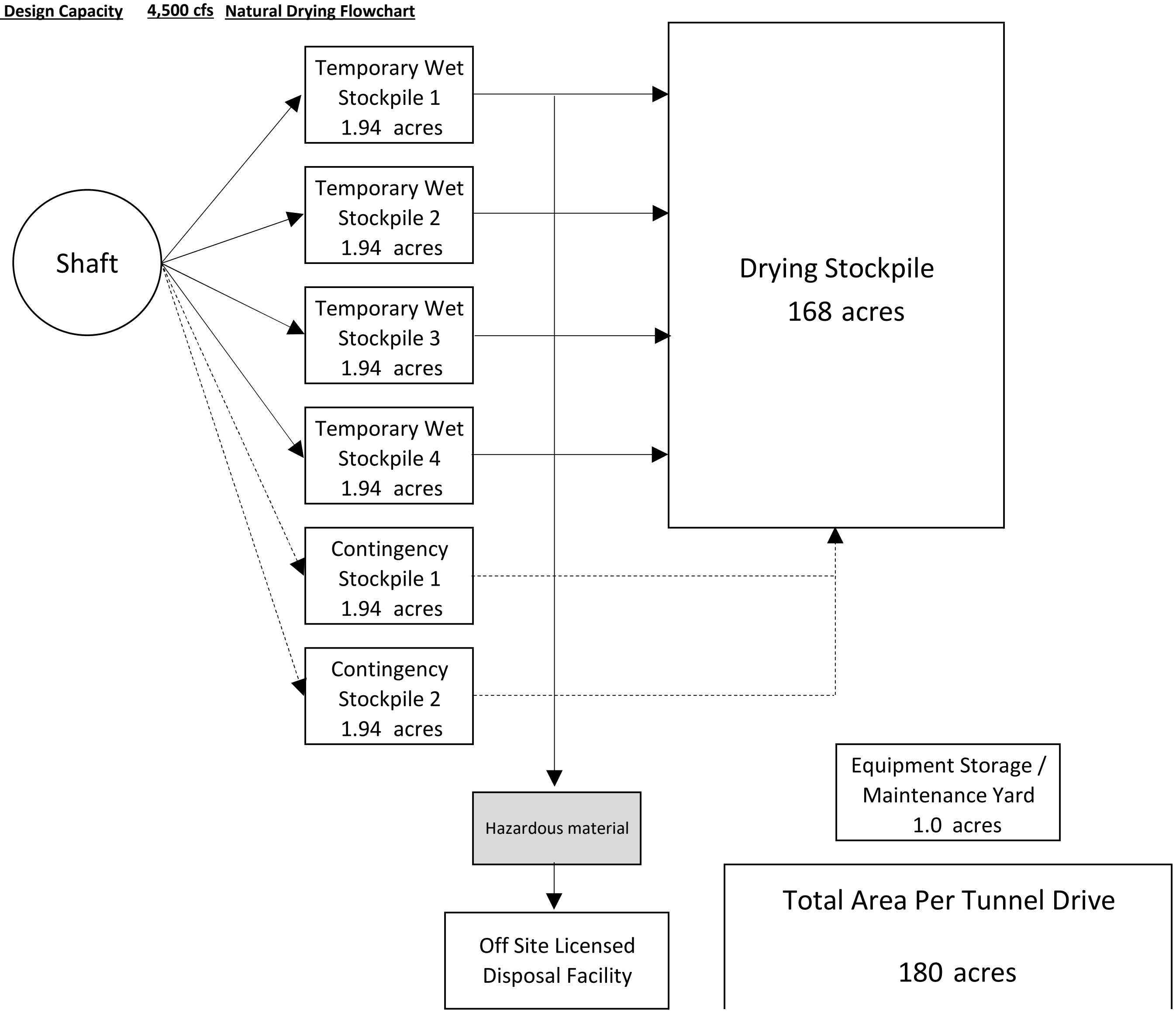
Permanent stockpiles (Surplus RTM)

		Based on max. height	
Bethany	Vol. of RTM to stockpile (yd3)	Area of perm. stockpile (acres)	Height of perm. stockpile (acres)
Twin Cities	3,623,175	157	15
Lower Roberts	3,167,175	137	15

Permanent stockpile notes

Both sites consolidated into one stockpile
Area calculated based on 15ft height
At TC volume includes ring levee degradation
Surplus volumes account for filling borrow pit

Project Design Capacity **4,500 cfs** **Natural Drying Flowchart**



CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **Natural Drying Annual Process**

Drying stockpile height per lift	18	in
Drying stockpile contingency	5	%
Tunnelling days / week	5	days / week
Tunnelling weeks / year	51	weeks / year
Wet season	7	months / year
Wet season	30	weeks / year
Number of drying cells	37	

Per Tunnel Drive Season	Cell > Area→ Week↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		
		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	Spreading	Compacting
Wet	1	Hold	Hold	Hold	Fill	< wet season begins with 3 full cells from previous drying season																																	0	0
Wet	2	Hold	Hold	Hold	Hold	Fill																																	0	0
Wet	3	Hold	Hold	Hold	Hold	Hold	Fill																																0	0
Wet	4	Hold	Hold	Hold	Hold	Hold	Hold	Fill																															0	0
Wet	5	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																														0	0
Wet	6	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																													0	0
Wet	7	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																												0	0
Wet	8	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																											0	0
Wet	9	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																										0	0
Wet	10	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																									0	0
Wet	11	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																								0	0
Wet	12	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																							0	0
Wet	13	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																						0	0
Wet	14	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																					0	0
Wet	15	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																				0	0
Wet	16	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																			0	0
Wet	17	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																		0	0
Wet	18	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																	0	0
Wet	19	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																0	0
Wet	20	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill															0	0
Wet	21	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill														0	0
Wet	22	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill													0	0
Wet	23	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill												0	0
Wet	24	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill											0	0
Wet	25	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill										0	0
Wet	26	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill									0	0
Wet	27	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill								0	0
Wet	28	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill							0	0
Wet	29	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill						0	0
Wet	30	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill					0	0
Dry	31	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill + Spread				3	0
Dry	32	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Fill + Spread			3	0
Dry	33	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Fill + Spread		3	0
Dry	34	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Fill + Spread	3	3
Dry	35	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	3	3
Dry	36	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	3	3
Dry	37	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	3	3
Dry	38	Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold					Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold					3	3
Dry	39		Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold						Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold					3	3
Dry	40			Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold							Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold					3	3
Dry	41				Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold								Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold					3	3
Dry	42					Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold									Dry + Compact	Dry	Dry	Spread	Hold	Hold					3	3
Dry	43						Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold										Dry + Compact	Dry	Dry	Spread	Hold					3	3
Dry	44							Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold											Dry + Compact	Dry	Dry	Spread					3	3
Dry	45								Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold												Dry + Compact	Dry	Dry					2	3
Dry	46									Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold													Dry + Compact	Dry					2	3
Dry	47										Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold														Dry + Compact					2	3
Dry	48											Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold																			2	2
Dry	49												Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread																			2	2
Dry	50	Fill												Dry + Compact	Dry	Dry		Dry + Compact	Dry	Dry																			0	2
Dry	51	Hold	Fill												Dry + Compact	Dry			Dry + Compact	Dry																			0	2
Dry	52	Hold	Hold	Fill												Dry + Compact				Dry + Compact																			0	2

Permanent stockpile per site

Shaft site	Total vol. of RTM (yd3)	Stockpile area (acres)	Final height of stockpile (ft)	Equivalent annual lift (in)
Twin Cities	3,623,175	336	6.7	24
Lower Roberts	3,167,175	336	5.8	24

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **Natural Drying Areas**

Excavation Rates per tunnel drive

Tunnel lining ID	31	ft
TBM cutterhead area	944	ft2
TBM advance rate (ave.)	46	ft / day
TBM advance rate (peak)	92	ft / day
Daily in-situ rate of excavation per tunnel (ave.)	1,608	yd3 / day
Daily in-situ rate of excavation per tunnel (peak)	3,216	yd3 / day
Bulking factor	1.30	
Daily excavated volume per tunnel (ave.)	2,091	yd3 / day
Daily excavated volume per tunnel (peak)	4,181	yd3 / day
Estimated duration of peak excavation	21	days
Volume loss due to drying	5	%
Equivalent daily dry excavated volume per tunnel (ave.)	1,986	yd3 / day
Equivalent daily dry excavated volume per tunnel (peak.)	3,972	yd3 / day

