Appendix G4. Soil Balance (Final Draft)

1. Introduction and Purpose

The Delta Conveyance Project (Project) would include intakes C-E-3 and C-E-5 along the Sacramento River between the confluences with American River and Sutter Slough, and the Bethany Reservoir Alignment tunnel to convey water from the intakes to the Bethany Reservoir Pumping Plant and associated facilities that pump water and discharge to the State Water Projects (SWP) existing Bethany Reservoir.

The Project would require an extensive amount of soil materials for fill at intakes, tunnel shafts and the pumping plant. Construction would also produce an extensive amount of excavated soil materials at most of these facilities and through generation of reusable tunnel material (RTM). Traditional construction approaches frequently stockpile excavated materials during the early construction phases for reuse as fill materials to reduce the amount of soil hauled into and out of the construction-site. However, soil balancing can be more complex for long-term construction projects with limited on-site storage areas and for projects where the amount of excavated soils is substantially different than the amount of fill required for each construction site.

Construction of the Project would occur over a period of years at most construction-sites and construction would not start simultaneously at all sites. For example at the tunnel launch shaft sites, soil fill material would be required several months before the tunneling operations that would produce RTM in large volumes; and the RTM volume would be greater than the need for other fill material at most of the tunnel launch shaft sites. The purpose of this technical memorandum for the soils balance would be to reduce the need for imported construction fill material, hauling of excavated soils to disposal areas, and the extent of long-term storage of RTM at tunnel launch sites following construction.

The soil balance generally excludes consideration of fills required for road and railroad construction or modifications, since these materials are specialty imports that cannot be sourced within the Project.

1.1 Organization

- Introduction and Purpose
- Methodology and Assumptions
- Temporary and Permanent Stockpiles
- Feature Summaries
- References

1.2 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 non-structural 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

The schedule for each activity was applied based on the Project schedule and the duration of the construction activities. 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 a compaction factor 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. Methodology and Assumptions

The Model includes a sitewide inventory of the fill needs of each of the Project features (e.g., intakes, shafts, etc.), 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 on available geological information and areas to be excavated, as shown on the engineering concept drawings. This information was 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.

2.1 Bulking and Compaction Factors

Excavated volumes from in situ conditions, as presented in BCY, would be converted to loose volumes, as presented in LCY, using a bulking factor of 1.3. The excavated volumes from in situ conditions, as presented in BCY, could be directly converted to compacted volumes, as presented in CCY, using compaction factors ranging from 0.9 to 0.99 based on several factors.

For RTM, the Model uses a bulking material of 1.3 and a compaction factor of 0.99 based on the in-situ material being generally older, more consolidated deposits that are confined at tunnel depths by saturated soil load. The available geotechnical information indicates that a major portion of RTM would be consolidated fine grained material which would expand when brought to the surface. The RTM material is expected to compact from the loose state by 5 percent due to drying and 80 percent upon compaction resulting in a compaction factor of 0.99.

For the near surface excavated materials, the Model uses compaction factors that range from 0.9 for the softer Deltaic soils to 0.95 for less compressible soils, especially for soils at the intakes and the SDCF. For import materials, the Model assumes published values from the Excavation Handbook (Horace K. Church, 1981, McGraw-Hill). Bulking and compaction factors assumed in the Model are summarized in Table 1.

Table 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
Southern Forebay	1.3	0.9
South Delta Conveyance Facilities	1.3	0.95
Logistics (Roads, Park-and-Ride)	1.3	0.9
RTM	1.3	0.99
Clay (Damp) imported from Commercial Sources[a]	1.4	0.9
Gravel (Dry) imported from Commercial Sources[a]	1.15	0.93
Silt imported from Commercial Sources[a]	1.36	0.83

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

2.2 Intake Assumptions

The Model assumes that no surplus material from the intakes would be available for use on other Delta Conveyance construction sites. To accomplish this, the intake sites would be constructed in a manner that on-site excavated materials would be reused as fill material at the intake site. The material for the embankment clay cores would be imported from commercial sources. No peat is anticipated to be excavated at the intake locations.

Based upon the Model input information, on-land excavation depths at the intakes would range from 23 feet to 28 feet at the Sedimentation Basins, 7 feet to 13.5 feet at the Sediment Drying Lagoons, and the range for excavation depths for other structures occurs at the intake ranging from approximately 0 feet to 20 feet on the waterside slope of the existing levee.

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. Any 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 Twin Cities Complex 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 fill from Lower Roberts Island would be used to construct shaft pads at Upper Jones Tract and Union Island.

