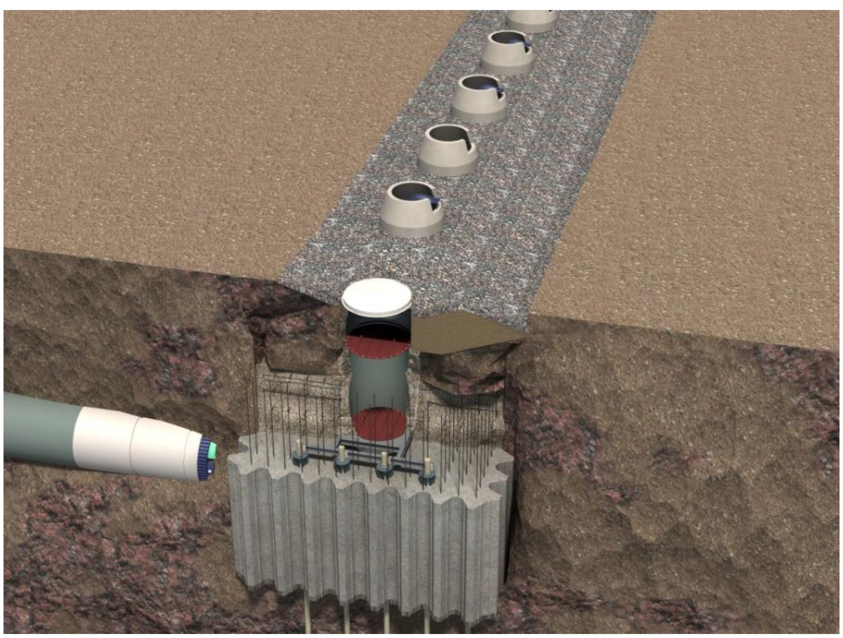
APPENDIX I
OUTFALL SYSTEM OPTIONS ANALYSIS

Part A: Report

Annacis Island WWTP New Outfall System

Vancouver Fraser Port Authority
Project and Environmental Review Application



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CDM Smith

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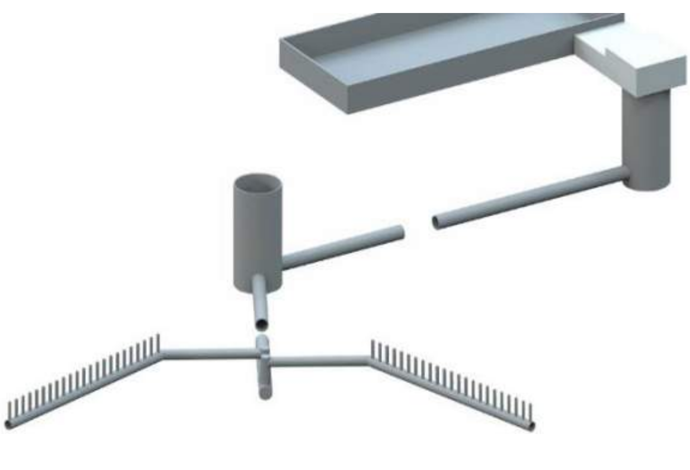
Outfall System Options Analysis

Annacis Island WWTP
Transient Mitigation and Outfall Project

CDM Smith Canada ULC



Prepared for:

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April 18, 2016

CDM Smith

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Section 1

Introduction

Metro Vancouver (MV) owns and operates the Annacis Island Wastewater Treatment Plant (AIWWTP). The original AIWWTP was commissioned in 1975 as a primary treatment plant. In 1999, the secondary treatment portion of the treatment plant (Stage IV expansion) was commissioned after a 10-year design and construction period. The Stage IV expansion was designed to provide treatment capacity up to approximately 500 million liters per day (MLD). Pre-design of the Stage V expansion commenced in summer 2012. The purpose of the Stage V expansion is to increase the AIWWTP secondary treatment capacity by over 25% to an average dry weather flow (ADWF) of 637 MLD, with a peak wet weather flow (PWWF) of 18.9 m^3/s. The ultimate plant buildout is Stage VIII, which will have a PWWF of 25.3 m^3/s. Construction of the first phase of the Stage V expansion is expected to be completed by the end of 2018, with the second phase completed by the end of 2019. **Figure 1-1** illustrates the plant layout and the Stage V to Stage VIII developments.

1.1 Existing Outfall System

The existing outfall was constructed in 1974 to transfer effluent flows from the chlorine contact tanks (CCTs) to the diffuser structure located in the Fraser River, and consists of on-land and marine sections. Both sections were constructed using traditional open-cut methods. The on-land outfall conduit consists of a buried concrete box culvert (3,050 mm x 2,135 mm) and marine section consists of three (3) steel pipes (two 1,670 mm outside diameter (OD) and one 1,220 mm OD, buried approximately 6 m below the river bed. These steel outfall pipes transport effluent to a system of riser pipes which release the effluent into the Fraser River. The outfall pipes are buried in the same trench as the existing South Surrey Interceptor (SSI).

The capacity of the existing outfall is approximately14.5 m^3/s and dilution ratios at the edge of the Initial Dilution Zone (IDZ) have been estimated to be as low as 7:1 under adverse conditions. The existing outfall currently has neither the capacity to handle anticipated Stage V flows (18.9 m^3/s) nor the ability to meet the desired dilution ratio of 20:1 under several discharge scenarios. Further, MVs' Seismic Design Criteria based on the National Building Code of Canada 2010 (NBCC 2010) requires new wastewater facilities to be designed as post-disaster level facilities, capable of remaining operational following a seismic event with an annual exceedance probability (AEP) of 1 in 2,475. The existing outfall system does not meet this criterion.

