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FINAL TECHNICAL MEMORANDUM

Date:	27 February 2018
Subject:	Strander Boulevard/Southwest 27th Street Extension – Wall and Seal
From:	Stuart Bennion, PE, SE
To:	Steve Carstens, PE

BACKGROUND INFORMATION

The decision to make the full buildout of the Strander Boulevard undercrossing watertight was made in April 2017. This memorandum presents a preliminary analysis of wall and seal type that could be used. Three alternatives are considered for this project. This memorandum summarizes the three alternatives, provides a preliminary cost estimate for each, lists the advantages and disadvantages associated with each alternative, a few general constraints that affect each alternative of the project, and a recommended approach to the project. The combination of wall type and seal construction method differentiate the three alternatives listed below the descriptions.

ALTERNATIVES

Two wall types considered are a sheet pile wall and secant pile wall, and two methods of seal construction considered are a soil replacement method and an open excavation method. A cost has been developed for a comparison of these alternatives, but it has been limited to the wall, seal, and bridge foundation elements only. Note that bridge superstructure, shoe fly embankment, roadway elements, drainage, and other components of the project are not included in the estimate to simplify the comparison. Attached to this memorandum is the breakdown of the cost comparison for each of these alternatives.

Sheet Pile Wall with Temporary Anchor Walls

The sheet-pile wall option is installed well below the bottom of seal excavation and uses anchors to temporarily shore for the seal construction. The sheet sizes vary with wall height, and the anchors are required when the excavation is greater than 20 feet. The anchors used around the BNSF bridge on the previous project were permanent ground anchors placed at an angle to miss the existing utilities in the vicinity. The proposed anchor system will be much shallower and a short length (assumed about 40 feet long) attaching to a dead-man wall buried in the ground. The dead-man wall can be either another sheet pile wall system or a cast-in-place (CIP) concrete wall system. A reinforced CIP structural wall, approximately 3 feet thick in a U-shape, will be placed inside the sheet pile walls and below the roadway as the permanent wall system. Once this CIP structural wall is in place, the dead-man wall and anchors would be abandoned or removed.

Secant Pile Wall

The secant-pile wall option consists of overlapping drilled shafts. Every other shaft is constructed first with an unreinforced lean concrete filled mix. The overlapping shafts are drilled between each of these unreinforced lean concrete shafts, and a reinforcing cage with structural concrete is placed to provide strength to the wall system. A CIP concrete cap is constructed along the top of the wall, and an extended CIP cantilever wall is brought up from the cap if additional wall height is required. Permanent brace beams can be connected between the caps of opposing walls if the lateral loads are too great for the cantilever section to work. If a brace is only required to facilitate a specific stage of construction, the braces are often used temporarily at varying heights and removed for the final condition. At this time, the preliminary design is showing that only temporary bracing may be required. A CIP concrete fascia is constructed on the exposed shaft face to provide a finished appearance, and a concrete topping is placed on the seal.

Excavated Seal Construction

One method for construction the seal uses temporary shoring headwalls perpendicular to the roadway every 30 feet (approximately) along the roadway. General contractor equipment can be used to open excavate underwater to the bottom of seal elevation using dredging techniques. A 4000W concrete mix is then pumped underwater in the excavated area, displacing the water head, and cured to form the seal. The temporary shoring headwall is then advanced another 30 feet and the method repeated. Once the seal is constructed along the entire roadway and the water is fully pumped out, a reinforced CIP concrete final seal layer and structural walls are added to the boat section. The CIP wall thickness differs for each wall type: a 1-foot minimum fascia is used for the secant pile wall, and a 3-foot minimum structural wall is used for the sheet pile wall.

Soil Replacement Seal Construction

The 180th project farther down the road constructed the seal utilizing specialty equipment that replaces the soil with a grouted concrete mix. This mixing took place from just below the design's bottom-of-seal to just above the finished top-of-seal to accommodate the variability of the grout placement. The soil replacement is also extended 10 feet beyond the center of the secant pile wall prior to drilling the shafts to adequately develop the wall-seal interaction. This type of construction method does not accommodate a sheet pile wall installation. The method of replacing the soil also displaces the water in the soil and sends the water to the surface. Contractors generally replace the soil to a lesser degree—about every four shafts—between the top-of-seal and existing ground to provide an adequate bearing area for the soil replacement equipment. This material is later excavated to the top of seal for a CIP concrete seal topping and construction of the roadway subsurface.

Constraints that effect all the alternatives

The following are items that have an effect on all the alternatives, but may be addressed differently.

- Sensitive utilities are located adjacent to, and running across, the footprint of the undercrossing. Construction techniques that extend beyond the footprint have to account for utilities and may require relocation of expensive utilities.

- Existing Phase 2 roadway and subsurface materials will have to be removed prior to seal construction. Generally, 2 feet of quarry spall material was specified to stabilize the roadway subsurface in Phase 2. Records show that an additional four to five feet of quarry spalls were placed and sunk into the soil before the required two feet was stabilized. Additional quarry spalls are located in a trench that filter storm water to the pump station and along the northern embankment.

- The existing pump station and drainage features continue to dewater the already excavated roadway from Strander Phase 2. At some point in construction, these pumps will have to be turned off, and the water table will return to the high elevation of 19.0 feet. Additional material will have to be brought in and placed above this elevation for contractor equipment access and to construct the walls and seals.

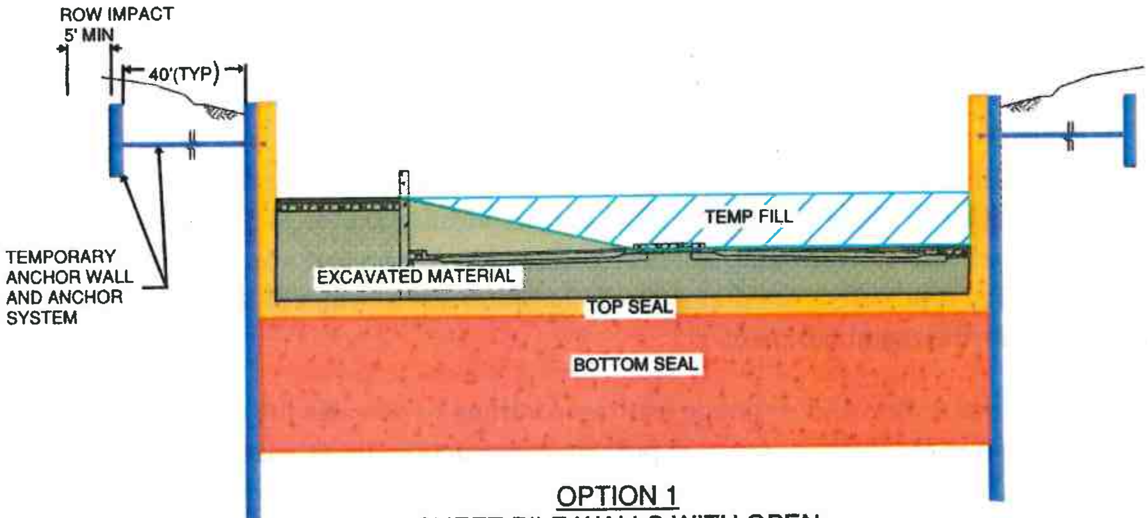
- The equipment used to install the sheet piles, drill the shafts, excavate, or replace the soil all have large construction footprints, and some activities have several support pieces of equipment. Grading and soil stabilizing methods will be required to allow the equipment to work and the methods to be performed on this project.