Upon stripping of topsoil and peat, soil fill for shaft pads would initially be sourced by excavation of borrow at Twin Cities or Lower Roberts. Shaft excavation material may not be used for construction of shaft pads because construction of the shaft pads at each site occurs before excavation of the associated shafts. Construction of the shaft pads creates an elevated platform approximately equal to or slightly above the surrounding levee crests, which provides a flood resilient working area and helps to address issues that may arise from artesian conditions during construction of the shafts. On-site borrow areas would be backfilled with RTM from the co-located tunnel launch shaft operations. Once RTM is being generated and available for reuse, structural fill needs will prioritize the use of RTM instead of local borrow. Based upon the Model input information, maximum borrow excavation depths would be approximately 10 feet at the Twin Cities Complex over 40 acre, and 10 feet at Lower Roberts Island over 26 acre.

2.3.1 Bethany Reservoir Pumping Plant Surge Basin Assumptions

The Surge Basin is a 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.

2.4 Levee Assumptions

The Model assumes that the Twin Cities Ring Levee would be constructed using excavated soil from the Twin Cities Complex. The Model assumes that that modifications to existing levees on Lower Roberts Island would be constructed using excavated materials from Lower Roberts Island initial construction activities.

2.5 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.

2.6 RTM Assumptions

RTM generation location, timing, and quantities are documented in the Concept Engineering Report (CER)Appendix C6 *Reusable Tunnel Material*. These details are imported directly into the Model, but with the following assumptions:

- No significant reuse of RTM for structural fill is planned for the Project resulting in all of the RTM generated either used for refilling on-site borrow areas, covering peat soil stockpiles, or placed in permanent stockpiles.
- The permanent stockpiles would be formed following completion of the tunneling and RTM management as RTM from temporary smaller stockpiles used for drying would be moved to the permanent storage area. Over the long-term, settling would occur in the permanent stockpiles, and the height would decline by approximately 20 percent. Therefore, approximately 20 percent of the RTM volume generated at the tunnel launch shaft at Lower Roberts Island is not included in the estimate of the height of the above grade permanent stockpile
- RTM stored at Twin Cities Complex and Lower Roberts Island would be used for on-site uses, such as filling borrow areas and restoring topography in excavated areas where soil was removed to construct tunnel shafts. RTM would not be transferred to other construction sites from the tunnel launch shaft sites.

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.

Below is a summary of peat, topsoil, and excavated material stockpiles developed based on anticipated site conditions, constraints, and conceptual layouts (refer to the CER Appendix C6 for information regarding RTM storage). The summary includes stockpile volumes, storage heights, and storage areas (acres), as well as the expected stockpile duration (for temporary stockpiles) and the locations of permanent stockpiles. This information is presented in Table 2 for the Project.

The stockpile heights in Table 2 include an allowance to account for the effects of each stockpile's side slopes on the overall size. It was assumed that the soil would be placed with side slopes similar to the soil's natural angle of repose or as recommended by the Project geotechnical engineers. 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).

For the reception and maintenance shafts the stockpile heights were determined based on the available area at the individual sites. For the launch shafts (i.e. Twin Cities Complex and Lower Roberts Island) a fixed height of 15 feet, where possible, was initially considered. At Lower Roberts Island that height was reduced to 10 feet to address the presence of compressible soils below the stockpiles. The Twin Cities Complex was site constrained due to flooding concerns and as a result the stockpile heights were increased.

Table 2. Stockpile Summary

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

Feature	Material	Volume (LCY)	Stockpile Duration (yrs)	Stockpile Area (Acres)	Stockpile Height (ft)
Intake C-E-3	Topsoil	202,758	6	13.2	10
Intake C-E 5	Topsoil	180,272	6	11.7	10
Twin Cities Complex	Topsoil	910,767	10	25.0	25
New Hope Tract	Topsoil	11,210	8	0.6	12
	Peat	0	0	0	0
	Excavated Material	36,690	Permanent	3.4	7
Canal Ranch Tract	Topsoil	11,063	9	0.5	14
	Peat	0	0	0	0
	Excavated Material	36,239	Permanent	3.6	6
Terminous Tract	Topsoil	13,895	5	0.7	14
	Peat	1,596	5	0.7	14
	Excavated Material	35,312	Permanent	3.4	7
King Island	Topsoil	12,668	6	0.7	13
	Peat	1,593	6	0.7	13
	Excavated Material	35,619	Permanent	3.3	7
Lower Roberts Island	Topsoil	537,949	9	35	15
	Peat	16,169	6	0.7	7
Upper Jones Tract	Topsoil	12,060	1	1.0	9
	Peat	3,040	1	1.0	9
	Excavated Material	34,102	Permanent	3.1	7