Temporary Wet Stockpile Area per tunnel drive

No. of days storage	5	days	assuming 5 days of peak excavation in a 7 day cycle
Volume of RTM to stockpile at peak excavation rate	20,905	yd3	per stockpile
Height of stockpile	10	ft	short term
Contingency	50	%	includes allowance for conveyor pits
Area required at peak excavation rate	1.94	acres	per stockpile = 291 x 291 ft or equivalent
No. of temporary stockpiles	6.0		
Total area of temporary stockpiles	11.7	acres	

Equipment Storage / Maintenance Yard per tunnel drive

Area required for equipment storage / maintenance yard 1.0 acres

Drying Stockpile

Contingency 5 %

Natural Drying Area Summary

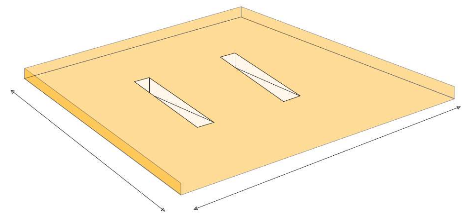
Alignment	Site	Tunnel Drive	Compacted RTM to store above grade	Temporary Wet Stockpile 10 ft high	Equipment / Maintenance Yard	Dry Stockpile (height varies)	Total RTM Area	Total RTM Area
Bethany	Twin Cities	North	1.3 m yd3	11.7 acres	1 acres	168 acres	180 acres	361 acres
		South	2.1 m yd3	11.7 acres	1 acres	168 acres	180 acres	
	Lower Roberts Island	North	1.6 m yd3	11.7 acres	1 acres	168 acres	180 acres	361 acres
		South	2.4 m yd3	11.7 acres	1 acres	168 acres	180 acres	

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **Natural Drying Equipment**

Temporary Wet Stockpile Filling per tunnel drive

Volume of RTM to stockpile at peak excavation rate	20,905	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for filling temporary stockpile	5	days	
Working hours per day	20	hours	
Average cycle time per shove	5	mins	
Efficiency	80	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	29.9	hours / day	
Total hours at average excavation rate per day	14.9	hours / day	
Total hours for operation per year	3,811	hours / year	



Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Temporary Wet Stockpile Emptying per tunnel drive

Assume two conveyor pits in the centre of the temporary stockpile each to be loaded from both sides.

Volume of RTM to stockpile at peak excavation rate	20,905	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for emptying temporary stockpile	10	days	
Working hours per day	10	hours	
Average cycle time per shove	5	mins	
Efficiency	81	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	29.7	hours / day	
Total hours at average excavation rate per day	14.8	hours / day	2 stockpiles emptied at any one time
Total hours for operation per year	3,782	hours / year	

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Moving per tunnel drive

Daily excavated volume per tunnel (peak)	2,091	yd3 / day	to be moved per day
Wheel Loader capacity	19.50	yd3 / wheel loader	
Working hours per day	10	hours	
Average cycle time	5	mins	
Efficiency	81	%	
Number of wheel loaders	2	wheel loaders	
Total hours at peak excavation rate per day	11.0	hours / day	
Total hours at average excavation rate per day	5.5	hours / day	
Total hours for operation per year	1,406	hours / year	

Example: Caterpillar, 990K, Capacity = 19.5yd3 (see equipment schedule for details)

Drying Area / Dry Stockpile Spreading per tunnel drive

Volume of RTM to be spread per cell (ave.)	10,453	yd3 / cell
Bulldozer capacity	14.50	yd3 / bulldozer
Working hours per week	50	hours / week / cell
Average cycle time per shove	5	mins
Efficiency	81	%
Number of bulldozers required	2	bulldozers / cell
Max. number of cells to spread in one week	3	cells
Number of bulldozers required	6	bulldozers
Total hours per cell (ave.)	74.2	hours / cell
Number of cells to spread per year	52	cells / year
Total hours for operation per year	3,856	hours / year

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Compacting per tunnel drive

Roller width	84	in	
Roller width	2.33	yd	
Area per cell	4.5	acres	per site (ie. two tunnel drives)
Area per cell	21,950	yd2	
Speed	6.8	mph	
Speed	11,968	yd/hr	
Area/hr	27,925	yd2/hr	
Working hours per day	10	hours	
Efficiency	50	%	
No. of passes	2	passes	
Time to compact one cell	3.1	hrs	
Max. number of cells to compact in one week	3	cells / week	
Number of compactors required	1	compactors	
Number of cells to compact per year	52	cells / year	
Total hours for operation per year	163	hours / year	

Example: Caterpillar, CS54B, Capacity = 84in roller at 6.8mph (see equipment schedule for details)

CA Delta Conveyance Tunnel - RTM Calculations

24 Jun 2021

Project Design Capacity **4,500 cfs** **Natural Drying Equipment Schedule**

Working Hours / Year

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule (per tunnel drive)

Operation	Equipment	Manufacturer	Model	Power	Power	Hours / Year / Operation	Hourly Operating Cost	Capital Cost	Average Excavation Rate: Total Hours / Year	Average Excavation Rate: Total Power / Year	Average Excavation Rate: Total Annual Operating Cost	Peak Excavation Rate: Quantity	Peak Excavation Rate: Total Capital Cost
Temporary Wet Stockpiles Filling	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	3811 hrs	$ 105	$ 196,000	3811 hrs	617 MWh	$ 400,107	2	$ 392,000
Temporary Wet Stockpiles Testing													
Temporary Wet Stockpiles Emptying	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	3782 hrs	$ 105	$ 196,000	3782 hrs	612 MWh	$ 397,143	4	$ 784,000
Drying Stockpile Moving	Wheel Loaders	Caterpillar	990K	699 hp	521 kW	1406 hrs	$ 120	$ 180,000	1406 hrs	733 MWh	$ 168,749	2	$ 360,000
Drying Stockpile Spreading	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	3856 hrs	$ 105	$ 196,000	3856 hrs	624 MWh	$ 404,930	6	$ 1,176,000
Drying Stockpile Compacting	Compactor	Caterpillar	CS54B	131 hp	98 kW	163 hrs	$ 55	$ 73,100	163 hrs	16 MWh	$ 8,992	1	$ 73,100

Equipment utilization 17%

	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Total Electrical	- hrs	- MWh	$ -	0	$ -
Total Gas/Diesel	13,019 hrs	2,602 MWh	$ 1,379,921	15	$ 2,785,100
Total	13,019 hrs	2,602 MWh	$ 1,379,921	15	$ 2,785,100

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **4,500 cfs** **Equipment Schedule Summary**

Working Hours

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule

No Drying - (per tunnel drive)			Annual usage		
Operation	Equipment	Power	Quantity required	Total Hours / Year	Notes
Temporary Wet Stockpiles Filling	Bulldozers	217 hp	2	3,811 hrs	Day and night shift, 12mths/yr
Temporary Wet Stockpiles Testing		hp		hrs	No activity
Temporary Wet Stockpiles Emptying	Bulldozers	217 hp	4	3,782 hrs	Day shift only, 12mths/yr
Drying Stockpile Moving	Wheel Loaders	699 hp	2	1,406 hrs	Day shift only, 12mths/yr
Drying Stockpile Spreading	Bulldozers	217 hp	6	3,856 hrs	Day shift only, 12mths/yr
Drying Stockpile Compacting	Compactor	131 hp	1	163 hrs	Two passes over each drying cell / yr
		Total Electrical	0	- hrs	
		Total Gas/Diesel	15	13,019 hrs	
		Total	15	13,019 hrs	

Attachment 4.3
RTM Calculations – 6,000 cfs, 36-foot-ID Tunnel

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor
Northern tunnels ID	36.0 ft	5 days	51 wks	141 yd2				141 yd2			
Main tunnels ID	36.0 ft	5 days	51 wks	141 yd2	1.30	5.00 %	0.80	141 yd2	1.30	5.00 %	0.80
Southern tunnels ID	36.0 ft	5 days	51 wks	141 yd2				141 yd2			