1.2 New Outfall System

1.2.1 Black & Veatch Preliminary Design

To address these deficiencies associated with the existing outfall system, Black & Veatch (B&V) was retained by MV to prepare a conceptual and preliminary design of outfall upgrades for the AIWWTP. Their Preliminary Design Brief (Black & Veatch, 2015) recommended an option that included two outfall alignment corridors, termed the Western Tunnel corridor and Central Tunnel corridor, each terminating in a diffuser pipe at the edge of the Fraser River shipping channel. For each of these corridors, deep and shallow tunnel alignment options were proposed between the AIWWAP and the Fraser River as shown on **Drawing No. C-001**.

1.2.2 Request for Proposal

Metro Vancouver issued Request for Proposal (RFP) No. 14-097 titled Annacis Island Wastewater Treatment Plant Transient Mitigation and Outfall – Consulting Engineering Services. CDM Smith was selected for this work with the first phase (Phase A) consisting of reviewing of the previously completed work and recommending options for final design (Phase B). To ensure that MV implements the best options for the outfall, CDM Smith is conducting an outfall system options analysis to a sufficient level of detail to adequately support a recommended option that achieves MV's objectives for the outfall, stated in the RFP as follows:

1. To provide an outfall system with a total capacity of 25.3 m^3/s (i.e. Stage VIII Peak Wet Weather Flow) at a river level of 103.18 m without impacting the hydraulic gradeline of the treatment plant and
2. To achieve a minimum dilution ratio of 20:1 under slack water and low flows in the river.

An outfall system option analysis is required by the RFP and includes a qualitative and quantitative evaluation of each option's advantages and disadvantages, the frequency which the desired 20:1 dilution ration can be achieved, reliability, post-disaster issues, operational issues, constructability, and risks. Per the RFP, the following minimum four (4) options are to undergo the outfall system options analysis:

1. One new gravity outfall with a capacity of 25.3 m^3/s;
2. Two new gravity outfalls with a total capacity of 25.3 m^3/s;
3. One new gravity outfall which supplements the existing outfall for a total combined capacity of 25.3 m^3/s; and
4. One new outfall to provide a capacity of 25.3 m^3/s via a new pump station.

1.3 Purpose

The purpose of this report is to define and describe: 1) the process of refining the outfall system options to be utilized in the options analysis, 2) the methodology used for evaluating outfall system options based on cost and risk, and 3) recommend an option for final design. The options selected for analysis are meant to represent comparable options for the purposes of the analysis and development of a recommended option. Specific elements of the recommended option may be further refined or modified in the final design to achieve the project that provides the best value to Metro Vancouver.

Once the recommended option receives MV support, a Preliminary Design Brief will be prepared detailing its design basis and presenting a concept design for the outfall system portion of the project.

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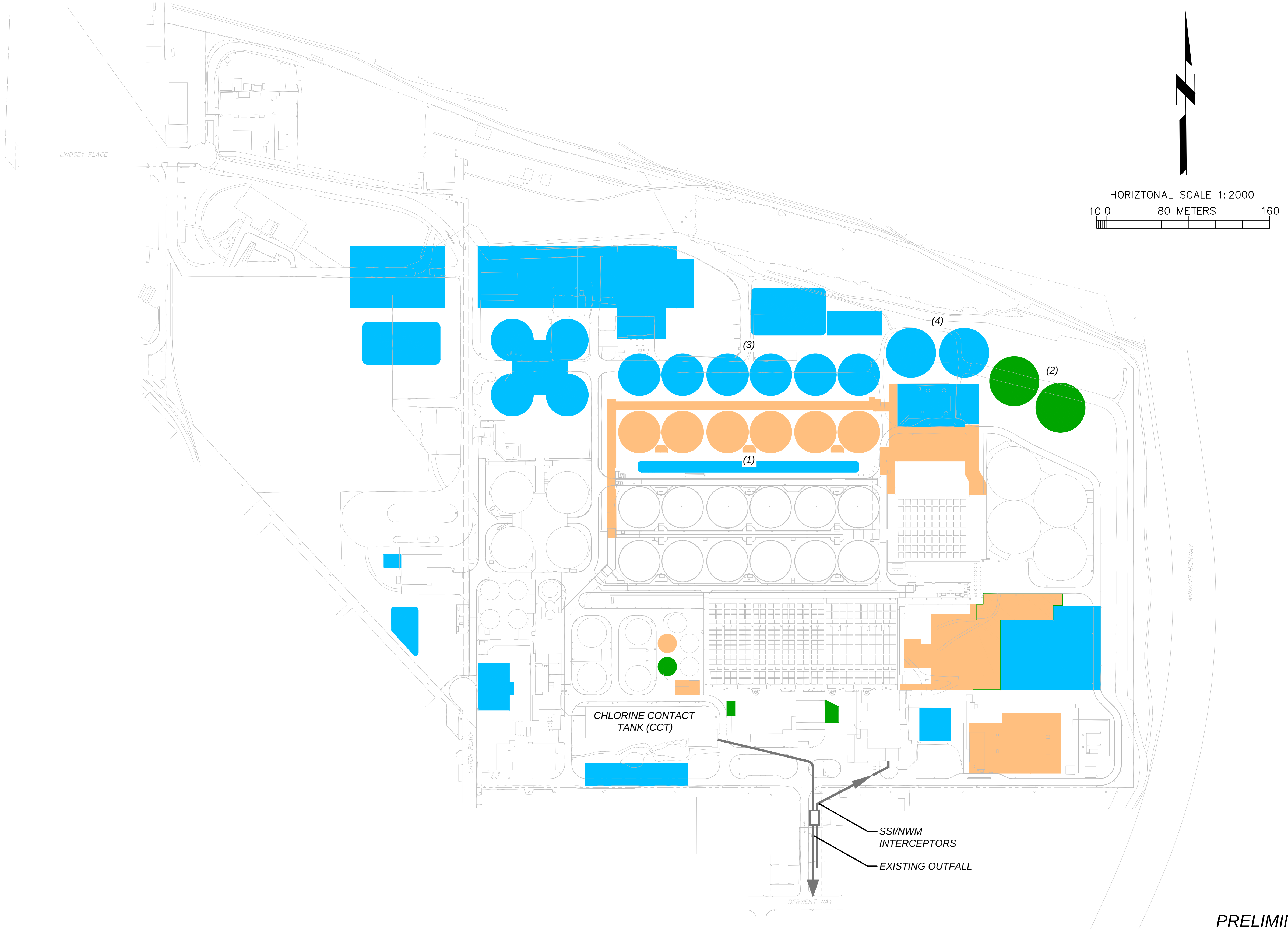