- The project has to be phased around the UPRR tracks, to accommodate a shoofly and to construct a new UPRR Bridge. A temporary shoring wall will be needed to phase these two pieces of work. The type of shoring wall selected affects how far to the east the shoofly alignment has to be located.

- The high ground-water table will require dewatering throughout the project. The temporary short term dewatering activities can be controlled by the contractor with the wall types and seal construction we are presenting. The only long term dewatering activity still being considered is if the bridge foundations have to be pile supported spread footing, similar to the existing BNSF bridge foundation. Heavy iron content, along with construction contaminates, will require treatment of the water before it can be discharged. Dewatering at this site is limited to the discharge amounts that can be permitted.

- The sheet-pile wall option was used to construct the existing portion of the BNSF overcrossing on this project with permanent ground anchors. These wall anchors are still in place behind the structure and adjacent to the existing structure where the extension of BNSF bridge will be built in this project. Either wall system can be tied into these existing walls.

Alternative 1: Sheet Pile Wall with Temporary Anchor Walls and Excavated Seal Construction



OPTION 1
SHEET PILE WALLS WITH OPEN EXCAVATION

The walls, seal, and structure foundations for the sheet pile wall with open excavation costs about $31,000,000.

Advantages

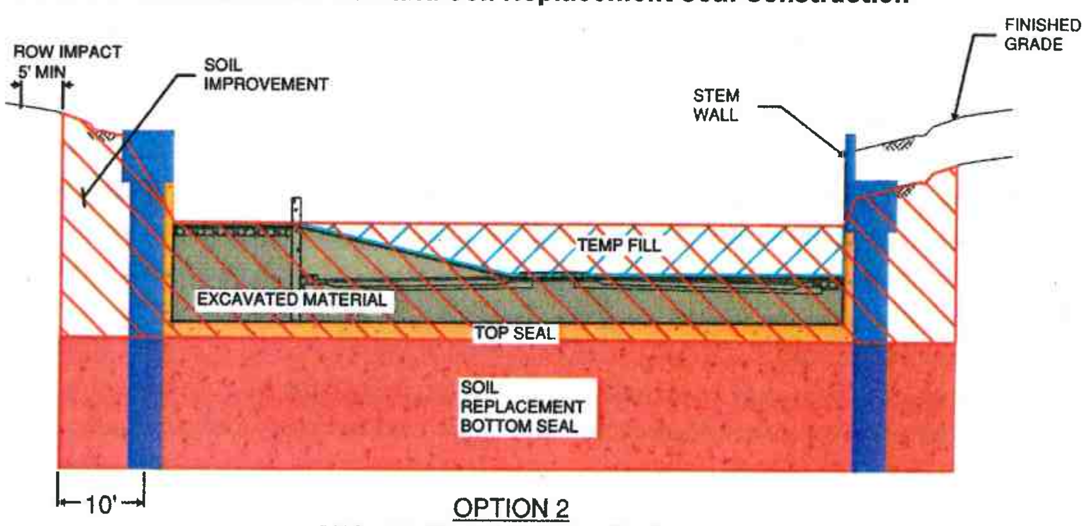
This alternative was presented in the proposal. It was initially proposed because it provided an overall project cost savings compared with a secant-pile-wall alternative (see cost comparison section below). This wall type is already in place behind the new BNSF bridge and can be extended without any difficulty. The prime contractor can use these construction methods for this type of wall system without bringing in specialty subcontractors. The anchor walls and tie rods can be abandoned or removed once the structural CIP concrete wall is constructed inside the sheet pile walls. The open-excavation method of seal placement requires internal temporary shoring walls, but these can be integrated with the permanent walls and added and removed effectively. The open excavation method will allow the buried quarry spalls to be removed as part of the seal excavation and limit the amount of temporary fill material that is required to be brought in to facilitate seal construction.

Disadvantages

The right-of-way (ROW) footprint is the largest with this alternative. The anchor walls and anchor rods have to be located around the railroad track, utilities, roadways, and parking lots to minimize interferences. Sensitive utilities such as fiber optic lines, petroleum gas lines, and power line stations and features may have to be relocated. All of the interferences have yet to be identified, as we are still resolving utility conflicts, and there may be locations where this type of anchor wall system does not work, and deeper, longer permanent ground anchors are required. This would require a larger ROW footprint for a subterranean easement. The contractor may introduce temporary bracing in the excavation to reduce sheet-pile wall section sizes, but this adds a level of complexity to the seal construction process. The seal placement footprint is limited by the amount of concrete material that can be delivered and placed at the project site on the day of the pour. This pouring process will displace the water in the excavation, and it will need to be treated for high pH content. The sheet pile sections are not watertight, so the contractor will either employ additional mitigation methods to seal the gaps, or added dewatering will be required with this alternative until the seal is completed and the structural CIP wall can be formed and poured.

The bridge foundations with this alternative are based on pile supported spread footings. These bridge foundation locations will require long term dewatering with high volumes to draw down the water table in the area.

Alternative 2: Secant Pile Wall and Soil Replacement Seal Construction



OPTION 2
SECANT PILE WALLS WITH SOIL REPLACEMENT

The walls, seal and structure foundations for the secant pile wall with soil replacement costs about $39,900,000.

Advantages

This alternative has been designed and constructed on several projects, including 180th Street undercrossing just south of this project. The soil replacement method reduces the overall material that is removed from this project. The secant pile shaft length only extends to near the bottom of the seal except at bridge structures. Overlapping the seal and the secant pile walls will reduce the amount of localized pressure grouting or other mitigating measures needed to make the structure watertight. The 4-foot-diameter shafts are specified to allow a larger cross-section for removal of small obstructions and debris during the drilling process.