			Drive Options				RTM Volume / Tunnel Length				RTM Volume / Shaft				RTM Volume / Tunnel Drive	
Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	In-Situ RTM Volume / Tunnel Length	Wet Excavated RTM Volume / Tunnel Length	Dry Excavated RTM Volume / Tunnel Length	Dry Compacted RTM Volume / Tunnel Length	Wet In-situ RTM Volume / Shaft	Wet Excavated RTM Volume / Shaft	Dry Excavated RTM Volume / Shaft	Dry Compacted RTM Volume / Shaft	Dry Compacted RTM Volume / Tunnel Drive	Ave. Quarterly Excavated Dry Compacted RTM Volume / Tunnel Drive
BETHANY		0.000 mi					- yd3	- yd3	- yd3	- yd3						
	Intake No. 3 Shaft		R													
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs		631,876 yd3	821,439 yd3	780,366.76 yd3	624,293 yd3					2,005,084 yd3	120,055 yd3
	Intake No. 5 Shaft		M													
	Northern Tunnel	5.640 mi	↑				1,397,561 yd3	1,816,829 yd3	1,725,988 yd3	1,380,790 yd3						
	Twin Cities Shaft		L			2					5,173,949 yd3	6,726,133 yd3	6,389,827 yd3	5,111,861 yd3		
	Main Tunnel	4.580 mi	↓				1,134,899 yd3	1,475,368 yd3	1,401,600 yd3	1,121,280 yd3						
	New Hope Shaft		M													
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs		743,383 yd3	966,398 yd3	918,079 yd3	734,463 yd3					3,106,778 yd3	122,937 yd3
	Canal Ranch		M													
	Main Tunnel	5.110 mi	↓				1,266,230 yd3	1,646,099 yd3	1,563,794 yd3	1,251,035 yd3						
	Terminous Tract Shaft		R													
	Main Tunnel	3.940 mi	↑				976,310 yd3	1,269,203 yd3	1,205,743 yd3	964,595 yd3						
	King Island Shaft		M	9.500 mi	4.8 yrs										2,325,799 yd3	120,448 yd3
	Main Tunnel	5.560 mi	↑				1,377,737 yd3	1,791,058 yd3	1,701,506 yd3	1,361,204 yd3						
	Lower Roberts Island Shaft		L			2					5,922,288 yd3	7,698,974 yd3	7,314,026 yd3	5,851,221 yd3		
	Southern Tunnels	5.130 mi	↓				1,271,186 yd3	1,652,541 yd3	1,569,914 yd3	1,255,931 yd3						
	Upper Jones Tract Shaft		M													
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs		1,050,649 yd3	1,365,843 yd3	1,297,551 yd3	1,038,041 yd3					3,525,422 yd3	128,114 yd3
	Union Island Shaft		M													
	Southern Tunnels	5.030 mi	↓				1,246,406 yd3	1,620,328 yd3	1,539,312 yd3	1,231,449 yd3						
	Surge Basin Shaft		R													
	Total	44.78 mi	2	44.78 mi		4	11,096,237 yd3	14,425,108 yd3	13,703,852 yd3	10,963,082 yd3	11,096,237 yd3	14,425,108 yd3	13,703,852 yd3	10,963,082 yd3	10,963,082 yd3	491,554 yd3

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter
Northern tunnels ID	36.0 ft
Main tunnels ID	36.0 ft
Southern tunnels ID	36.0 ft

Tunnelling days / week	Tunnelling weeks / year
5 days	51 wks
5 days	51 wks
5 days	51 wks

Option	Element	Tunnel Length	Drive Options: Tunnel Drive	Drive Length	Drive Duration	TBM's
BETHANY		0.000 mi				
	Intake No. 3 Shaft		R			
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs	
	Intake No. 5 Shaft		M			
	Northern Tunnel	5.640 mi	↑			
	Twin Cities Shaft		L			2
	Main Tunnel	4.580 mi	↓			
	New Hope Shaft		M			
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs	
	Canal Ranch		M			
	Main Tunnel	5.110 mi	↓			
	Terminous Tract Shaft		R			
	Main Tunnel	3.940 mi	↑			
	King Island Shaft		M	9.500 mi	4.8 yrs	
	Main Tunnel	5.560 mi	↑			
	Lower Roberts Island Shaft		L			2
	Southern Tunnels	5.130 mi	↓			
	Upper Jones Tract Shaft		M			
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs	
	Union Island Shaft		M			
	Southern Tunnels	5.030 mi	↓			
	Surge Basin Shaft		R			
	Total	44.78 mi	2	44.78 mi		4

Quarterly Dry Compacted RTM Volume Generated by Tunnel Drive (m yd3)

Start	HIDE	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
17	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Quarterly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.37	0.37	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25	0.37	0.74	1.11	1.60	2.09	2.59	3.08	3.57	4.06	4.55

Start	HIDE	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
20	0	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly		0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.46	0.37	0.37	0.37	0.37	0.29	0.16	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5.04	5.54	6.03	6.52	7.01	7.50	7.99	8.45	8.82	9.19	9.56	9.93	10.22	10.38	10.51	10.64	10.77	10.90	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **RTM Volumes**

Column Inputs	Internal Diameter
Northern tunnels ID	36.0 ft
Main tunnels ID	36.0 ft
Southern tunnels ID	36.0 ft

Tunnelling days / week	Tunnelling weeks / year
5 days	51 wks
5 days	51 wks
5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	Start
BETHANY		0.000 mi					
	Intake No. 3 Shaft		R				
	Northern Tunnel	2.550 mi	↑	8.190 mi	4.2 yrs		20
	Intake No. 5 Shaft		M				
	Northern Tunnel	5.640 mi	↑				
	Twin Cities Shaft		L			2	
	Main Tunnel	4.580 mi	↓				
	New Hope Shaft		M				
	Main Tunnel	3.000 mi	↓	12.690 mi	6.3 yrs		17
	Canal Ranch		M				
	Main Tunnel	5.110 mi	↓				
	Terminous Tract Shaft		R				
	Main Tunnel	3.940 mi	↑				
	King Island Shaft		M	9.500 mi	4.8 yrs		22
	Main Tunnel	5.560 mi	↑				
	Lower Roberts Island Shaft		L			2	
	Southern Tunnels	5.130 mi	↓				
	Upper Jones Tract Shaft		M				
	Southern Tunnels	4.240 mi	↓	14.400 mi	6.9 yrs		20
	Union Island Shaft		M				
	Southern Tunnels	5.030 mi	↓				
	Surge Basin Shaft		R				
	Total	44.78 mi	2	44.78 mi		4	

Quarterly Dry Compacted RTM Volume Generated at Each Shaft (m yd3)

	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Twin Cities Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Lower Roberts Island Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.37	0.37	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25	0.37	0.74	1.11	1.60	2.09	2.59	3.08	3.57	4.06	4.55

	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Twin Cities Shaft	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.21	0.12	0.12	0.12	0.12	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Roberts Island Shaft	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.17	0.13	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Quarterly	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.46	0.37	0.37	0.37	0.37	0.29	0.16	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	5.04	5.54	6.03	6.52	7.01	7.50	7.99	8.45	8.82	9.19	9.56	9.93	10.22	10.38	10.51	10.64	10.77	10.90	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96	10.96

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Stockpiles**

Maximum allowable stockpile heights

Max. permanent stockpile height at Twin Cities	15	ft	above grade
Max. permanent stockpile height at Lower Roberts	15	ft	above grade
Contingency	5	%	

Temporary stockpiles (All RTM)

Bethany	Vol. of RTM to stockpile (yd3)	Area of temp. stockpile (acres)	Height of temp. stockpile (ft)	Resulting individual lift (in)
Twin Cities North	1,828,519	196	5.8	18.0
Twin Cities South	2,833,200	196	9.0	18.0
Lower Roberts North	2,198,745	196	7.0	18.0
Lower Roberts South	3,332,834	196	10.5	18.0

Temporary stockpile notes

Twin Cities

- < 7,500 cfs, area based on drying method
- 7,500 cfs uses same area as for 6,000 cfs

Lower Roberts

- Area based on drying method
- Max. available area 196 acres / tunnel drive
- See 'No Drying Annual Process' sheet.