LEGEND

(1) SECONDARY CLARIFIERS

(2) TRICKLING FILTERS

(3) DIGESTERS

(4) TRICKLING FILTERS

STAGE V – PHASE 1

STAGE V – PHASE 2

STAGE VI – VII, FUTURE

PRELIMINARY - NOT FOR CONSTRUCTION

CDM Smith

CHECK PRINT

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Issue	Date	Des'n	Dr'n	Chkd	App'd	Description
A	–	XXX	XXX	XXX	?	ISSUED FOR RFP –– –––

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Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

PLAN LAYOUT AND FUTURE IMPROVEMENT

SCALE: 1:2000

DISTRICT FILE ##–####

DRAWING NUMBER FIGURE 1–1

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PRELIMINARY - NOT FOR CONSTRUCTION

NOTES:

1. COORDINATES ARE IN UTM NAD83 ZONE 10 – 4.0.0.BC.1.GVRD CONVERTED TO GROUND LEVEL USING A COMBINED SCALE FACTOR OF 1.000397558.
2. ELEVATIONS ARE IN METERS AND REFER TO CVD28GVRD – GEODETIC DATUM PLUS 100 METERS AND TIED BENCHMARKS 87H3500 (ELEV. 3.699) and 87H3493 (ELEV. 3.514).
3. THE TUNNEL PROFILE IS SUBJECT TO CHANGE BASED ON RESULTS OF GEOTECHNICAL INVESTIGATIONS AND FURTHER ENGINEERING EVALUATION.
4. DEEP TUNNEL ALTERNATIVE PROFILE ESTABLISHED BASED ON EMPIRICAL LIQUEFACTION ANALYSES & TO AVOID POTENTIAL SETTLEMENT UNDER BUILDING DURING MINING.
5. FOR MORE DETAILS REGARDING THE TUNNEL/DIFFUSER CONNECTION, REFER TO PDB.

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Building a world of difference.

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–	OCT. 2014	–	–	–	–	ISSUED FOR CLIENT REVIEW

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GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

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Drawn: AG
Checked:
Approved
Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

OVERALL PROJECT SITE PLAN

SCALE: AS NOTED
DISTRICT FILE ##-####
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Section 2

Option Refinement

2.1 Factors Considered

2.1.1 Topography/Bathymetry

The ground surface in the area surrounding the AIWWTP and both proposed outfall alignments is generally flat, with a nominal surface elevation of 104.5 m[1]. The ground surface remains generally flat or slopes gently toward the Fraser River, which has a design high water level of El. 103.18 and design low water level of El. 98.5.

Results of a 2013 bathymetry survey indicates distinct features such as rippling of the Fraser River bed and a large scour hole known as Mungo's hole. In general the river channel has a lowest bed level of approximately El. 85.0; however this varies in the area of Mungo's hole and existing South Surrey Interceptor. It is believed that Mungo's hole has been expanding since construction of piers for the Alex Fraser Bridge, and at the time of the 2013 survey, had a lowest bed level approximately 20.m below the surrounding river bed, and was approximately 400 m long.

2.1.2 Alignment Corridors

As discussed in **Section 1.2.1**, two horizontal corridors and four tunnel alignments (one shallow and one deep in each corridor) were identified by B&V for the effluent conveyance from the AIWWTP to the Fraser River. For the purposes of this option analysis, these corridors are considered the practical routes for new effluent conveyance conduits. Within each corridor, alignments primarily within the plant property and public right-of-way are preferred. For the West Alignment Corridor an alternative tunnel alignment, termed the West Corridor Alignment (Modified), was included that traverses private property. This alignment results in the longest tunnel; however, the riser end of the tunnel would be closest to the diffuser manifold minimizing construction in the Fraser River. These three alignments are shown on **Figure 2-1** and a discussion of each of alignment is presented below.

2.1.2.1 West Alignment Corridor

This corridor is in the mid-range (786 m) of the alignments considered between the AIWWTP and the Fraser River. The West Alignment Corridor starts at the east side of the Chlorine Contact Tank (CCT) and runs in the westerly direction crossing Eaton Place to a private parking lot. Then, the corridor turns in the southerly direction to run along the Fraser View Place while making a horizontal curve in the vicinity of Brewery Building to run in the south-easterly direction to the Fraser River. As discussed subsequently the termination of this corridor would be at a riser shaft serving the diffuser system approximately 150 m offshore.

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[1] All elevations are in meters and referenced to CVD28GRVD - Geodetic Datum (GD) plus 100 meters.

2.1.2.2 West Alignment Corridor (Modified)

This corridor is the longest corridor (862 m) of the alignments considered between the AIWWTP and the Fraser River. The corridor starts at the east side of the Chlorine Contact Tank (CCT) and runs in the westerly direction crossing Eaton Place in to a private parking lot. Then, the corridor turns in the south-easterly direction which runs under an existing building (Amazon Warehouse Building) located on land and an existing rail pier located in the Fraser River before stopping at a riser shaft serving the diffuser system approximately 150 m offshore.

2.1.2.3 Central Alignment Corridor

This corridor is the shortest corridor (683 m) of the alignments considered between the AIWWTP and the Fraser River. This corridor starts at the east side of the CCT located in the AIWWTP and running in the easterly direction towards the Influent Pump Station (IPS) located in the AIWWTP. Then, the corridor turns in the southerly direction in the vicinity of the IPS and runs towards the Derwent Way. After crossing Derwent Way, the corridor runs along Derwent Place to the Fraser River. As for the West Alignment Corridor, the termination of this corridor would be at a riser shaft serving the diffuser system approximately 125 m offshore.