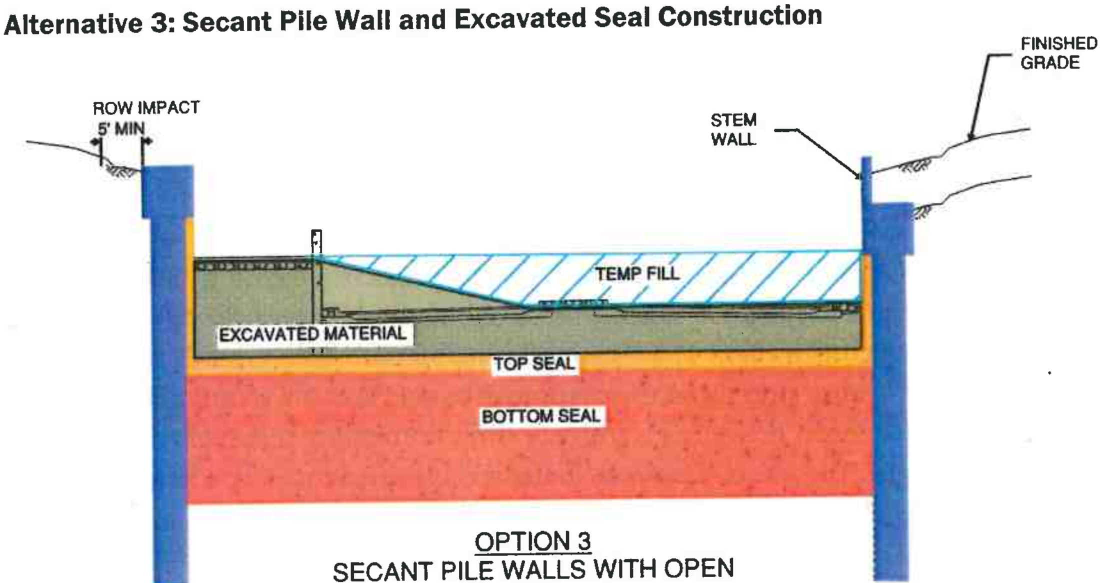
Disadvantages

Shafts will likely require full casing because of the high water table and questionable material on site. Larger drilling equipment is needed to install and extract the full-depth casing. A secant pile wall is generally more expensive that a sheet pile wall, though obstructions can be mitigated easier with drilled shafts.

The actual methods for soil replacement are based on the contractor's means and methods to meet contract-required performance goals. The ability to perform this task is more dependent on the specialty subcontractors understanding, experience, equipment, and the team they assign to the project. The geotechnical engineers recommend we extend the seal a minimum of 10 feet beyond the centerline of the secant shaft to create an adequate seal. This footprint is much larger and has some utility and ROW impacts compared to the over excavated construction alternative of the seal. The zone of soil between the seal and the top of ground at the time of construction will also have to have a reduced amount of soil replacement. This was a lesson learned on the 180th project to mitigate the water that moves to the surface during the soil replacement process. This adds a significant amount of soil replacement volume to the estimate, as it also extends out to ten feet beyond the centerline of secant pile shaft. Soil replacement will add construction time to the project.

The existing quarry spalls from Strander Phase 2, and likely under the UPRR railroad line, are not compatible with soil replacement. All materials such as quarry spalls will have to be removed completely before the soil replacement operation can begin, or delays and claims may be expected. To mitigate this risk, we would need the contractor to over-excavate these materials and then place the imported temporary fill material above the existing water table to perform the soil replacement. This over excavation is within ten feet of the bottom of seal and a significant amount of material is removed, replaced, and improved to remove these quarry spalls.

Alternative 3: Secant Pile Wall and Excavated Seal Construction



OPTION 3
SECANT PILE WALLS WITH OPEN EXCAVATION

The walls, seal, and structure foundations for the secant pile wall with open excavation costs about $35,900,000.

Advantages
This alternative provides the smallest construction footprint and was used successfully on a project in Yakima, Washington. The 4-foot-diameter shafts are specified to allow a larger cross-section for removal of small obstructions and debris during the drilling process. The open excavation seal construction provides a cost saving compared to soil replacement methods. The internal temporary shoring walls required for open excavation of the seal can be integrated with the secant pile walls and both added and removed effectively. This method of construction will allow the buried quarry spalls to be removed as part of the seal excavation and limit the amount of temporary fill material imported to facilitate seal construction.

Disadvantages
Shafts will likely require full casing because of the high water table and questionable material on site. Larger drilling equipment is needed to install and extract the full depth casing. A secant pile wall is generally more expensive that a sheet pile wall, though obstructions can be mitigated easier with drilled shafts. The shaft length with the open excavation seal construction method extends further into the ground to withstand the lateral demands of the excavation to the bottom of seal. This offsets some of the savings from of the seal construction.

The contractor may introduce temporary bracing in the excavation to help stabilize the secant pile wall during seal construction, but this adds a level of complexity to the seal construction process. The seal placement footprint is limited by the amount of concrete material that can be delivered and placed at the project site on the day of the pour. This pouring process will displace the water in the excavation, and it will need to be treated for high pH content. The interface between secant pile wall and seal will only be as watertight as the contact surface is cleaned during the excavated process. Since this is underwater work, it will be difficult to inspect. The contractor will either employ additional mitigation methods to seal the gaps or added dewatering will be required with this alternative until the seal is completed and the structural CIP fascia and seal top slab can be formed and poured.

CONCLUSIONS & RECOMMENDATIONS
It is our understanding that the two highest risk concerns of the project for the City are impacts to ROW and impacts to sensitive utilities. In evaluating the wall and seal alternatives, the highest risk to construction is mitigating the water discharge and working around the quarry spalls placed during the Strander Phase 2 project. Alternative 3 provides the design team and contractor the best chance to mitigate these four risks, and it is our recommendation that the design move forward with a 4-foot-diameter secant pile wall system using the open-excavated construction method for the seal. In discussion with the City, Alternative 3 has been selected as the solution to carry forward in the design.

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Attachments

Strander Boulevard Cost Estimate (Walls, Seal, and Structure Foundations)