Permanent stockpiles (Surplus RTM)

		Based on max. height	
Bethany	Vol. of RTM to stockpile (yd3)	Area of perm. stockpile (acres)	Height of perm. stockpile (acres)
Twin Cities	4,924,578	214	15
Lower Roberts	4,361,335	189	15

Permanent stockpile notes

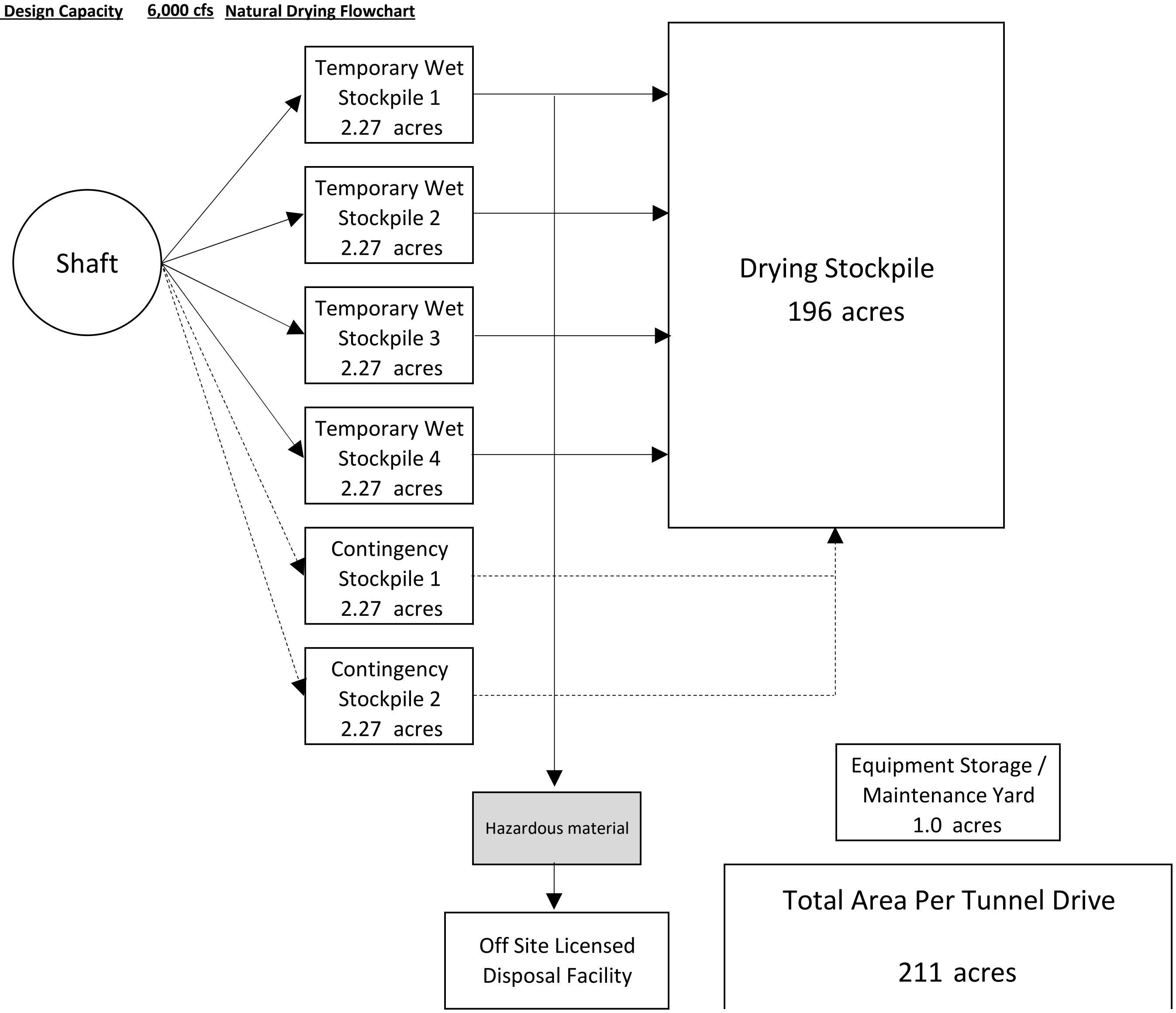
Both sites consolidated into one stockpile

Area calculated based on 15ft height

At TC volume includes ring levee degradation

Surplus volumes account for filling borrow pit

Project Design Capacity **6,000 cfs** **Natural Drying Flowchart**



CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Annual Process**

Drying stockpile height per lift	18	in
Drying stockpile contingency	5	%
Tunnelling days / week	5	days / week
Tunnelling weeks / year	51	weeks / year
Wet season	7	months / year
Wet season	30	weeks / year
Number of drying cells	37	

Per Tunnel Drive	Cell >	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37		
	Area→	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	Spreading	Compacting
Season	Week↓																																							
Wet	1	Hold	Hold	Hold	Fill	< wet season begins with 3 full cells from previous drying season																																	0	0
Wet	2	Hold	Hold	Hold	Hold	Fill																																	0	0
Wet	3	Hold	Hold	Hold	Hold	Hold	Fill																																0	0
Wet	4	Hold	Hold	Hold	Hold	Hold	Hold	Fill																															0	0
Wet	5	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																														0	0
Wet	6	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																													0	0
Wet	7	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																												0	0
Wet	8	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																											0	0
Wet	9	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																										0	0
Wet	10	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																									0	0
Wet	11	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																								0	0
Wet	12	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																							0	0
Wet	13	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																						0	0
Wet	14	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																					0	0
Wet	15	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																				0	0
Wet	16	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																			0	0
Wet	17	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																		0	0
Wet	18	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																	0	0
Wet	19	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																0	0
Wet	20	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill															0	0
Wet	21	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill														0	0
Wet	22	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill													0	0
Wet	23	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill												0	0
Wet	24	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill											0	0
Wet	25	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill										0	0
Wet	26	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill									0	0
Wet	27	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill								0	0
Wet	28	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill							0	0
Wet	29	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill						0	0
Wet	30	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill					0	0
Dry	31	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill + Spread				3	0
Dry	32	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Fill + Spread			3	0
Dry	33	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Fill + Spread		3	0
Dry	34	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Fill + Spread	3	3
Dry	35	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	3	3
Dry	36	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	3	3
Dry	37	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	3	3
Dry	38	Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold					Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold					3	3
Dry	39		Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold						Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold					3	3
Dry	40			Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold							Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold					3	3
Dry	41				Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold								Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold					3	3
Dry	42					Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold									Dry + Compact	Dry	Dry	Spread	Hold	Hold					3	3
Dry	43						Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold										Dry + Compact	Dry	Dry	Spread	Hold					3	3
Dry	44							Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold											Dry + Compact	Dry	Dry	Spread					3	3
Dry	45								Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold												Dry + Compact	Dry	Dry					2	3
Dry	46									Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold													Dry + Compact	Dry					2	3
Dry	47										Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold														Dry + Compact					2	3
Dry	48											Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold																			2	2
Dry	49												Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread																			2	2
Dry	50	Fill												Dry + Compact	Dry	Dry		Dry + Compact	Dry	Dry																			0	2
Dry	51	Hold	Fill												Dry + Compact	Dry			Dry + Compact	Dry																			0	2
Dry	52	Hold	Hold	Fill												Dry + Compact				Dry + Compact																			0	2

Permanent stockpile per site

Shaft site	Total vol. of RTM (yd3)	Stockpile area (acres)	Final height of stockpile (ft)	Equivalent annual lift (in)
Twin Cities	4,924,578	392	7.8	24
Lower Roberts	4,361,335	392	6.9	24

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Areas**

Excavation Rates per tunnel drive

Tunnel lining ID	36	ft
TBM cutterhead area	1,267	ft2
TBM advance rate (ave.)	40	ft / day
TBM advance rate (peak)	80	ft / day
Daily in-situ rate of excavation per tunnel (ave.)	1,877	yd3 / day
Daily in-situ rate of excavation per tunnel (peak)	3,754	yd3 / day
Bulking factor	1.30	
Daily excavated volume per tunnel (ave.)	2,440	yd3 / day
Daily excavated volume per tunnel (peak)	4,881	yd3 / day
Estimated duration of peak excavation	21	days
Volume loss due to drying	5	%
Equivalent daily dry excavated volume per tunnel (ave.)	2,318	yd3 / day
Equivalent daily dry excavated volume per tunnel (peak.)	4,637	yd3 / day

Temporary Wet Stockpile Area per tunnel drive

No. of days storage	5	days	assuming 5 days of peak excavation in a 7 day cycle
Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile
Height of stockpile	10	ft	short term
Contingency	50	%	includes allowance for conveyor pits
Area required at peak excavation rate	2.27	acres	per stockpile = 314 x 314 ft or equivalent
No. of temporary stockpiles	6.0		
Total area of temporary stockpiles	13.6	acres	

Equipment Storage / Maintenance Yard per tunnel drive

Area required for equipment storage / maintenance yard	1.0	acres

Drying Stockpile

Contingency	5	%

Natural Drying Area Summary

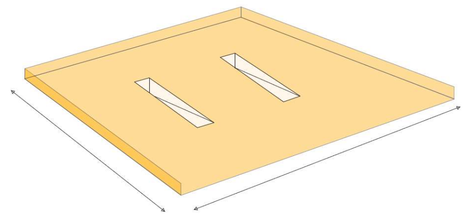
Alignment	Site	Tunnel Drive	Compacted RTM to store above grade	Temporary Wet Stockpile 10 ft high	Equipment / Maintenance Yard	Dry Stockpile (height varies)	Total RTM Area	Total RTM Area
Bethany	Twin Cities	North	1.8 m yd3	13.6 acres	1 acres	196 acres	211 acres	421 acres
		South	2.8 m yd3	13.6 acres	1 acres	196 acres	211 acres	
	Lower Roberts Island	North	2.2 m yd3	13.6 acres	1 acres	196 acres	211 acres	421 acres
		South	3.3 m yd3	13.6 acres	1 acres	196 acres	211 acres	

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Equipment**

Temporary Wet Stockpile Filling per tunnel drive

Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for filling temporary stockpile	5	days	
Working hours per day	20	hours	
Average cycle time per shove	5	mins	
Efficiency	80	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	34.9	hours / day	
Total hours at average excavation rate per day	17.4	hours / day	
Total hours for operation per year	4,448	hours / year	



Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Temporary Wet Stockpile Emptying per tunnel drive

Assume two conveyor pits in the centre of the temporary stockpile each to be loaded from both sides.