Feature	Material	Volume (LCY)	Stockpile Duration (yrs)	Stockpile Area (Acres)	Stockpile Height (ft)
Union Island	Topsoil	14,472	2	1.0	11
	Peat	33,22	2	1.0	11
	Excavated Material	37,634	Permanent	3.0	8
Bethany Reservoir Pumping Plant Complex	Topsoil	228,504	7	7.1	22
	Excavated Material	2,840,272	Permanent	70	33
Aqueduct and Connection to Bethany Reservoir	Topsoil	109,795	4	5.4[a]	14
Discharge Structure	Topsoil	14,891	5	0.5	22

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)
[a] Temporary topsoil storage will be temporarily stored in permanent storage locations during phased construction, and will be distributed as components are completed.

4. Feature Summaries

The Model includes a sitewide inventory for each Project feature (e.g., intakes, shafts, etc.) of the fill needs and source material generated from earthwork activities, with the exception of road and railroad fill requirements. Road and railroad fill will generally be specialty base materials that will not be generated on-site 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 in the following section including a series of tables that summarize the fill need volumes, sources, and remnant quantities for each feature. The results of the soil balance for the intakes are detailed in tables 3 and 4 summarizing the fill needs and material sources and are presented in. See Tables 5 through 14 for remaining soil balance summary tables.

Table 3. Intake C-E-3

Need	Source	On-Site/Import	Volume (CCY)
Intake C-E-3	not applicable	On-Site	-1,599,912
not applicable	Phase 1 Excavation	On-Site	376,641
not applicable	Phase 2 Excavation	On-Site	648,316
not applicable	Phase 3 Excavation	On-Site	519,955
not applicable	Specialty Material	Import	55,000

Table 4. Intake C-E-5

Need	Source	On-Site/Import	Volume (CCY)
Intake C-E-5	not applicable	On-Site	-1,467,850
not applicable	Phase 1 Excavation	On-Site	322,901
not applicable	Phase 2 Excavation	On-Site	544,159
not applicable	Phase 3 Excavation	On-Site	545,790
not applicable	Specialty Material	Import	55,000

Table 5. Twin Cities

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Twin Cities Shaft-Pad	not applicable	not applicable	On-Site	-83,168
Twin Cities Ring Levee	not applicable	not applicable	On-Site	-262,859
Restore Topo from Twin Cities Shaft Pad Borrow	not applicable	not applicable	On-Site	-92,409
Restore Topo from Twin Cities Ring Levee Borrow	not applicable	not applicable	On-Site	-292,065
Restore Topo from New Hope Borrow	not applicable	not applicable	Export	-35,386
Restore Topo from Canal Ranch Borrow	not applicable	not applicable	Export	-31,922
Restore Topo from Terminous Borrow	not applicable	not applicable	Export	-70,233
Restore Topo from King Borrow	not applicable	not applicable	Export	-87,176
not applicable	Twin Cities Shaft Pad Borrow from TCC	not applicable	On-Site	83,168
not applicable	Twin Cities Ring Levee Borrow from TCC	not applicable	On-Site	262,859
not applicable	Twin Cities Ring Levee Degrade/Stockpile	not applicable	On-Site	262,859
not applicable	Twin Cities Shaft Excavation	not applicable	On-Site	186,308
not applicable	TCC RTM	not applicable	On-Site	5,111,861
not applicable	not applicable	Stockpile of Twin Cities Levee Degrade	On-Site	-262,859
not applicable	not applicable	Surplus Reusable RTM Stockpile at Twin Cities	On-Site	-4,688,978-3,220,642

Table 6. New Hope Tract

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
New Hope Tract Shaft-Pad	not applicable	not applicable	On-Site	-31,848
not applicable	New Hope Pad Borrow from TCC	not applicable	Import	31,848
not applicable	New Hope Tract Shaft-Excavation	not applicable	On-Site	36,690
not applicable	not applicable	New Hope Tract Shaft-On Site Stockpile	On-Site	-36,690

Table 7. Canal Ranch Tract

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Canal Ranch Tract Shaft-Pad	not applicable	not applicable	On-Site	-28,730
not applicable	Canal Ranch Pad Borrow from TCC	not applicable	Import	28,730
not applicable	Canal Ranch Tract Shaft-Excavation	not applicable	On-Site	36,239
not applicable	not applicable	Canal Ranch Tract Shaft-On Site Stockpile	On-Site	-36,239