Ott-Sakai & Associates Constructability Comments

STRANDER BOULEVARD WALLS, SEAL AND STRUCTURAL FOUNDATION COST ESTIMATE

PROJECT COST LINE ITEM	*PHASE III TOTAL (Sheet Piles With open Ex)*				*PHASE III TOTAL (Secant Pile Walls W/Ground Improvements)*				*PHASE III TOTAL (Secant Pile Walls W/Open Ex)*			
	Total				*Total*				*Total*			
	Total	Unit	Unit Cost	Price	Total	Unit	Unit Cost	Price	Total	Unit	Unit Cost	Price
WALLS			Subtotal	$ 10,751,940			Subtotal	$ 14,488,248			Subtotal	$ 17,475,584
FURNISH STEEL SHEET PILING	1,800	TON	$ 3,000	$ 5,400,000	0	TON	$ 2,000	$ -	0	TON	$ 2,000	$ -
INSTALL STEEL SHEET PILE	1,940	LF	$ 100	$ 194,000	0	LF	$ 350	$ -	0	LF	$ 100	$ -
CONCRETE ANCHOR WALL	480	CY	$ 800	$ 384,000	0	CY	$ 800	$ -	0	CY	$ 800	$ -
TIE RODS FOR SHEET PILE WALL	39,820	LB	$ 2	$ 79,640	0	LF	$ 25	$ -	0	LF	$ 25	$ -
STRUCTURAL CARBON STEEL FOR WALER	85,190	LB	$ 2	$ 170,380	0	LB	$ 2	$ -	0	LB	$ 2	$ -
CONCRETE CLASS 4000 FOR CONCRETE WALLS AND BOTTOM	8,970	CY	$ 300	$ 2,691,000	9,180	CY	$ 300	$ 2,754,000	9,180	CY	$ 300	$ 2,754,000
ST. REINF. FOR CONCRETE WALLS AND BOTTOM SLAB	1,792,200	LB	$ 1.00	$ 1,792,200	1,835,400	LB	$ 1.00	$ 1,835,400	1,835,400	LB	$ 1.00	$ 1,835,400
TEMPORARY STRUT	0	LF	$ 300.00	$ -	0	LF	$ 300.00	$ -	0	LF	$ 250.00	$ -
SHEET PILE INTERLOCKS	1,940	LF	$ 8.00	$ 15,520	0	LF	$ 8.00	$ -	0	LF	$ 8.00	$ -
MODULAR BLOCK WALL	720	SF	$ 35.00	$ 25,200	720	SF	$ 35.00	$ 25,200	720	SF	$ 35.00	$ 25,200
SOIL EX PRIMARY SHAFT INCL HAUL	0	CY	$ 300.00	$ -	5,100	CY	$ 300.00	$ 1,530,000	6,660	CY	$ 300.00	$ 1,998,000
SOIL EX SECONDARY SHAFT INCL HAUL	0	CY	$ 300.00	$ -	5,100	CY	$ 300.00	$ 1,530,000	6,660	CY	$ 300.00	$ 1,998,000
FURNISH AND PLACING TEMP. CASING FOR PRIMARY SHAFTS	0	LF	$ 125.00	$ -	10,940	LF	$ 125.00	$ 1,367,500	14,300	LF	$ 125.00	$ 1,787,500
FURNISH AND PLACING TEMP. CASING FOR SECONDARY SHAFTS	0	LF	$ 125.00	$ -	10,940	LF	$ 125.00	$ 1,367,500	14,300	LF	$ 125.00	$ 1,787,500
LEAN CONCRETE FOR PRIMARY SHAFTS	0	CY	$ 200.00	$ -	5,100	CY	$ 200.00	$ 1,020,000	6,660	CY	$ 200.00	$ 1,332,000
CONC. CLASS 4000P FOR SECONDARY SHAFTS	0	CY	$ 250.00	$ -	5,100	CY	$ 250.00	$ 1,275,000	6,660	CY	$ 250.00	$ 1,665,000
ST. REINF. FOR SHAFT	0	LB	$ 1.20	$ -	1,018,040	LB	$ 1.20	$ 1,221,648	1,330,570	LB	$ 1.20	$ 1,596,684
CSL ACCESS TUBE	0	LF	$ 10.00	$ -	43,750	LF	$ 10.00	$ 437,500	57,180	LF	$ 10.00	$ 571,800
CSL TEST	0	EACH	$ 1,500.00	$ -	83	EACH	$ 1,500.00	$ 124,500	83	EACH	$ 1,500.00	$ 124,500
SEAL			Subtotal	$ 10,764,401			Subtotal	$ 18,363,900			Subtotal	$ 11,263,404
FURNISH STEEL SHEET PILING	210	TON	$ 2,000	$ 420,000	0	TON	$ 2,000	$ -	80	TON	$ 2,000	$ 160,000
INSTALL STEEL SHEET PILE	2,810	LF	$ 100	$ 281,000	0	LF	$ 350	$ -	2,360	LF	$ 100	$ 236,000
CONCRETE ANCHOR WALL	120	CY	$ 800	$ 96,000	0	CY	$ 800	$ -	0	CY	$ 800	$ -
TIE RODS FOR SHEET PILE WALL	5,820	LB	$ 2	$ 11,640	0	LF	$ 25	$ -	0	LF	$ 25	$ -
STRUCTURAL CARBON STEEL FOR WALER	20,090	LB	$ 2	$ 40,180	0	LB	$ 2	$ -	0	LB	$ 2	$ -
STRUCTURE EX. CLASS B INC HAUL - BOAT SLAB	95,004	CY	$ 25	$ 2,375,100	6,010	CY	$ 25	$ 150,250	100,270	CY	$ 25	$ 2,506,750
LEAN CONCRETE FOR SEAL	32,670	CY	$ 200	$ 6,534,024	0	CY	$ 200	$ - x	36,544	CY	$ 200	$ 7,308,872
SOIL MIXING	0	CY	$ -	$ -	46,830	CY	$ 250	$ 11,707,500	0	CY	$ -	$ -
SOIL STABILITY	0	CY	$ -	$ -	76,150	CY	$ 63	$ 4,759,375	0	CY	$ -	$ -
REMOVAL OF STRUCTURE AND OBSTRUCTION	1	LS	$ 445,457	$ 445,457	1	LS	$ 1,185,775	$ 1,185,775	1	LS	$ 490,782	$ 490,782
GRAVEL BORROW	2,460	CY	$ 25	$ 61,500	14,440	CY	$ 25	$ 361,000	2,460	CY	$ 25	$ 61,500
QUARRY SPALLS	5,990	CY	$ 50	$ 299,500	0	CY	$ 50	$ -	5,990	CY	$ 50	$ 299,500
STRANDER PHASE II DEMOLITION	1	LS	$ 200,000	$ 200,000	1	LS	$ 200,000	$ 200,000	1	LS	$ 200,000	$ 200,000