2.1.3 Structures and Utilities

2.1.3.1 West Alignment Corridor

The first 295 m of the West Alignment Corridor runs from the CCT towards the Co-Generation Building within the AIWWTP property. For open excavation options, below-grade utilities may have to be temporarily relocated and/or bypassed. In addition, any construction in the vicinity of the Co-Generation Building requires maintaining its structural integrity.

The West Alignment Corridor shown on **Figure 2-1** generally follows the shallow western tunnel alignment identified by B&V. It is primarily within the established public right-of-ways (ROW), except for crossing a private property and a private parking lot.

The West Alignment Corridor makes a horizontal curve in the vicinity of Brewery Building to run in the in the south-easterly direction before crossing two rail road tracks owned by Southern Railway of British Columbia (SRBC). Then it continues running towards the proposed riser shaft and diffuser location in the Fraser River. Open cut or tunnel shaft excavations on this portion of the corridor will impact the near-shore environment.

2.1.3.2 West Alignment Corridor (Modified)

The first 295 m of the West Alignment Corridor (Modified) is the same as for the West Alignment Corridor. The remaining 567m of this corridor shown on **Figure 2-1** starts at the private parking lot and runs primarily through private properties until it crosses the two rail road tracks owned by SRBC. These private properties include one to two story warehouse-type structures. It is expected that these structures are founded on slab-on-grade foundations without basements or piles; however, no structural details for the structures in the area have been obtained at the time of preparation of this interim report.

After crossing two rail road tracks, the West Alignment Corridor (Modified) runs under the existing rail pier towards the proposed riser shaft location in the Fraser River. Open cut or tunnel shaft excavations on this portion of the corridor will impact the near-shore environment.

2.1.3.3 Central Alignment Corridor

The first 91 m of the Central Alignment Corridor runs from the CCT towards the IPS in the AIWWTP property crossing the existing outfall, South Surrey and New Westminster Interceptors. For open excavation options, maintaining uninterrupted operation conditions of the existing outfall, SSI, NWI would be required. In addition, any construction in the vicinity of the IPS requires maintaining its structural integrity.

The Central Alignment Corridor shown on **Figure 2-1** similarly follows the shallow central tunnel alignment identified by B&V. It is primarily also within the established public ROW. The deep central tunnel alignment shown as an option by B&V would also pass under one to two story warehouse-type structures similar to those on the western alignment.

The Central Alignment Corridor also crosses the SRBC railroad tracks before continuing to the proposed riser shaft and diffuser location in the Fraser River. Open cut or tunnel shaft excavations on this portion of the corridor will impact the near-shore environment.

2.1.4 Hydraulics

The new outfall will be designed to convey the full range of flows from the treatment plant ranging from minimum flows of around 4 m^3/s up to the Stage VIII peak capacity of 25.3 m^3/s. The outfall must be designed to effectively deliver this range of flows when the Fraser River is at the low level of 98.5 m up to the 200-year flood level of 103.18 m.

The chlorine contact basins are the last treatment process at the plant and are equipped with Amil Gates designed to maintain a constant water level upstream from the gates. According to the April of 2000 Contract A17 drawing A61 M5204, the Amil Gates will maintain a water surface elevation of 106.01 m in the chlorine contact basin with a water surface elevation downstream from the gates of 105.86 m for Stage VIII flows. According to the drawings, the top of the wall in the Amil Gate structure is 106.60 m. Since production of these drawings, the Amil Gates structure has settled approximately 22 cm and it is predicted to settle an additional 9 cm over the next 50 years.

For purposes of this preliminary design evaluation, is assumed that the water surface elevation in the chlorine contact tanks will need to be maintained at an elevation of 105.70 m for the long-term condition (106.01 m original design less 0.31 m settlement). The design 200-year flood level in the Fraser River is 103.18 m. To account for higher river water density from saline effects due to the seasonal presence of a salt wedge, the river was raised by 0.11 m to 103.29 m. The combined impact of settlement and river salinity reduces the allowable head loss for the design condition to 2.41 m (105.70 m to 103.29 m).

2.1.5 Geotechnical Conditions

Geotechnical investigations were conducted between July and September 2015 by Golder Associates (as a subcontractor to both B&V and CDM Smith) along the West and Central Alignment Corridors. Exploration locations and preliminary subsurface cross sections for the West and Central Alignment Corridors are shown on **Figure 2-2** and **Figure 2-4**, respectively. Additional geotechnical data was reviewed for the Stage V expansion project and other historic projects within the AIWWTP property. The following description of subsurface conditions is based on the historical data and review of the new data.

In general, the AIWWTP site is underlain by normally consolidated, compressible silt and sand. The general subsurface profile consists of surficial silt and sand fill, typically about 2 m thick, overlying loose to dense, clean, uniform sand to about 40 m below ground surface (bgs). The sand overlies silt with sandy interbedding grading to clayey silt at depth, overlying very dense glacial or interglacial deposits (Klohn Crippen Berger, 2013a).

Sand and gravel fill of varying thickness was encountered overlying the natural soils at the Annacis Academy site (Klohn Krippen Berger, 2010) and at the Codigestion Facility Site (Levelton Associates, 2010). The top of the dense glacial deposits was not encountered during any previous AIWWTP subsurface investigations and is therefore inferred to be at least 119 m bgs.

Figure 2-3 and **Figure 2-5** provide additional preliminary subsurface information for the West and Central Alignment Corridors, respectively. A legend is provided for the soil types shown and the 'stick' boring logs include annotation of SPT N-values indicative of soil density or stiffness.