Table 8. Terminous Tract

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Terminous Tract Shaft-Pad	not applicable	not applicable	On-Site	-63,210
not applicable	Terminous Pad Borrow from TCC	not applicable	Import	63,210
not applicable	Terminous Tract Shaft-Excavation	not applicable	On-Site	35,312
not applicable	not applicable	Terminous Tract Shaft-On Site Stockpile	On-Site	-35,312

Table 9. King Island

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
King Island Shaft-Pad	not applicable	not applicable	On-Site	-78,458
not applicable	King Pad Borrow from TCC	not applicable	Import	78,458
not applicable	King Island Shaft-Excavation	not applicable	On-Site	35,619
not applicable	not applicable	King Island Shaft-On Site Stockpile	On-Site	-35,619

Table 10. Lower Roberts Island

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Lower Roberts Island Shaft-Pad	not applicable	not applicable	On-Site	-212,250
Lower Roberts Island Levee	not applicable	not applicable	On-Site	-39,424
Restore Topo from Lower Roberts Shaft Pad Borrow	not applicable	not applicable	On-Site	-235,833
Restore Topo from Lower Roberts Levee Borrow	not applicable	not applicable	On-Site	-43,804
Restore Topo from Upper Jones Shaft Pad Borrow	not applicable	not applicable	Export	-60,883
Restore Topo from Union Island Shaft Pad Borrow	not applicable	not applicable	Export	-55,223
not applicable	Lower Roberts Shaft Pad Borrow from Lower Roberts	not applicable	On-Site	212,250
not applicable	Lower Roberts Levee Borrow from Lower Roberts	not applicable	On-Site	39,424
not applicable	Lower Roberts Island Shaft-Excavation	not applicable	On-Site	178,291
not applicable	Lower Roberts RTM	not applicable	On-Site	4,680,976

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
not applicable	not applicable	Surplus Reusable RTM at Lower Roberts Island	On-Site	-4,463,523

Table 11. Upper Jones Tract

Needs	Sources	Material Export/Reuse		Volume (CCY)
Upper Jones Tract Shaft-Pad	not applicable	not applicable	On-Site	-54,795
not applicable	Upper Jones Shaft Pad Borrow from Lower Roberts	not applicable	Import	54,795
not applicable	Upper Jones Tract Shaft-Excavation	not applicable	On-Site	34,102
not applicable	not applicable	Upper Jones Tract Shaft-On Site Stockpile	On-Site	-34,102

Table 12. Union Island

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Union Island Shaft-Pad	not applicable	not applicable	Onsite	-49,701
not applicable	Union Island Shaft Pad Borrow from Lower Roberts Island	not applicable	Import	49,701
not applicable	Union Island Shaft-Excavation	not applicable	Onsite	37,634
not applicable	not applicable	Union Island Shaft-On Site Stockpile	Onsite	-37,634

Table 13. Bethany Reservoir Pumping Plant and Surge Basin

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
Surge Basin-Access Ramp Free Draining Backfill	not applicable	not applicable	Onsite	-10,083
Bethany Pumping Plant-Site Grading	not applicable	not applicable	Onsite	-7,121
not applicable	Surge Basin-Shaft	not applicable	Onsite	39,399

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)
not applicable	Surge Basin-Excavation	not applicable	Onsite	934,835
not applicable	Surge Basin-Drilled Shafts	not applicable	Onsite	151,016
not applicable	Surge Basin-Diaphragm Walls	not applicable	Onsite	45,810
not applicable	Bethany Pumping Plant	not applicable	Onsite	1,270,298
not applicable	Surge Basin-Access Ramp Free Draining Backfill	not applicable	Import	10,083
not applicable		Surge Basin-On Site Stockpile	Onsite	-2,434,237

Table 14. Bethany Reservoir Aqueduct and Bethany Reservoir Discharge Structures 6,000-cfs Project Design Capacity)

Needs	Sources	Material Export/Reuse	On-Site/Import	Volume (CCY)[a]
Bethany Reservoir Aqueduct between Pump Station and Bethany Reservoir	not applicable	not applicable	Onsite	-1,349,489 -
not applicable	Bethany Reservoir Aqueduct between Pump Station and Bethany Reservoir Excavation	not applicable	Onsite	1,755,403
not applicable	not applicable	Bethany Pump Station to Bethany Reservoir Surplus	Onsite	-405,914

5. References

Church, Horace. 1980. Excavation Handbook. McGraw-Hill.