STRANDER BOULEVARD WALLS, SEAL AND STRUCTURAL FOUNDATION COST ESTIMATE

PROJECT COST LINE ITEM	PHASE III TOTAL (Sheet Piles With open Ex)				PHASE III TOTAL (Secant Pile Walls W/Ground Improvements)				PHASE III TOTAL (Secant Pile Walls W/Open Ex)			
	Total				Total				Total			
	Total	Unit	Unit Cost	Price	Total	Unit	Unit Cost	Price	Total	Unit	Unit Cost	Price
BNSF BRIDGE (4th Track Foundation Only)			Subtotal	$ 1,470,200			Subtotal	$ 196,166			Subtotal	$ 188,808
STRUCTURE EXCAVATION CLASS A INC HAUL - BNSF BRIDGE	1,220	CY	$ 20	$ 24,400	0	CY	$ 20	$ -	0	CY	$ 20	$ -
SHORING OR EXTRA EXCAVATION CLASS A	1	LS	$ -	$ -	0	LS	$ -	$ -	0	LS	$ -	$ -
FURNISHING AND DRIVING STEEL TEST PILE - BNSF BRIDGE	2	EACH	$ 21,000	$ 42,000	0	EACH	$ 21,000	$ -	0	EACH	$ 21,000	$ -
FURNISHING STEEL PILING - BNSF BRIDGE	2,945	LF	$ 100	$ 294,500	0	LF	$ 100	$ -	0	LF	$ 100	$ -
DRIVING STEEL PILING - BNSF BRIDGE	31	EACH	$ 4,000	$ 124,000	0	EACH	$ 4,000	$ -	0	EACH	$ 4,000	$ -
FURNISH STEEL PILE TIP - CONICAL - BNSF BRIDGE	31	EACH	$ 2,500	$ 77,500	0	EACH	$ 2,500	$ -	0	EACH	$ 2,500	$ -
CONCRETE CLASS 4000 - BNSF BRIDGE	1,200	CY	$ 500	$ 600,000	20	CY	$ 500	$ 10,000	19	CY	$ 500	$ 9,309
STEEL REINFORCEMENT - BNSF BRIDGE	298,500	LB	$ 1.00	$ 298,500	3,800	LB	$ 1.00	$ 3,800	3,695	LB	$ 1.00	$ 3,695
PERVIOUS BACKFILL - BNSF BRIDGE	310	TON	$ 30.00	$ 9,300	310	TON	$ 30.00	$ 9,300	310	TON	$ 30.00	$ 9,300
PIER 2 SHAFT - BNSF BRIDGE	0	LF	$ -	$ -	100	LF	$ 1,730.66	$ 173,066	96	LF	$ 1,730.66	$ 166,504
UPRR BRIDGE			Subtotal	$ 2,613,500			Subtotal	$ 187,024			Subtotal	$ 152,467
STRUCTURE EXCAVATION CLASS A INC HAUL - UPRR BRIDGE	1,820	CY	$ 20	$ 36,400	0	CY	$ 20	$ -	0	CY	$ 20	$ -
FURNISHING AND DRIVING STEEL TEST PILE - UPRR BRIDGE	2	EACH	$ 21,000	$ 42,000	0	EACH	$ 21,000	$ -	0	EACH	$ 21,000	$ -
FURNISHING STEEL PILING - UPRR BRIDGE	6,080	LF	$ 100	$ 608,000	0	LF	$ 100	$ -	0	LF	$ 100	$ -
DRIVING STEEL PILING - UPRR BRIDGE	64	EACH	$ 4,000	$ 256,000	0	EACH	$ 4,000	$ -	0	EACH	$ 4,000	$ -
FURNISH STEEL PILE TIP - CONICAL - UPRR BRIDGE	64	EACH	$ 2,500	$ 160,000	0	EACH	$ 2,500	$ -	0	EACH	$ 2,500	$ -
CONCRETE CLASS 4000 - UPRR BRIDGE	2,000	CY	$ 500	$ 1,000,000	20	CY	$ 500	$ 10,000	20	CY	$ 500	$ 10,000
STEEL REINFORCEMENT - UPRR BRIDGE	499,100	LB	$ 1.00	$ 499,100	3,800	LB	$ 1.00	$ 3,800	3,800	LB	$ 1.00	$ 3,800
SHORING OR EXTRA EXCAVATION - UPRR BRIDGE	1	LS	$ -	$ -	0	LS	$ -	$ -	0	LS	$ -	$ -
PERVIOUS BACKFILL - UPRR BRIDGE	400	TON	$ 30	$ 12,000	0	TON	$ -	$ -	0	TON	$ -	$ -
PIER 2 SHAFT - UPRR BRIDGE	0	LF	$ -	$ -	100	LF	$ 1,732	$ 173,224	100	LF	$ 1,387	$ 138,667
VEHICULAR BRIDGE			Subtotal	$ 3,004,700			Subtotal	$ -			Subtotal	$ -
STRUCTURE EXCAVATION CLASS A INC HAUL - FLYOVER BRIDGE	2,250	CY	$ 20	$ 45,000	0	CY	$ 20	$ -	0	CY	$ 20	$ -
FURNISHING AND DRIVING STEEL TEST PILE - FLYOVER BRIDGE	2	EACH	$ 21,000	$ 42,000	0	EACH	$ 21,000	$ -	0	EACH	$ 21,000	$ -
FURNISHING STEEL PILING - FLYOVER BRIDGE	6,080	LF	$ 100	$ 608,000	0	LF	$ 100	$ -	0	LF	$ 100	$ -
DRIVING STEEL PILING - FLYOVER BRIDGE	64	EACH	$ 4,000	$ 256,000	0	EACH	$ 4,000	$ -	0	EACH	$ 4,000	$ -
FURNISH STEEL PILE TIP - CONICAL - FLYOVER BRIDGE	64	EACH	$ 2,500	$ 160,000	0	EACH	$ 2,500	$ -	0	EACH	$ 2,500	$ -
CONCRETE CLASS 4000 - FLYOVER BRIDGE	2,500	CY	$ 500	$ 1,250,000	0	CY	$ 500	$ -	0	CY	$ 500	$ -
STEEL REINFORCEMENT - FLYOVER BRIDGE	623,900	LB	$ 1.00	$ 623,900	0	LB	$ 1.00	$ -	0	LB	$ 1.00	$ -
SHORING OR EXTRA EXCAVATION - FLYOVER BRIDGE	1	LS	$ -	$ -	0	LS	$ -	$ -	0	LS	$ -	$ -
PERVIOUS BACKFILL - FLYOVER BRIDGE	660	TON	$ 30	$ 19,800	0	TON	$ -	$ -	0	TON	$ -	$ -

	PHASE III TOTAL (Sheet Piles With open Ex)	PHASE III TOTAL (Secant Pile Walls W/Ground Improvements)	PHASE III TOTAL (Secant Pile Walls W/Open Ex)
Total	$ 28,605,000	$ 33,236,000	$ 29,081,000
Design Contingency	20%	20%	20%
TOTAL	$ 34,400,000.00	$ 39,900,000.00	$ 34,900,000.00

Ott-Sakai and Associates
2-11-2018

Project: Strander Blvd, SW 27th Extension

Constructability Comments based Upon Options Under Consideration

Option 1: Sheet pile wall with dead man anchors, internal concrete "boat" with open excavation placing concrete tremie seal in small 30 foot long sections.

Option 2: Secant pile walls with soil replacement for seal. The width of the Soil Replacement/ground improvement is anticipated to extend about 10 feet beyond each of the Secant pile walls. Secant Pile walls would be drilled through the ground improvement.

Option 3: Secant pile walls with open excavation placing concrete tremie seal in small 30 foot long sections.

OPTION 1: Sheet Pile walls

Most of the local larger heavy civil general contractors and most foundation subcontractors have the equipment and experience to complete this work. Typically sheet pile shoring walls can be installed significantly faster and at less costs than secant pile wall systems.

ROW (Right of Way):
The dead man anchors will require the Right of Way to be wider by approximately 80 feet to accommodate the installation. The cost to this ROW needs to be taken into consideration.

Quarry Spalls:
In the previously constructed Phase 2 of Strander Blvd (East end of current Project), a six (6) foot deep layer of quarry spalls was placed under the roadway and extends beyond the location of the longitudinal walls.
For sheet pile installation it is anticipated that the quarry spalls will need to be removed. This could be either a narrow slot that would accommodate the sheet pile installation or removal of the entire 6 foot deep layer of Quarry Spalls. Either way the Contractor will likely want to salvage and reuse the majority of the existing quarry spalls. It is anticipated that the cost of removal will be offset by the salvage value of the quarry spalls.

Sheet Piles:
The current option uses a single row of ground anchors installed about 40ft behind each sheet pile wall with anchor rods/strands connecting the anchors to the sheet pile wall. We anticipate a large/heavy sheet to be needed and that the Project will require American made steel (Federally Funded Projects). Because of the potential for future steel tariffs, steel cost

may increase significantly. The furnished steel amounts carried in the current cost estimate may be too low.

A water tight wall is also needed, so a joint sealant for the sheet pile interlocks will need to be added at a cost of $ 8.00 per lf of sheet.