Volume of RTM to stockpile at peak excavation rate	24,404	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for emptying temporary stockpile	10	days	
Working hours per day	10	hours	
Average cycle time per shove	5	mins	
Efficiency	81	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	34.6	hours / day	
Total hours at average excavation rate per day	17.3	hours / day	2 stockpiles emptied at any one time
Total hours for operation per year	4,415	hours / year	

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Moving per tunnel drive

Daily excavated volume per tunnel (peak)	2,440	yd3 / day	to be moved per day
Wheel Loader capacity	19.50	yd3 / wheel loader	
Working hours per day	10	hours	
Average cycle time	5	mins	
Efficiency	81	%	
Number of wheel loaders	2	wheel loaders	
Total hours at peak excavation rate per day	12.9	hours / day	
Total hours at average excavation rate per day	6.4	hours / day	
Total hours for operation per year	1,642	hours / year	

Example: Caterpillar, 990K, Capacity = 19.5yd3 (see equipment schedule for details)

Drying Area / Dry Stockpile Spreading per tunnel drive

Volume of RTM to be spread per cell (ave.)	12,202	yd3 / cell
Bulldozer capacity	14.50	yd3 / bulldozer
Working hours per week	50	hours / week / cell
Average cycle time per shove	5	mins
Efficiency	81	%
Number of bulldozers required	2	bulldozers / cell
Max. number of cells to spread in one week	3	cells
Number of bulldozers required	6	bulldozers
Total hours per cell (ave.)	86.6	hours / cell
Number of cells to spread per year	52	cells / year
Total hours for operation per year	4,502	hours / year

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Compacting per tunnel drive

Roller width	84	in	
Roller width	2.33	yd	
Area per cell	5.3	acres	per site (ie. two tunnel drives)
Area per cell	25,624	yd2	
Speed	6.8	mph	
Speed	11,968	yd/hr	
Area/hr	27,925	yd2/hr	
Working hours per day	10	hours	
Efficiency	50	%	
No. of passes	2	passes	
Time to compact one cell	3.7	hrs	
Max. number of cells to compact in one week	3	cells / week	
Number of compactors required	1	compactors	
Number of cells to compact per year	52	cells / year	
Total hours for operation per year	191	hours / year	

Example: Caterpillar, CS54B, Capacity = 84in roller at 6.8mph (see equipment schedule for details)

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Natural Drying Equipment Schedule**

Working Hours / Year

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule (per tunnel drive)

									Average Excavation Rate			Peak Excavation Rate	
Operation	Equipment	Manufacturer	Model	Power	Power	Hours / Year / Operation	Hourly Operating Cost	Capital Cost	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Temporary Wet Stockpiles Filling	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4448 hrs	$ 105	$ 196,000	4448 hrs	720 MWh	$ 467,073	2	$ 392,000
Temporary Wet Stockpiles Testing													
Temporary Wet Stockpiles Emptying	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4415 hrs	$ 105	$ 196,000	4415 hrs	714 MWh	$ 463,614	4	$ 784,000
Drying Stockpile Moving	Wheel Loaders	Caterpillar	990K	699 hp	521 kW	1642 hrs	$ 120	$ 180,000	1642 hrs	856 MWh	$ 196,993	2	$ 360,000
Drying Stockpile Spreading	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	4502 hrs	$ 105	$ 196,000	4502 hrs	728 MWh	$ 472,704	6	$ 1,176,000
Drying Stockpile Compacting	Compactor	Caterpillar	CS54B	131 hp	98 kW	191 hrs	$ 55	$ 73,100	191 hrs	19 MWh	$ 10,497	1	$ 73,100

Equipment utilization 20%

	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Total Electrical	- hrs	- MWh	$ -	0	$ -
Total Gas/Diesel	15,198 hrs	3,037 MWh	$ 1,610,882	15	$ 2,785,100
Total	15,198 hrs	3,037 MWh	$ 1,610,882	15	$ 2,785,100

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **6,000 cfs** **Equipment Schedule Summary**

Working Hours

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule

No Drying - (per tunnel drive)				Annual usage			
Operation	Equipment	Power		Quantity required	Total Hours / Year		Notes
Temporary Wet Stockpiles Filling	Bulldozers	217	hp	2	4,448	hrs	Day and night shift, 12mths/yr
Temporary Wet Stockpiles Testing			hp			hrs	No activity
Temporary Wet Stockpiles Emptying	Bulldozers	217	hp	4	4,415	hrs	Day shift only, 12mths/yr
Drying Stockpile Moving	Wheel Loaders	699	hp	2	1,642	hrs	Day shift only, 12mths/yr
Drying Stockpile Spreading	Bulldozers	217	hp	6	4,502	hrs	Day shift only, 12mths/yr
Drying Stockpile Compacting	Compactor	131	hp	1	191	hrs	Two passes over each drying cell / yr

Total Electrical	0	-	hrs
Total Gas/Diesel	15	15,198	hrs
Total	15	15,198	hrs

Attachment 4.4
RTM Calculations – 7,500 cfs, 40-foot-ID Tunnel

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor	TBM Cutterhead Area	Bulking factor	Volume reduction due to drying	Compaction factor
Northern tunnels ID	40.0 ft	5 days	51 wks	179 yd2				179 yd2			
Main tunnels ID	40.0 ft	5 days	51 wks	179 yd2	1.30	5.00 %	0.80	179 yd2	1.30	5.00 %	0.80
Southern tunnels ID	40.0 ft	5 days	51 wks	179 yd2				179 yd2			

			Drive Options				RTM Volume / Tunnel Length			
Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	In-Situ RTM Volume / Tunnel Length	Wet Excavated RTM Volume / Tunnel Length	Dry Excavated RTM Volume / Tunnel Length	Dry Compacted RTM Volume / Tunnel Length
BETHANY	Intake No. 2 Shaft		R							
	Northern Tunnel	2.110 mi	↑				666,005 yd3	865,807 yd3	822,517 yd3	658,013 yd3
	Intake No. 3 Shaft		M							
	Northern Tunnel	2.550 mi	↑	10.300 mi	6.1 yrs		804,888 yd3	1,046,355 yd3	994,036.85 yd3	795,229 yd3
	Intake No. 5 Shaft		M							
	Northern Tunnel	5.640 mi	↑				1,780,223 yd3	2,314,290 yd3	2,198,576 yd3	1,758,860 yd3
	Twin Cities Shaft		L			2				
	Main Tunnel	4.580 mi	↓				1,445,642 yd3	1,879,335 yd3	1,785,368 yd3	1,428,295 yd3
	New Hope Shaft		M							
	Main Tunnel	3.000 mi	↓	12.690 mi	7.5 yrs		946,927 yd3	1,231,005 yd3	1,169,455 yd3	935,564 yd3
	Canal Ranch		M							
	Main Tunnel	5.110 mi	↓				1,612,933 yd3	2,096,813 yd3	1,991,972 yd3	1,593,578 yd3
	Terminous Tract Shaft		R							
	Main Tunnel	3.940 mi	↑				1,243,631 yd3	1,616,720 yd3	1,535,884 yd3	1,228,708 yd3
	King Island Shaft		M	9.500 mi	5.7 yrs					
	Main Tunnel	5.560 mi	↑				1,754,972 yd3	2,281,463 yd3	2,167,390 yd3	1,733,912 yd3
	Lower Roberts Island Shaft		L			2				
	Southern Tunnels	5.130 mi	↓				1,619,246 yd3	2,105,019 yd3	1,999,768 yd3	1,599,815 yd3
	Upper Jones Tract Shaft		M							
	Southern Tunnels	4.240 mi	↓	14.400 mi	8.2 yrs		1,338,324 yd3	1,739,821 yd3	1,652,830 yd3	1,322,264 yd3
	Union Island Shaft		M							
	Southern Tunnels	5.030 mi	↓				1,587,681 yd3	2,063,986 yd3	1,960,786 yd3	1,568,629 yd3
	Surge Basin Shaft		R							
	Total	46.89 mi	2	46.89 mi		4	14,800,472 yd3	19,240,614 yd3	18,278,584 yd3	14,622,867 yd3