For the West Alignment Corridor (**Figure 2-3**), conditions are similar to those at the AIWWTP near the plant; however, there are significant gravel layers above and within the clayey silt beginning between the plant and shoreline and continuing off shore. Also, the clayey silt layer is shallower in the nearshore area. The sand generally becomes denser between El. 75 to El. 70.

For the Central Alignment Corridor (**Figure 2-5**), conditions are similar to those at the AIWWTP with the sand becoming denser between about El. 75 to El. 70. The clayey silt was encountered between about El. 65 and El. 60.

Groundwater levels observed at the AIWWTP site vary with proximity to the river and with seasonal precipitation and tides. In general, the groundwater level within the outfall alignments is expected to be around El 101.0 to 101.5, with higher levels possible during periods of heavy precipitation or nearby higher flood or tidal river water levels.

2.1.6 Seismic Setting and Risk

Seismicity at the project site results from three basic sources or types of regional earthquakes:

- Relatively shallow crustal earthquakes (depths in the order of 20 km);
- Deeper earthquakes (depths in the order of 60 km) within the thrusting (subducting) offshore Juan de Fuca Plate beneath the continental North American Plate; and
- Very large inter-plate earthquakes, often referred to as the "mega-thrust" or "subduction" earthquakes.

Earthquakes within the first two categories (intra-plate) have occurred at regular intervals over the last several decades. The largest are those were near Campbell River in 1946 (M7.3), near Olympia in 1949 (M7.1), near Seattle/Tacoma in 1965 (M6.5), and in Nisqually in 2001 (M6.8). The duration of strong shaking of these two types of earthquakes is expected to be about 15 to 20 seconds. A very large earthquake apparently occurred near the USA/Canada border in 1872.

Large subduction earthquakes have not occurred in the region in historic time. However, there is geologic evidence that they have occurred in the past (possibly at 400 to 600 year intervals). The measured accumulation of strain between the tectonic plates suggests that these large earthquakes should be expected in the future. The consensus is that the magnitude of a large subduction earthquake would be in the order of M8.2+ occurring with the center of energy release located some 140 km from the project site.

MV's seismic design criteria refer to the 4th generation seismic hazard maps for the seismic design considerations, which were developed as input to the seismic design provisions in the National Building Code of Canada (NBCC, 2005) and refer to the upcoming 5th generation seismic hazard maps developed as input to the 2015 NBCC for future considerations. The 5th generation seismic hazard maps have been finalized recently with improvements in incorporating the epistemic uncertainties in the probabilistic seismic hazard assessment.

The site specific hazard parameters based on both 4th and 5th generation seismic hazard maps were obtained from the Geological Survey of Canada (GSC). The controlling event is a Magnitude 7.0 shallow crustal earthquake. Design ground motions as summarized in **Table 2-1** below and they correspond to a "reference ground condition" referred to as Site Class C and denoted by an average shear wave velocity (Vs) varying between 360 m/s and 760 m/s in the upper 30 m.

Table 2-1: Site-Specific Probabilistic Firm-Ground Motion Parameters (Site Class C)

Return Period (2,475 Years)	PHGA	Sa (0.2s)	Sa (0.5s)	Sa (1.0s)	Sa (2.0s)
NBCC 2010	0.51	1.04	0.69	0.34	0.17
NBCC 2015	0.36	0.84	0.75	0.42	0.25

Note: PHGA refers to peak horizontal ground acceleration; Sa refers to spectral acceleration for a given period.

Evaluation of the ground response along the outfall alignments is in progress. Based on the Preliminary Geotechnical Report (Technical Memo 6b) prepared for the AIWWTP Stage V expansion (Klohn Crippen Berger, 2013a) and recommendations in the NBCC:

- The average shear wave velocity near the surface is approximately 140 m/s, increasing to approximately 240 m/s, at a depth of 30 m.
- Liquefaction of the loose sands is expected from the water table depth to a depth of approximately 30 m to 35m.
- Liquefaction could result in ground surface settlement of 550 mm to 1,180 mm.
- Differential settlements may be up to 50% of the estimated total settlement.

In addition, more detailed seismic studies including both one and two dimensional non-linear site response analyses are planned at the 30% design. The analyses will incorporate firm ground acceleration time histories as input to the wave propagation models and the results of advanced laboratory testing including cyclic simple shear tests especially on silt. Limited cyclic simple shear tests were already completed on silt and additional tests are planned.

Seismic hazard parameters consistent with NBCC 2010 and NBCC 2015 are recommended. The seismic hazard parameters associated with the NBCC 2010 will be considered for design compatibility with Stage V expansion, especially for the tie-ins. The liquefaction potential of the sand and silt underlying the site and the extent of liquefaction will be established based on the site specific ground response analyses. A liquefaction assessment for the existing outfall is not planned; however, one will be performed as part of the design for a truncated outfall. To the extent that the existing outfall infrastructure will be retained, it will be included as part of the design for the truncated outfall.

2.1.7 Archeological

A letter report prepared as part of B&V's conceptual design (AMEC, 2014) indicates a total of 25 documented archaeological sites are recorded within a 4-km radius of the project site, however only one site actually lies within the proposed outfall location. This site is a 1000 m long stretch of the Fraser River foreshore downstream of the Alex Fraser Bridge. The site is comprised of scattered wooden fish weir stakes, stone artifacts, and mammal bones.

The landward portion of the site towards the existing AIWWTP was historically used for low-impact farming, and a traditional fishing camp may have existed in this area, with its remnants buried deeply below the fill that now covers the project site. If they exist, these remnants may be encountered during excavations near the AIWWTP and along the proposed outfall alignments.

Due to the likelihood of encountering archaeological remnants, a high archaeological resource potential has been assessed to the Fraser River foreshore area in the vicinity of the proposed outfall alignments. The landward and offshore areas were assessed a low potential due to their historic use as low-impact farmlands.