Equipment:
Handling of the large sheet sizes (Length and weight) will require large cranes and support equipment and may add significant costs to establish and maintain access.

The design of the sheet pile walls with the single row of anchors has not been fully developed and as that design progresses we may find that the long/heavy sheets may require the use of a multileveled template system to support the sheet pile walls during excavation and placement of the Tremie Concrete which will slow production and increase installation costs.

Ground Settlement:
The heavy equipment weight, the poor soil conditions, and the large vibratory hammer may cause some settlement issues with nearby utilities, Railroad, neighbors, etc. during driving of the sheet pile.

Excavation
The existing water table is only a few feet under the ground surface.
The area between the sheet pile walls will be partitioned into manageable areas for excavation and pouring of the 20 foot deep Tremie seal. The partitions are made installing sheet piles perpendicular and transverse to the longitudinal walls (referred to as "Cutoff walls"). The cutoff walls will be placed at about 30-40 foot spacing depending upon the actual equipment used and the access. This 30-40foot long bathtub is then excavated by reaching down through 35-40 feet of water and loading the excavated material into trucks and hauling to disposal.

Settling Ponds: The excavated material will be very sloppy and most likely will need to drain for a day or two before hauling to disposal. The disposal cost of this very wet material will is normally priced as contaminated material.

Because of the depth of foundation excavation and the seal pour, very large volumes of dredge spoils and water from dewatering will have to accounted for. Excavating the seal pour in the wet will result in a large volume of saturated dredge spoils. This material will have to be temporarily stored and decanted in onsite containment structures prior to disposal offsite. Job site space or construction time may not be sufficient to allow this to occur. Because of the high water content, it is unlikely the dredge spoils will pass the paint filter required by the local disposal sites. All disposal trucks will need to be lined and the waste soil processed . Processing will require the addition of 8 to 10 percent fly ash or other demetrius earth to stabilize the material. Containment and treatment of the decant and dewatering water will be very significant. I do not believe the current estimate has properly accounted for these costs. Therefore, I believe the cost estimate should also include the cost to prepare the waste soil for disposal at certified disposal sites.

Tremie Concrete Seal Foundation

Using the Tremie method of placing concrete underwater is relatively wide used by contractors and with a 20 foot deep Seal it is unlikely that a leak will develop. After the Concrete Tremie Seal is placed and cured then the "bathtub" can be dewatered. However there is always that chance for a leak and the Contractor must be prepared to perform pressure injection to seal-up the leaking spots. This is a cost that will need to be included.

Option 1, Summary of Advantages over the other two Options:

- More competitive pricing for installation
- One solid pour of concrete in walls (30 ft length) and base along the entire length of the project (except existing BNSF) which decreases chance for leaks
- Less expensive than the other two options
- Faster construction assuming no conflicts

Option 1, Summary of Disadvantages compared to the other two options:

- Uncertainty of Steel prices
- Difficulty in obtaining a waterproof or an acceptably waterproof wall
- Buy America Requirements can delay procurement and significantly increase costs.
- Higher volume of water removed from excavation after concrete seal is poured, which would likely have a high pH and require treatment before disposal
- Purchase cost for extra temporary/permanent easement

Sheet Pile Wall Risks:

- Sheet pile walls are not completely waterproof so constant pumping of construction water will be needed. This water will also have high pH making it more costly to treat. The amount of water that will come through the walls is unknown
- Quality control of seal concrete slab is difficult to perform underwater, the seal could be uneven and may have imperfections and voids that could affect the seal integrity. Post-grouting could be required to repair affected areas of seal.
- Additional and unforeseen utility conflicts at deadman and/or tiebacks

- Dewatering being shut down due to pond (or outfall) not able to keep up with quantities of water needing to be pumped.
- The flexibility of the longitudinal walls can create a separation between the seal plug and the walls when the area is excavated and dewatered, resulting in leakage between the longitudinal walls and the seal course. This would be the case for all types of seal courses - just less risk in the case of a tremie pour.

OPTION 2: Secant pile walls with soil replacement for seal.

The Soil replacement or Mixing will extend 10ft beyond each of the secant pile walls creating a footprint that is 20 feet wider than the longitudinal retaining walls. Soil replacement can be accomplished with two different methods:

1. Deep Soil Mixing

Mechanical mixing tools are used to shear the soil in-situ and mix it with a cement slurry. Bentonite may be added for waterproofing. Depending upon the type of mixing head it can be mounted on a large excavator or a drilling machine. As the soil is mixed a cementitious slurry is pumped at low pressure into and mixed with the mixed soil, creating a soil mixed column (rectangular or round) that can be up to 10 feet in diameter. Additional mixing of the soil is completed as the tool is withdrawn to the surface. Mass wet soil mixing, or mass stabilization, is performed with a horizontal rotary mixing tool at the end of a track hoe arm. The binder slurry is injected through a feed pipe attached to the arm.

To create a waterproof seal the soil mixed columns can be interlocking to create a fully mixed block of mixed soil.

In all cases the mixing starts at the ground surface and the soil is mixed from the ground surface to the bottom of the mixed soil area. This process constructs individual soilcrete columns, rows of overlapping columns for 100% mass stabilization, all with a designed strength and stiffness.

There are only 2 or 3 companies that have this capability and equipment in the Northwest. Each has its own preference and slightly different equipment, but the basic operation for each company is described above.

The unit cost for this method is based upon the volume of soil mixed which is from the existing ground surface to the bottom of the concrete Seal. This results in a quantity that is roughly twice the volume treated with jet grouting and results in lower unit prices but not necessarily a lower total cost.

2. Jet Grouting

Jet Grouting is used to create an in situ mass of improved soil by injecting a stream of fluid grout at a high pressure/ high velocity stream. The drill rig advances a 4-8inch diameter jet grout tool to the bottom of the proposed treatment zone and then horizontally injects fluid grout with a very high pressure and velocity. The drill tool is rotated as it is withdrawn at a constant rate as the grout erodes and mixes the surrounding soil. The type and density of the soil will determine the area or diameter of the mixed soil columns.

Jet grouting mixes and treats the soil from the bottom up, so that only the desired area of mixing is actually treated.

In a continuous operation, they can achieve several columns per hour which when spaced properly will produce interlocking columns that will become watertight and provide the desired Seal. This method was successfully used at the Seattle Seawall Project.

The Unit costs are more than Soil mixing but the volume of mixing/ treated are about half.

Summary of Soil Replacement Methods:

The soil replacement would be installed prior to the Secant Pile walls. Secant Pile walls will be installed vertically through the soil improvement and should provide a positive watertight seal between the soil improvement and the secant pile wall.

Both Jet Grouting and Deep Soil Mixing will equally provide the desired foundation seal.

a. Jet grouting can work around obstructions and some utilities whereas soil mixing cannot.
b. Jet grouting will generally produce higher strengths but the higher strength is most likely not necessary for the roadway loading.
c. Both methods are effective in a wide range of soil types.
d. More investigation is needed to compare the pricing for this specific project
e. There should be a huge savings in dewatering and dredge soil removal and disposal costs. Some excess water and fine soil material will be pushed to the surface during grouting operations and will have to be contained and disposed of as contaminated material. However, since the seal pour is effectively cast in place through soil mixing or jet grouting, seal excavation and dewatering is mostly eliminated. The balance of the excavation for the structures foundation can occur after the soil replacement process has been complete. This should greatly reduce the dewatering effort for that material.
f. The density of the soil replacement material will be less than the density of tremie seal concrete and will most likely require a deeper depth for the soil replacement seal. I am not sure this has been included in the cost estimate.