	RTM Volume / Shaft				RTM Volume / Tunnel Drive	
Element	Wet In-situ RTM Volume / Shaft	Wet Excavated RTM Volume / Shaft	Dry Excavated RTM Volume / Shaft	Dry Compacted RTM Volume / Shaft	Dry Compacted RTM Volume / Tunnel Drive	Ave. Quarterly Excavated Dry Compacted RTM Volume / Tunnel Drive
Intake No. 2 Shaft						
Northern Tunnel						
Intake No. 3 Shaft						
Northern Tunnel					3,212,103 yd3	130,967 yd3
Intake No. 5 Shaft						
Northern Tunnel						
Twin Cities Shaft	7,256,619 yd3	9,433,605 yd3	8,961,924 yd3	7,169,540 yd3		
Main Tunnel						
New Hope Shaft						
Main Tunnel					3,957,436 yd3	131,842 yd3
Canal Ranch						
Main Tunnel						
Terminous Tract Shaft						
Main Tunnel						
King Island Shaft					2,962,620 yd3	129,908 yd3
Main Tunnel						
Lower Roberts Island Shaft	7,543,854 yd3	9,807,010 yd3	9,316,659 yd3	7,453,327 yd3		
Southern Tunnels						
Upper Jones Tract Shaft						
Southern Tunnels					4,490,708 yd3	136,866 yd3
Union Island Shaft						
Southern Tunnels						
Surge Basin Shaft						
Total	14,800,472 yd3	19,240,614 yd3	18,278,584 yd3	14,622,867 yd3	14,622,867 yd3	529,584 yd3

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter	Tunnelling days / week	Tunnelling weeks / year
Northern tunnels ID	40.0 ft	5 days	51 wks
Main tunnels ID	40.0 ft	5 days	51 wks
Southern tunnels ID	40.0 ft	5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's
BETHANY	Intake No. 2 Shaft		R			
	Northern Tunnel	2.110 mi	↑			
	Intake No. 3 Shaft		M			
	Northern Tunnel	2.550 mi	↑	10.300 mi	6.1 yrs	
	Intake No. 5 Shaft		M			
	Northern Tunnel	5.640 mi	↑			
	Twin Cities Shaft		L			2
	Main Tunnel	4.580 mi	↓			
	New Hope Shaft		M			
	Main Tunnel	3.000 mi	↓	12.690 mi	7.5 yrs	
	Canal Ranch		M			
	Main Tunnel	5.110 mi	↓			
	Terminous Tract Shaft		R			
	Main Tunnel	3.940 mi	↑			
	King Island Shaft		M	9.500 mi	5.7 yrs	
	Main Tunnel	5.560 mi	↑			
	Lower Roberts Island Shaft		L			2
	Southern Tunnels	5.130 mi	↓			
	Upper Jones Tract Shaft		M			
	Southern Tunnels	4.240 mi	↓	14.400 mi	8.2 yrs	
	Union Island Shaft		M			
	Southern Tunnels	5.030 mi	↓			
	Surge Basin Shaft		R			
	Total	46.89 mi	2	46.89 mi		4

Quarterly Dry Compacted RTM Volume Generated by Tunnel Drive (m yd3)

Start	HIDE	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
17	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
22	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13
20	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Quarterly		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.40	0.40	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.26	0.40	0.80	1.19	1.72	2.25	2.78	3.31	3.84	4.37	4.90

Start	HIDE	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
20	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.11	0.00	0.00	0.00	0.00
Quarterly		0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.44	0.27	0.27	0.14	0.14	0.14	0.14	0.14	0.11	0.00	0.00	0.00	0.00
Total		5.43	5.96	6.49	7.02	7.55	8.08	8.61	9.14	9.67	10.20	10.73	11.26	11.79	12.32	12.85	13.29	13.56	13.83	13.96	14.10	14.24	14.38	14.51	14.62	14.62	14.62	14.62	14.62

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **RTM Volumes**

Column Inputs	Internal Diameter
Northern tunnels ID	40.0 ft
Main tunnels ID	40.0 ft
Southern tunnels ID	40.0 ft

Tunnelling days / week	Tunnelling weeks / year
5 days	51 wks
5 days	51 wks
5 days	51 wks

Drive Options

Option	Element	Tunnel Length	Tunnel Drive	Drive Length	Drive Duration	TBM's	Start
BETHANY	Intake No. 2 Shaft		R				
	Northern Tunnel	2.110 mi	↑				
	Intake No. 3 Shaft		M				
	Northern Tunnel	2.550 mi	↑	10.300 mi	6.1 yrs		20
	Intake No. 5 Shaft		M				
	Northern Tunnel	5.640 mi	↑				
	Twin Cities Shaft		L			2	
	Main Tunnel	4.580 mi	↓				
	New Hope Shaft		M				
	Main Tunnel	3.000 mi	↓	12.690 mi	7.5 yrs		17
	Canal Ranch		M				
	Main Tunnel	5.110 mi	↓				
	Terminous Tract Shaft		R				
	Main Tunnel	3.940 mi	↑				
	King Island Shaft		M	9.500 mi	5.7 yrs		22
	Main Tunnel	5.560 mi	↑				
	Lower Roberts Island Shaft		L			2	
	Southern Tunnels	5.130 mi	↓				
	Upper Jones Tract Shaft		M				
	Southern Tunnels	4.240 mi	↓	14.400 mi	8.2 yrs		20
	Union Island Shaft		M				
	Southern Tunnels	5.030 mi	↓				
	Surge Basin Shaft		R				
	Total	46.89 mi	2	46.89 mi		4	

Quarterly Dry Compacted RTM Volume Generated at Each Shaft (m yd3)

	Y1				Y2				Y3				Y4				Y5				Y6				Y7			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Twin Cities Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Lower Roberts Island Shaft	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.14	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Quarterly	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.40	0.40	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Total	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.26	0.40	0.80	1.19	1.72	2.25	2.78	3.31	3.84	4.37	4.90

	Y8				Y9				Y10				Y11				Y12				Y13				Y14			
	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Twin Cities Shaft	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.20	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Roberts Island Shaft	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.24	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.11	0.00	0.00	0.00	0.00
Quarterly	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.44	0.27	0.27	0.14	0.14	0.14	0.14	0.14	0.11	0.00	0.00	0.00	0.00
Total	5.43	5.96	6.49	7.02	7.55	8.08	8.61	9.14	9.67	10.20	10.73	11.26	11.79	12.32	12.85	13.29	13.56	13.83	13.96	14.10	14.24	14.38	14.51	14.62	14.62	14.62	14.62	14.62

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **Stockpiles**

Maximum allowable stockpile heights

Max. permanent stockpile height at Twin Cities	15	ft	above grade
Max. permanent stockpile height at Lower Roberts	15	ft	above grade
Contingency	5	%	

Temporary stockpiles (All RTM)

Bethany	Vol. of RTM to stockpile (yd3)	Area of temp. stockpile (acres)	Height of temp. stockpile (ft)	Resulting individual lift (in)
Twin Cities North	3,010,430	196	9.5	20.7
Twin Cities South	3,708,967	196	11.7	20.7
Lower Roberts North	2,835,566	196	9.0	20.7
Lower Roberts South	4,298,120	196	13.6	20.7

Temporary stockpile notes

Twin Cities
- < 7,500 cfs, area based on drying method
- 7,500 cfs uses same area as for 6,000 cfs

Lower Roberts
- Area based on drying method
- Max. available area 196 acres / tunnel drive
- See 'No Drying Annual Process' sheet.