2.1.8 Fluvial Geomorphology

Changes in the bathymetry of the Fraser River have been observed previously and are expected to continue following the construction of the new outfall. Both erosion and deposition are occurring simultaneously within the Fraser River channel in the vicinity of the proposed outfall alignments. Recent surveys are being reviewed and geomorphological models are being prepared in order to better evaluate the effect of these processes on the riverbed bathymetry.

B&V (Black & Veatch, 2015) noted that the northern side of the navigation channel in the vicinity of the Central Corridor has experienced a trend of slow erosion, with bed levels gradually falling between 1999 and 2013. In the vicinity of the West Corridor, it was noted that the northern side of the channel is relatively shallow and that deposition is expected in this area since it is on the inside of the river bend.

2.1.9 Fraser River Shipping Channel

Port Metro Vancouver (PMV) currently performs maintenance dredging between June 16 and the end of February (once every year or two) within the established channel along the Fraser River. Dredge depths are referenced to the navigation chart datum which varies along the river. In the vicinity of AIWWTP chart datum is approximately El. 98.41. The minimum depth of the channel is 10.9 m below chart datum (El. 87.51); however, PMV dredges below this depth to a 'subgrade' elevation which PMV reported to vary from 1.8 m and 2.1 m below the minimum channel depth between the vicinity of the Central Alignment Corridor and the vicinity of the West Alignment corridor, respectively.

PMV indicated that Fraser Surrey Dock (FSD) is contemplating future plans to deepen and widen the shipping channel. This could include deepening the river channel by 1 m to 2 m and widening would be limited to a maximum of about 50 m outside the current limits of the shipping channel.

2.1.10 Operations and Maintenance

The in-river sections of the new outfall will require annual external inspections to confirm that scour protection measures are functioning effectively. This inspection is likely to be conducted through the use of sonar bathymetric surveys as is currently practiced by MV. External inspections by divers or remotely operated vehicles (ROVs) is also likely be required on an annual basis to visually inspect the condition of risers, flanges, diffuser ports, and any potential debris or obstructions along the outfall alignment. Repairs can then be conducted as necessary.

Interior inspection of the outfall is also required, but on a less frequent 5- to 10-year basis. Inspection may also be warranted following a major seismic event that results in significant ground displacement in the AIWWTP vicinity. These inspection are likely to be conducted using ROVs due to the hazards associated with man entry into the outfall conduits.

2.2 Option Elements

In refining elements of the options to be carried forward for the outfall system options analysis, CMD Smith considered all the factors described in **Section 1.2**. This section describes aspects of each option selected for analysis, why these were selected, and the extent to which they vary from aspects of the previous conceptual and preliminary designs prepared by B&V (Black & Veatch, 2015).

2.2.1 Conveyance Alignment, Conduits, and Shafts

2.2.1.1 Effluent Conveyance Alignment

To the extent practical, buried conduits or tunnels should be located on property owned by MV and the public street right-of-way. This will minimize risks of damage to structures on private property. CDM Smith's experience is that negotiation of easements under private property occupied by structures can be a complex, costly, and lengthy process which often significantly increases project cost and/or project delays. Therefore, the corridor alignments for the selected options generally are consistent with the "shallow tunnel alignments" identified by B&V. An exception is an alternative for the Western Alignment that would pass through private properties such that the river riser could be located closer to the center of the diffuser manifold.

2.2.1.2 Buried Conduits vs. Mined Tunnels

Buried Conduit is typically installed via an open-cut method. Open-cut methods are the most common installation type for pipe and box culverts. Open-cut excavations include trenching ground, placing the pipe, backfilling the trench and then restoring the surface area to the original condition. An excavation support system is required for open-cut depths greater than 1.25 m. Excavation support system may consist of the use of trench boxes, convention shoring or sloping the sides of the excavation. Dewatering may also be required, if the groundwater level happens to be above the required excavation depths.

For the purpose of this report, two types of excavation methods were considered for the Mined Tunnel option. The two excavation methods consist of using a microtunnel boring machine (MTBM) with a jacked pipe or a tunnel boring machine (TBM) to excavate the tunnel. Both methods feature a closed face to maintain face stability; laser guided alignment control, and the capability to excavate alignments with simple curves. Both tunneling methods provide constant positive face pressure and hydrostatic pressure to provide a counterbalance to the driving forces that are moving toward an open tunnel face. The face pressure could prevent catastrophic ground loss during tunneling. Excavated soil is transported to the surface by a slurry pumping system. Both machines are launched from a shaft at the design invert elevation. The applicability of these methods for this project is further discussed in Section 3.

While the construction of buried conduits will result in significant surface disturbance, traffic interruption and congestion, and impacts to utilities and nearby structures, they are significantly less expensive than mined tunnels. For the outfall project, this cost savings will be partially offset by requirements for ground improvement or pile foundations to meet post disaster seismic design standards, and further offset by the potential mitigation measures required to address impacts to public and private property and commercial operations. Similarly to the B&V conceptual and preliminary design, the selected options utilize mined tunnels for the majority of the effluent conveyance alignments. However, options were selected that include buried conduit portions primarily located on the AIWWTP property for comparative analysis of potential project savings.

2.2.1.3 Limited Shaft Locations

The B&V conceptual and preliminary designs included tunnel launch shafts in the nearshore area near the end of the Fraser View Place and Derwent Place ROW corridors. None of the selected options include shafts south of Derwent Way since shafts in these areas (and in particular launch shafts) present significant construction impacts and risks due to limited access, vehicle traffic and railroad infrastructure impacts, and nearshore environmental and archeological conditions. The nearshore area is susceptible to lateral spreading and slope failure during strong seismic shaking placing any permanent shallow outfall system components in this area at risk.

The selected options were selected based on minimizing the overall number of shafts since they can be particularly expensive to construct, particularly for deeper tunnel alignments.

2.2.1.4 Potential Pump Station

Results of a preliminary multiport diffuser design and initial dilution modeling for the terminus (diffuser) of the outfall system for the AIWWTP have indicated that the wide range of potential flows to the outfall system with future plant expansions will make it very difficult to design a diffuser system that will meet regulatory guidelines and MV objectives given the available head, therefore, a pump station will be required to increase head driving the effluent discharge in future plant expansions (after Stage V).