Summary of Advantages over the Tremie Seal Option:

a. Can be performed from the existing ground surface.
b. Quarry Spalls: the jet grouting can most likely be performed without removing the quarry spalls, whereas the Deep Soil Mixing will most likely require the quarry spalls to be removed prior to the Soil Replacement.
c. Vibration and potential settlement of the area is minimized
d. Less contaminated material will be generated and removed from the site
e. Smaller quantities of excavation resulting in fewer trucks hauling to disposal.
f. I would expect fewer leaks with either soil improvement vs. sheet pile joints.
g. Less risk with either of these methods.

Summary of Disadvantages over the Tremie Seal Option:

a. Higher cost
b. Fewer contractors have the capabilities and they are currently in very high demand

3. Four (4) ft Diameter Secant Pile Walls

The Secant piles will be install after the Soil Replacement has been install and will be drilled through the Soil Replacement layer.

Secant Pile walls are typically used where tiebacks and or soil nails are difficult to install or where a watertight wall is needed and /or the dense soil conditions prevent installation of the more cost effective sheet pile shoring systems.

Secant pile shoring walls have also been installed locally on many projects and there are several of these specialty foundation subcontractors in the local area. They are capable of installing 4 foot diameter secant piles.

Secant pile installation is complicated on this project. Due to the loose soil conditions, high water table, and small size of the piles, the installation is more complicated and most likely will require the drilled holes to be filled with a bentonite slurry to hold the walls of the shaft until concrete is poured or alternatively the hole may require temporary casing

For the 4 foot diameter secant pile wall requires large drillng equipment, but not near the size of the cranes required to handle the sheet piles referenced in Option1 above.

The drill water's suspended solids and PH levels will require it to be contained and treated prior to disposal. Drill spoils will be extremely saturated and sloppy. Excess grout could also get mixed in the drill spoils. Considering the volume of drill spoils (in excess of 10,000 cys), water, and excess grout, costs associated with handling, treating, and disposing of this material will be significant and handled and disposed of as contaminated material. I do not believe the current cost estimate has addressed these costs

Summary of Advantages over the Sheet Pile Wall in Option 1:

- Does not require the additional Right of Way needed in Option 1 for the Tieback anchors.
- Much easier to ensure that secant pile wall is watertight.
- Removes the risk of the steel prices escalating faster than the economy.
- Removes the uncertainty of the Buy America requirements and the potential delays in fabrication.
- Minimizes vibration and potential settlement of the ground creating issues with some of the utilities and the Railroads.

Summary of Disadvantages compared to the Sheet Pile Wall in Option 1:

- Higher cost
- Fewer contractors to bid on this type of work. Scheduling

<u>Option 3: **Secant pile walls with open excavation placing concrete tremie seal in small 30 foot long sections.**</u>

This Option incorporates portions of both Option 1 and 2. In this Option the Secant Pile Walls will be installed prior to the Seal similar to Option 1.

The area between the sheet pile walls will be partitioned into manageable areas for excavation and pouring of the 20 foot deep Tremie seal. The partitions are made installing sheet piles perpendicular and transverse to the longitudinal walls (referred to as "Cutoff walls"). The cutoff walls will be placed at about 30-40 foot spacing depending upon the actual equipment used and the access. This 30-40foot long bathtub is then excavated by reaching down through 35-40 feet of water and loading the excavated material into trucks and hauling to disposal.

The discussion in Option 1 regarding the Sheet pile walls is also applicable for the Secant Pile Walls, except as noted:

ROW (Right of Way): Not applicable

Quarry Spalls: For 4ft diameter secant pile installation it is anticipated that the quarry spalls will need to be removed. This could be either a narrow slot that would accommodate the secant pile installation or removal of the entire 6 foot deep layer of Quarry Spalls. Either way the Contractor will likely want to salvage and reuse the majority of the existing quarry spalls. It is anticipated that the cost of removal will be offset by the salvage value of the quarry spalls.

Sheet Piles: Not applicable

Equipment:

Drilling equipment used for the drilling of 4 ft secant piles is much smaller than the Cranes needed to install the heavy sheet piles.

Excavation

The existing water table is only a few feet under the ground surface.

The area between the sheet pile walls will be partitioned into manageable areas for excavation and pouring of the 20 foot deep Tremie seal. The partitions are made installing sheet piles or secant piles perpendicular and transverse to the longitudinal walls (referred to as "Cutoff walls"). The cutoff walls will be placed at about 30-40 foot spacing depending upon the actual equipment used and the access. This 30-40foot long bathtub is then excavated by reaching down through 35-40 feet of water and loading the excavated material into trucks and hauling to disposal.

Settling Ponds: The excavated material will be very sloppy and most likely will need to drain for a day or two before hauling to disposal will be very. The disposal cost of this very wet material will is normally priced as contaminated material.

Because of the depth of foundation excavation and the seal pour, very large volumes of dredge spoils and water from dewatering will have to be accounted for. Excavating the seal pour in the wet will result in a large volume of saturated dredge spoils. This material will have to be temporarily stored and decanted in onsite containment structures prior to disposal offsite. Job site space or construction time may not be sufficient to allow this to occur. Because of the high water content, it is unlikely the dredge spoils will pass the paint filter required by the local disposal sites. All disposal trucks will need to be lined and the waste soil processed. Processing will require the addition of 8 to 10 percent fly ash or other demetrius earth to stabilize the material. Containment and treatment of the decant and dewatering water will be very significant. I do not believe the current estimate has properly accounted for these co Therefore, I believe the cost estimate should also include the cost to prepare the waste soil for disposal at certified disposal sites.

Tremie Concrete Seal Foundation

Extra care will need to be taken in the cleaning of the secant wall face that will be against the tremie concrete seal to ensure a watertight joint. Using the Tremie method of placing concrete underwater is relatively wide used by contractors and with a 20 deep Seal it is unlikely that a leak will develop. After the Concrete Tremie Seal is placed and cured then the "bathtub" can be dewatered. However there is always that chance for a leak and the

Contractor must be prepared to perform pressure injection to seal-up the leaking spots. This is a cost that will need to be included.

Summary of Advantages over the other two Options:

a. Does not require the highly specialized contractors that are capable of ground improvement.
b. More competitive pricing for installation
c. Less risk of having water intrusion through the secant pile wall than the reliability of the sheet\pile joints.
d. One solid pour of concrete in walls (30 ft length) and base along the entire length of the project (except existing BNSF) which decreases chance for leaks
e. Less expensive than Option 2.
f. Faster construction than Option 2 assuming no conflicts

Summary of Disadvantages compared to the other two options:

a. Secant Pile wall will cost more than the sheet pile wall.
b. Higher volume of water removed from excavation after concrete seal is poured, which would likely have a high pH and require treatment before disposal

Seal Construction Risks:

a. Quality control of seal concrete slab is difficult to perform underwater, the seal could be uneven and may have imperfections and voids that could affect the seal integrity. Post-grouting could be required to repair affected areas of seal.
b. Dewatering being shut down due to pond (or outfall) not able to keep up with quantities of water needing to be pumped.