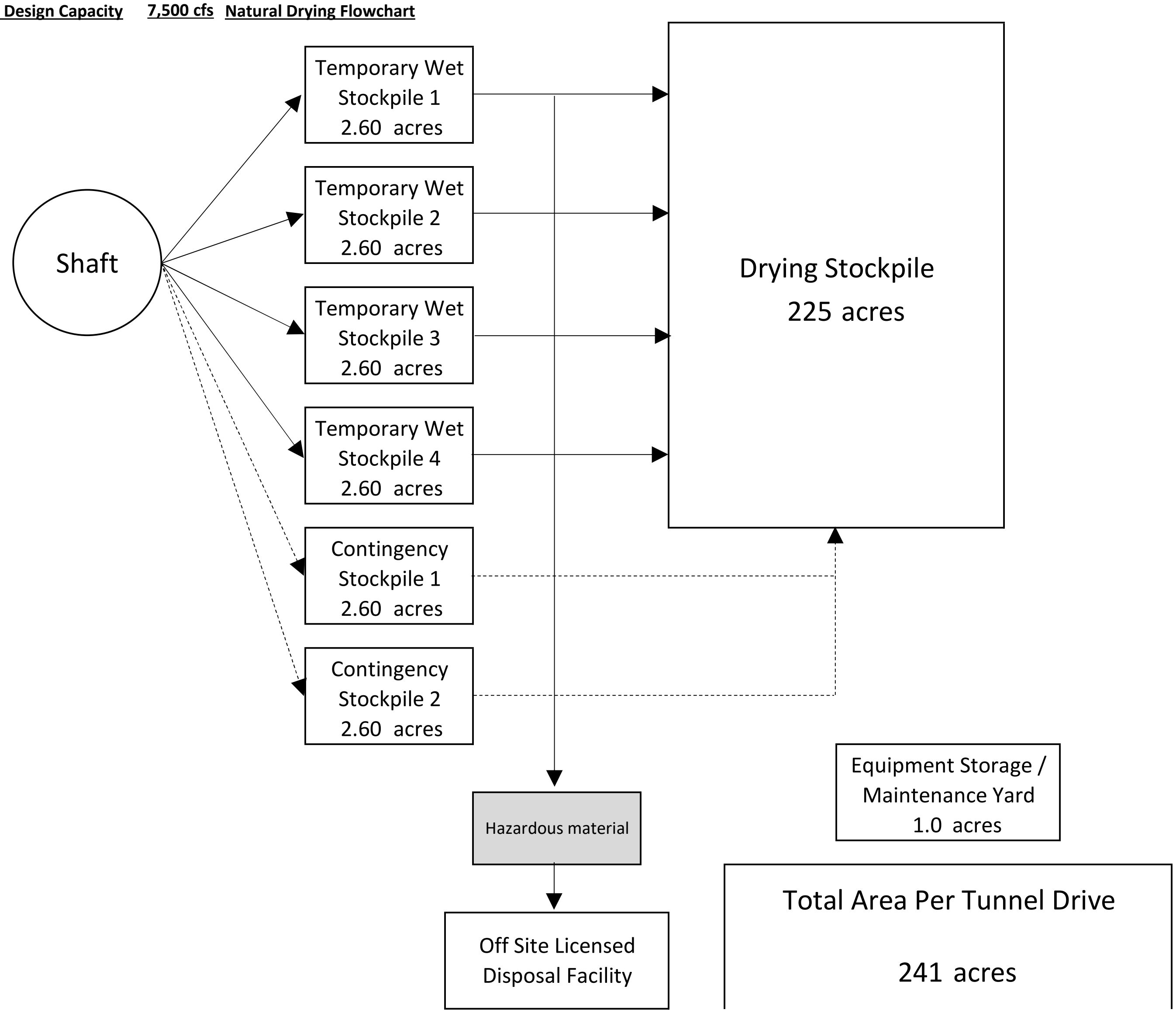
Permanent stockpiles (Surplus RTM)

		Based on max. height	
Bethany	Vol. of RTM to stockpile (yd3)	Area of perm. stockpile (acres)	Height of perm. stockpile (acres)
Twin Cities	6,982,256	303	15
Lower Roberts	5,643,021	245	15

Permanent stockpile notes

Both sites consolidated into one stockpile
Area calculated based on 15ft height
At TC volume includes ring levee degradation
Surplus volumes account for filling borrow pit

Project Design Capacity **7,500 cfs** **Natural Drying Flowchart**



CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **Natural Drying Annual Process**

Drying stockpile height per lift	18	in
Drying stockpile contingency	5	%
Tunnelling days / week	5	days / week
Tunnelling weeks / year	51	weeks / year
Wet season	7	months / year
Wet season	30	weeks / year
Number of drying cells	37	

Per Tunnel Drive Season	Cell > Area→ Week↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Spreading	Compacting
		6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1		
Wet	1	Hold	Hold	Hold	Fill	< wet season begins with 3 full cells from previous drying season																																	0	0
Wet	2	Hold	Hold	Hold	Hold	Fill																																	0	0
Wet	3	Hold	Hold	Hold	Hold	Hold	Fill																																0	0
Wet	4	Hold	Hold	Hold	Hold	Hold	Hold	Fill																															0	0
Wet	5	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																														0	0
Wet	6	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																													0	0
Wet	7	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																												0	0
Wet	8	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																											0	0
Wet	9	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																										0	0
Wet	10	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																									0	0
Wet	11	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																								0	0
Wet	12	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																							0	0
Wet	13	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																						0	0
Wet	14	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																					0	0
Wet	15	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																				0	0
Wet	16	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																			0	0
Wet	17	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																		0	0
Wet	18	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																	0	0
Wet	19	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill																0	0
Wet	20	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill															0	0
Wet	21	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill														0	0
Wet	22	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill													0	0
Wet	23	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill												0	0
Wet	24	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill											0	0
Wet	25	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill										0	0
Wet	26	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill									0	0
Wet	27	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill								0	0
Wet	28	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill							0	0
Wet	29	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill						0	0
Wet	30	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill					0	0
Dry	31	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Fill + Spread				3	0
Dry	32	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Fill + Spread			3	0
Dry	33	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry	Dry	Fill + Spread		3	0
Dry	34	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Dry + Compact	Dry	Dry	Fill + Spread	3	3
Dry	35	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold		Dry + Compact	Dry	Dry	3	3
Dry	36	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold			Dry + Compact	Dry	3	3
Dry	37	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold				Dry + Compact	3	3
Dry	38	Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold					Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold					3	3
Dry	39		Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold						Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold					3	3
Dry	40			Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold							Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold					3	3
Dry	41				Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold	Hold								Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold					3	3
Dry	42					Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold	Hold									Dry + Compact	Dry	Dry	Spread	Hold	Hold					3	3
Dry	43						Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold	Hold										Dry + Compact	Dry	Dry	Spread	Hold					3	3
Dry	44							Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold	Hold											Dry + Compact	Dry	Dry	Spread					3	3
Dry	45								Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold	Hold												Dry + Compact	Dry	Dry					2	3
Dry	46									Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold	Hold													Dry + Compact	Dry					2	3
Dry	47										Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold	Hold														Dry + Compact					2	3
Dry	48											Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread	Hold																			2	2
Dry	49												Dry + Compact	Dry	Dry	Fill + Spread	Dry + Compact	Dry	Dry	Spread																			2	2
Dry	50	Fill												Dry + Compact	Dry	Dry		Dry + Compact	Dry	Dry																			0	2
Dry	51	Hold	Fill												Dry + Compact	Dry			Dry + Compact	Dry																			0	2
Dry	52	Hold	Hold	Fill												Dry + Compact				Dry + Compact																			0	2

Permanent stockpile per site

Shaft site	Total vol. of RTM (yd3)	Stockpile area (acres)	Final height of stockpile (ft)	Equivalent annual lift (in)
Twin Cities	6,982,256	449	9.6	24
Lower Roberts	5,643,021	449	7.8	24

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **Natural Drying Areas**

Excavation Rates per tunnel drive

Tunnel lining ID	40	ft
TBM cutterhead area	1,614	ft2
TBM advance rate (ave.)	36	ft / day
TBM advance rate (peak)	72	ft / day
Daily in-situ rate of excavation per tunnel (ave.)	2,152	yd3 / day
Daily in-situ rate of excavation per tunnel (peak)	4,304	yd3 / day
Bulking factor	1.30	
Daily excavated volume per tunnel (ave.)	2,798	yd3 / day
Daily excavated volume per tunnel (peak)	5,595	yd3 / day
Estimated duration of peak excavation	21	days
Volume loss due to drying	5	%
Equivalent daily dry excavated volume per tunnel (ave.)	2,658	yd3 / day
Equivalent daily dry excavated volume per tunnel (peak.)	5,316	yd3 / day