While only one option includes a pump station for the design condition in the RFP, MV also anticipates that pumping to increase the effluent driving head may be required in the future to offset head losses due to global warming rise in river levels and long-term settlement of the AIWWTP facilities. The B&V conceptual and preliminary design included considerations for future pump stations constructed at the location of the nearshore tunnel launch shafts. Options selected for analysis include considerations for either a future pump station near the CCTs or at launch shafts located in private parking lots.

2.2.1.5 River Risers and Shafts

Shafts or riser pipes need to be constructed within the Fraser River to transition the effluent flow from the conveyance tunnels to the near surface diffuser systems. The B&V conceptual and preliminary designs had riser shafts located at the edge of the shipping channel. The selected options all include shafts or riser pipes constructed 50 m outside the current shipping channel. Two main factors influenced this selection. First, construction of the risers and shafts will require barges and other equipment to be located in the area for significant, sustained periods. Placing the shafts and risers away from the limits of the shipping channel boundary minimizes potential construction impacts on ship traffic. Second, these shafts and risers and their connection to the tunnel are key components of the outfall system that are not easily modified. Placing them away from the limits of dredging and outside the likely limits of possible future channel widening minimizes risks that they will need to be modified in the future. However, placing the risers closer to, or at the edge, of the shipping channel will reduce the need for distribution piping between the risers and diffusers; therefore this will continue to be considered during final design.

2.2.1.6 Vertical Tunnel Alignment

The invert for the mined tunnel segments in each selected option is located just below the depth of anticipated significant ground displacement during and after a strong seismic event. This minimizes the risk of damage to the tunnels during strong seismic ground shaking and subsequent ground deformation and eliminates requirements for ground improvement for these segments. However, lowering the tunnel invert elevation any deeper than required for seismic risk mitigation greatly increases both tunnel and shaft construction costs and risks. The B&V conceptual and preliminary design for the deep tunnel alignment options had much deeper invert elevations, particularly at the river end of the tunnels.

2.2.2 WWTP Connection and Diffuser System

Specific design requirements for the connection of the outfall system to the existing CCTs and for the diffuser system were of less significance in selecting options for analysis since they will be similar for each option. The general nature of these elements are discussed in this section.

2.2.2.1 WWTP Connection

Currently, treated effluent from the plant discharges from the Chlorine Contact Tank (CCT) through two Amil gates before entering an on-land box conduit that flows southward to the Fraser River. The Amil gates ensure that there is minimal level fluctuation within the CCT by regulating flow of effluent into the existing outfall. The B&V conceptual and preliminary design considered installation of two additional Amil gates and short transition channels to connect the flow to two separate nearby tunnel drop shafts. For the purposes of the outfall system options analysis, similar configurations will be considered and are not considered to be a significant factor in the analysis. For the final design, other options for connecting the selected outfall system will be considered and included if found to provide operational or cost advantages.

2.2.2.2 Diffuser System

CDM Smith prepared a draft report (**Appendix B**) that presents a preliminary multiport diffuser design and initial dilution modeling for the terminus (diffuser) of the outfall system for the AIWWTP for the purpose of identifying what can be achieved in terms of dilution and mixing within the physical constraints identified in the preliminary concept development (Black and Veatch, 2015).

Early modeling of the diffuser system made it evident that the project's dilution objectives could not be achieved using a gravity outfall system, particularly for the maximum future (Stage VIII plant expansion) effluent flow combined with the 200-year flood stage on the Fraser River. Since future plant capacity expansions, beyond the current Stage V expansion project, are anticipated to only be required several decades in the future, CDM Smith recommends the preliminary diffuser design be optimized for Stage V flows using the majority of available gravity head. The diffuser would still be designed such that it could be modified to accommodate higher future flows. Initial dilution modeling was performed using this preliminary design to estimate achievable dilution and mixing in the Fraser River. Under this scenario, future plant capacity expansions are likely to require pumping to augment the available hydraulic head.

This draft report describes the physical constraints, regulatory requirements, preliminary diffuser design, Fraser River and effluent data used as inputs for the diffuser modeling, and initial dilution modeling results. It also describes how the diffuser system would be expanded for future Stage VIII flows, estimated pumping requirements, and presents preliminary dilution modeling for these future flows.

The following are the elements of the preferred diffuser design presented in the respective draft report: **Figure 2A** shows a schematic of the diffuser along the edge of the navigation channel.

- A 240-m long diffuser manifold would be located at the edge of the navigation channel. The manifold would connect to the main vertical riser from the tunnel at its western end.
- The manifold would have 24 risers about 750 mm in diameter with ports discharging horizontally pointed toward the center of the river. All of the risers would be open at Stage VIII when peak wet weather flow was 25.3 m^3/s; at Stage V, six of the risers would be blocked off to aid in increasing dilution.
- The ports would be fitted with variable orifices (e.g., Tideflex diffuser valves) to increase exit velocities at low effluent flows. These valves will also reduce sediment entering the diffuser system.
- The diffuser risers would be protected by a conical sleeve or cap to protect the risers from anchors, ship strikes and submerged debris. The sleeve needs to accommodate access to the port terminus to permit maintenance of the variable orifices.
- The end of the manifold should be fitted with a bulkhead to facilitate internal access and/or cleaning.