Summary of Options:

Option 1. Sheet pile with anchors and a tremie seal will most likely be the least cost but creates a wider footprint due to the 40ft long anchors and ROW acquisition may offset the savings. An issue is the disposal of the contaminated water/sludge that will need to be removed. The cost for an additional 80feet of ROW width may make Option 1 unacceptable. This Option is most likely the less cost to the Owner but higher risk to the contractor.

Option 2A. Secant Pile with a Jet Grouting seal appears to be least overall risk when considering the wall irregularities and need for a watertight joint, and the cost of disposal for contaminated material. Highest cost to the Owner and least risk to the contractor.

Option 2B. Secant pile and soil mixing may cost more due to mixing of the soil volume above the top of the seal and potential leakage between the seal and the sheet pile walls. Cost to the Owner may be a little lower than using Jet Grouting but the cost of soil mixing of the overburden may make the costs nearly equal

Option 3. Secant pile walls with a tremie seal. Use transverse sheet pile walls to divide the length into manageable sections (compartments). Flexure in the secant walls will reducing the risk of breaking the watertight joint between the seal and the walls. The contractors risk is significantly reduced without the sheet pile wall, but the cost to the owner is higher.

The BergerABAM Pros and Cons list is pretty accurate and until we have more information and time to actually estimate the options it is difficult to provide a magnitude of cost difference between the Options.

Bottom seal and Wall construction

Option 1: Sheet pile wall with dead man anchors, internal concrete "boat" with open excavation placing concrete seal in small sections.

Construction Sequence:

1. Relocate utilities near UPRR and trail
2. Shoofly UPRR (road to train station stays open)
3. Construct project to the west including new UPRR bridge, ped bridge, PSE access and fast food access
    a. During this phase ped path will be detoured from long acres way to 180th on West valley
    b. Drive sheet piles just west of shoofly and along the North and South of the proposed road towards west valley.
    c. Dewater excavation as the pile supported foundation for the UPRR bridge is excavated and installed. Install waterstop on both sides of foundation and abutments to improve water tight connection in cold joint
        i. Construction water will need to be treated before disposal.
    d. At this point the UPRR bridge can be finished and UPRR can be moved back to the main line.
    e. As the contractor works his way out of the hole for UPRR foundation he will pour seal in sections.
4. Install pump in CB farthest west. Pump will move water from this CB up over the sheet piles into the 72" inlet manhole with the knifegate valve in it
5. Relocate water line crossing strander
6. Install sheet piles along remainder of project. Leave sheets out where road currently goes to Tukwila station so trucks can keep access
7. Demo walls not to remain
8. Install 4th track footing at BNSF and flyover using sheetpile shoring. Use same pile supported foundation as the phase 2 bridge
    a. Before shoring is installed to excavate, plug drainage sleeve and pipe that goes through the south side of the existing footing and install a trash pump on the SE corner of the bridge. This pump will move all ground water over the footing excavation to the next CB West of the excavation.
    b. Hole will need to be dewatered using pumps in low spots of footing excavation and kept separate from storm water
9. Remove roadway not to remain
10. Fill in roadway as needed to keep equipment out of the wet
11. Starting at east side of project excavate for bottom seal. This may allow underdrain to stay intact as the excavation is completed. The excavation for the seal will be in the wet. Trucks will enter and exit from Tukwila station. Place the seal in sections as 20-30' sections are excavated.
12. Once entire seal has lift of concrete, dewater hole and pour any remaining concrete seal
13. Update drainage and connect to pump station
14. Pour U shape for walls and final water proofing along length of the project

15. Construct roadway section

Advantages:

- Easy to remove obstructions
- One solid pour of concrete in walls and base along the entire length of the project (except existing BNSF) which decreases chance for leaks
- Less expensive
- Faster assuming no conflicts

Disadvantages:

- Due to open excavation shoring system needs to hold more material resulting in large sheetpile sections
- Water removed from excavation after seal is poured would likely have high pH and require treatment before disposal
- Purchase extra temporary easement

Risks:

- Sheet pile walls are not waterproof so constant pumping of construction water will be needed. This water will also have high pH making it more costly to treat. The amount of water that will come through the walls is unknown
- Quality control of seal concrete slab is difficult to perform underwater, the seal could be uneven and may have imperfections and voids that could affect the seal integrity. Post-grouting could be required to repair affected areas of seal.
- Possible utility conflicts at deadman and/or tiebacks
- Dewatering being shut down due to pond (or outfall) not able to keep up with quantities of water needing to be pumped

Option 2: Secant pile walls with soil replacement for seal

Construction Sequence:

1. Relocate utilities near UPRR and trail
2. Shoofly UPRR (road to train station stays open)
3. Construct new UPRR bridge
    a. During this phase ped path will be detoured from long acres way to 180th on West valley
    b. Install unreinforced temporary secant piles just west of shoofly and permanent secant piles along north and south of road. This includes shafts for abutments and pier for UPRR bridge
    c. Using soil replacement drill and place seal
    d. Excavate and dewater to seal. West side should be water proof at this time
    e. Build superstructure
4. Shift tracks to new bridge
5. Remove all existing structures not to remain

6. Install pump in CB farthest west. Pump will move water from this CB up over the secant piles into the 72" inlet manhole with the knifegate valve in it
7. Relocate water line crossing strander
8. Remove roadway and any quarry spalls deposited in the phase 2
9. Fill entire project to elevation 21 with borrow to facilitate secant pile installation.
10. Install secant pile walls for entire project including the intermediate pier at BNSF
    a. For interaction between existing concrete structures and new secant pile walls the contractor will need to drill behind the secant wall and do soil replacement to plug the gap as much as possible. When the entire seal is completed, high pressure grout will be used to plug any leaks
11. Using soil replacement drill for seal along length of project
12. Update drainage and connect to pump station
13. Fix any leaks in seal
14. Construct roadway section

Advantages:

- Less dewatering
- Lower risk. Not as many items to go wrong that could impact schedule or budget

Disadvantages:

- Cost
- Slower construction

Risks:

- Leaking at existing structure. Might not be as water tight or may take more work to get to water tight
- Obstruction in soil replacement auger or secant piles

Option 3: Secant pile walls with open excavation for seal

Advantages:

- Least dewatering
- Lowest risk. Not as many items to go wrong that could impact schedule or budget
- Cheaper than Option 2

Disadvantages:

- More expensive than option 1
- Slower construction
- Less water tight at interaction between Walls and seal

Risks:

- Leaking at existing structure. Might not be as water tight or may take more work to get to water tight

- Leaking at interaction between walls and seal. Might not be as water tight or may take more work to get to water tight
- Obstruction in secant piles