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Temporary Wet Stockpile Area per tunnel drive

No. of days storage	5	days	assuming 5 days of peak excavation in a 7 day cycle
Volume of RTM to stockpile at peak excavation rate	27,977	yd3	per stockpile
Height of stockpile	10	ft	short term
Contingency	50	%	includes allowance for conveyor pits
Area required at peak excavation rate	2.60	acres	per stockpile = 337 x 337 ft or equivalent
No. of temporary stockpiles	6.0		
Total area of temporary stockpiles	15.6	acres	

Equipment Storage / Maintenance Yard per tunnel drive

Area required for equipment storage / maintenance yard 1.0 acres

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Drying Stockpile

Contingency 5 %

Natural Drying Area Summary

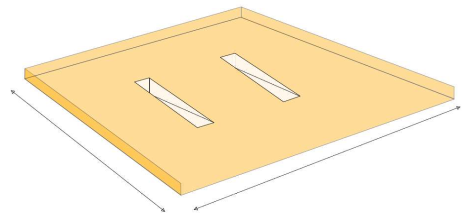
Alignment	Site	Tunnel Drive	Compacted RTM to store above grade	Temporary Wet Stockpile 10 ft high	Equipment / Maintenance Yard	Dry Stockpile (height varies)	Total RTM Area	Total RTM Area
Bethany	Twin Cities	North	3.0 m yd3	15.6 acres	1 acres	196 acres	212 acres	425 acres
		South	3.7 m yd3	15.6 acres	1 acres	196 acres	212 acres	
	Lower Roberts Island	North	2.8 m yd3	15.6 acres	1 acres	196 acres	213 acres	425 acres
		South	4.3 m yd3	15.6 acres	1 acres	196 acres	213 acres	

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **Natural Drying Equipment**

Temporary Wet Stockpile Filling per tunnel drive

Volume of RTM to stockpile at peak excavation rate	27,977	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for filling temporary stockpile	5	days	
Working hours per day	20	hours	
Average cycle time per shove	5	mins	
Efficiency	80	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	40.0	hours / day	
Total hours at average excavation rate per day	20.0	hours / day	
Total hours for operation per year	5,100	hours / year	



Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Temporary Wet Stockpile Emptying per tunnel drive

Assume two conveyor pits in the centre of the temporary stockpile each to be loaded from both sides.

Volume of RTM to stockpile at peak excavation rate	27,977	yd3	per stockpile as for Natural Drying
Bulldozer capacity	14.50	yd3 / bulldozer	
Target time for emptying temporary stockpile	10	days	
Working hours per day	10	hours	
Average cycle time per shove	5	mins	
Efficiency	81	%	
Number of bulldozers required	2	bulldozers	
Total hours at peak excavation rate per day	39.7	hours / day	
Total hours at average excavation rate per day	19.9	hours / day	2 stockpiles emptied at any one time
Total hours for operation per year	5,062	hours / year	

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Moving per tunnel drive

Daily excavated volume per tunnel (peak)	2,798	yd3 / day	to be moved per day
Wheel Loader capacity	19.50	yd3 / wheel loader	
Working hours per day	10	hours	
Average cycle time	5	mins	
Efficiency	81	%	
Number of wheel loaders	2	wheel loaders	
Total hours at peak excavation rate per day	14.8	hours / day	
Total hours at average excavation rate per day	7.4	hours / day	
Total hours for operation per year	1,882	hours / year	

Example: Caterpillar, 990K, Capacity = 19.5yd3 (see equipment schedule for details)

Drying Area / Dry Stockpile Spreading per tunnel drive

Volume of RTM to be spread per cell (ave.)	13,989	yd3 / cell
Bulldozer capacity	14.50	yd3 / bulldozer
Working hours per week	50	hours / week / cell
Average cycle time per shove	5	mins
Efficiency	81	%
Number of bulldozers required	2	bulldozers / cell
Max. number of cells to spread in one week	3	cells
Number of bulldozers required	6	bulldozers
Total hours per cell (ave.)	99.3	hours / cell
Number of cells to spread per year	52	cells / year
Total hours for operation per year	5,161	hours / year

Example: Komatsu, D65EX-18 WH, Capacity = 14.5yd3 (see equipment schedule for details)

Drying Stockpile Compacting   per tunnel drive

Roller width	84	in	
Roller width	2.33	yd	
Area per cell	6.1	acres	per site (ie. two tunnel drives)
Area per cell	29,376	yd2	
Speed	6.8	mph	
Speed	11,968	yd/hr	
Area/hr	27,925	yd2/hr	
Working hours per day	10	hours	
Efficiency	50	%	
No. of passes	2	passes	
Time to compact one cell	4.2	hrs	
Max. number of cells to compact in one week	3	cells / week	
Number of compactors required	1	compactors	
Number of cells to compact per year	52	cells / year	
Total hours for operation per year	219	hours / year	

Example: Caterpillar, CS54B, Capacity = 84in roller at 6.8mph (see equipment schedule for details)

CA Delta Conveyance Tunnel - RTM Calculations

24 Jun 2021

Project Design Capacity **7,500 cfs** **Natural Drying Equipment Schedule**

Working Hours / Year

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule (per tunnel drive)

Operation	Equipment	Manufacturer	Model	Power	Power	Hours / Year / Operation	Hourly Operating Cost	Capital Cost	Average Excavation Rate: Total Hours / Year	Average Excavation Rate: Total Power / Year	Average Excavation Rate: Total Annual Operating Cost	Peak Excavation Rate: Quantity	Peak Excavation Rate: Total Capital Cost
Temporary Wet Stockpiles Filling	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	5100 hrs	$ 105	$ 196,000	5100 hrs	825 MWh	$ 535,465	2	$ 392,000
Temporary Wet Stockpiles Testing													
Temporary Wet Stockpiles Emptying	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	5062 hrs	$ 105	$ 196,000	5062 hrs	819 MWh	$ 531,499	4	$ 784,000
Drying Stockpile Moving	Wheel Loaders	Caterpillar	990K	699 hp	521 kW	1882 hrs	$ 120	$ 180,000	1882 hrs	981 MWh	$ 225,838	2	$ 360,000
Drying Stockpile Spreading	Bulldozers	Komatsu	D65EX-18 WH	217 hp	162 kW	5161 hrs	$ 105	$ 196,000	5161 hrs	835 MWh	$ 541,921	6	$ 1,176,000
Drying Stockpile Compacting	Compactor	Caterpillar	CS54B	131 hp	98 kW	219 hrs	$ 55	$ 73,100	219 hrs	21 MWh	$ 12,034	1	$ 73,100

Equipment utilization 23%

	Total Hours / Year	Total Power / Year	Total Annual Operating Cost	Quantity	Total Capital Cost
Total Electrical	- hrs	- MWh	$ -	0	$ -
Total Gas/Diesel	17,424 hrs	3,482 MWh	$ 1,846,758	15	$ 2,785,100
Total	17,424 hrs	3,482 MWh	$ 1,846,758	15	$ 2,785,100

CA Delta Conveyance Tunnel - RTM Calculations 24 Jun 2021

Project Design Capacity **7,500 cfs** **Equipment Schedule Summary**

Working Hours

Day shift only

Hours / day	10	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	2550	hours

Day and night shift

Hours / day	20	hours
Days / week	5	days
Weeks / year	51	weeks
Total hours / year	5100	hours

Equipment Schedule

No Drying - (per tunnel drive)				Annual usage			
Operation	Equipment	Power		Quantity required	Total Hours / Year		Notes
Temporary Wet Stockpiles Filling	Bulldozers	217	hp	2	5,100	hrs	Day and night shift, 12mths/yr
Temporary Wet Stockpiles Testing			hp			hrs	No activity
Temporary Wet Stockpiles Emptying	Bulldozers	217	hp	4	5,062	hrs	Day shift only, 12mths/yr
Drying Stockpile Moving	Wheel Loaders	699	hp	2	1,882	hrs	Day shift only, 12mths/yr
Drying Stockpile Spreading	Bulldozers	217	hp	6	5,161	hrs	Day shift only, 12mths/yr
Drying Stockpile Compacting	Compactor	131	hp	1	219	hrs	Two passes over each drying cell / yr
		Total Electrical		0	-	hrs	
		Total Gas/Diesel		15	17,424	hrs	
		Total		15	17,424	hrs	