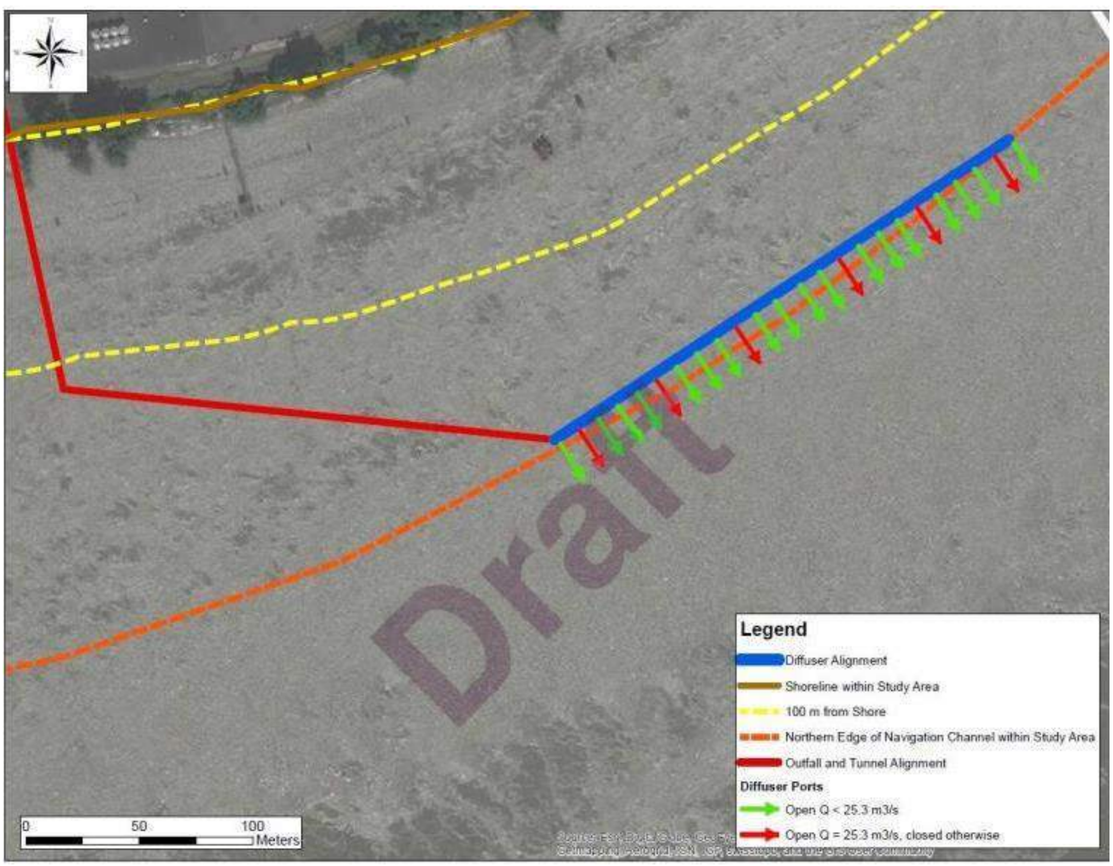

Figure 2A - Schematic of the diffuser along the edge of the navigation channel

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CDM Smith

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Professional Seal

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0 20 Bar is 20mm On Original Drawing. If Not On This Sheet, Adjust Scales Accordingly.

Design: INT.
Drawn: INT.
Checked: INT.
INT. Approved
INT. Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

ALIGNMENT CORRIDOR OPTIONS

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 2–1

SUPERSEDES PRINTS OF THIS DRAWING NUMBER WITH LETTERS PREVIOUS TO ➡ A

2013-10-09 GVRD 3DCivil Template.dwg
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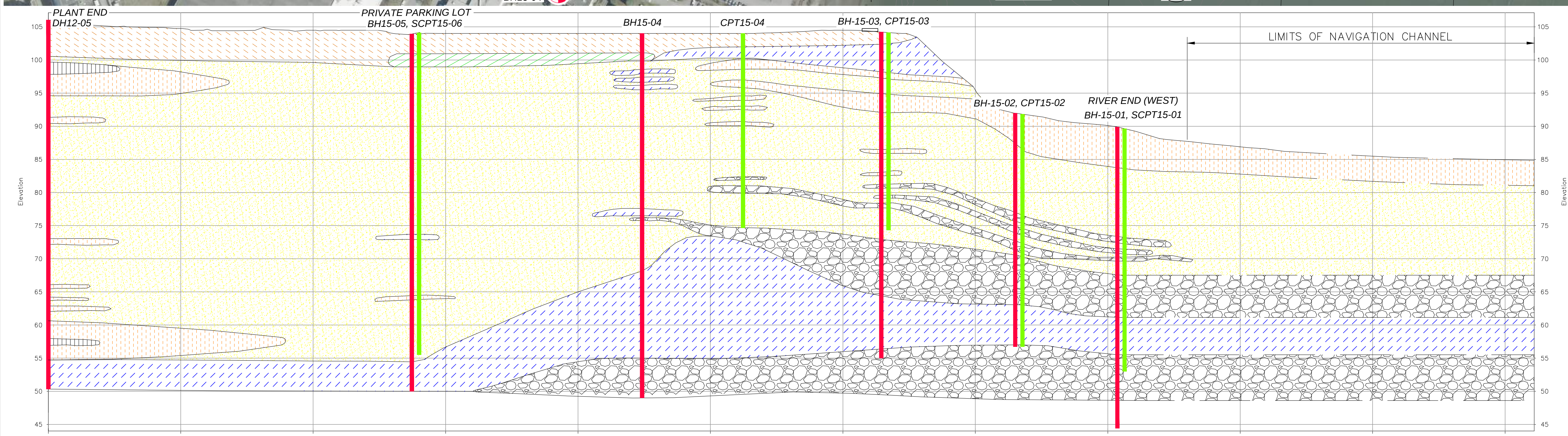

PROFILE

PRELIMINARY - NOT FOR CONSTRUCTION

LEGEND

- BORINGS DRILLED IN 2013
- BORINGS DRILLED IN 2015
- CPT LOGGING CONDUCTED IN 2015

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Professional Seal

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Drawn: INT.
Checked: INT.
INT. Approved
INT. Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

SUBSURFACE PROFILE ALONG WEST ALIGNMENT CORRIDOR

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 2-2

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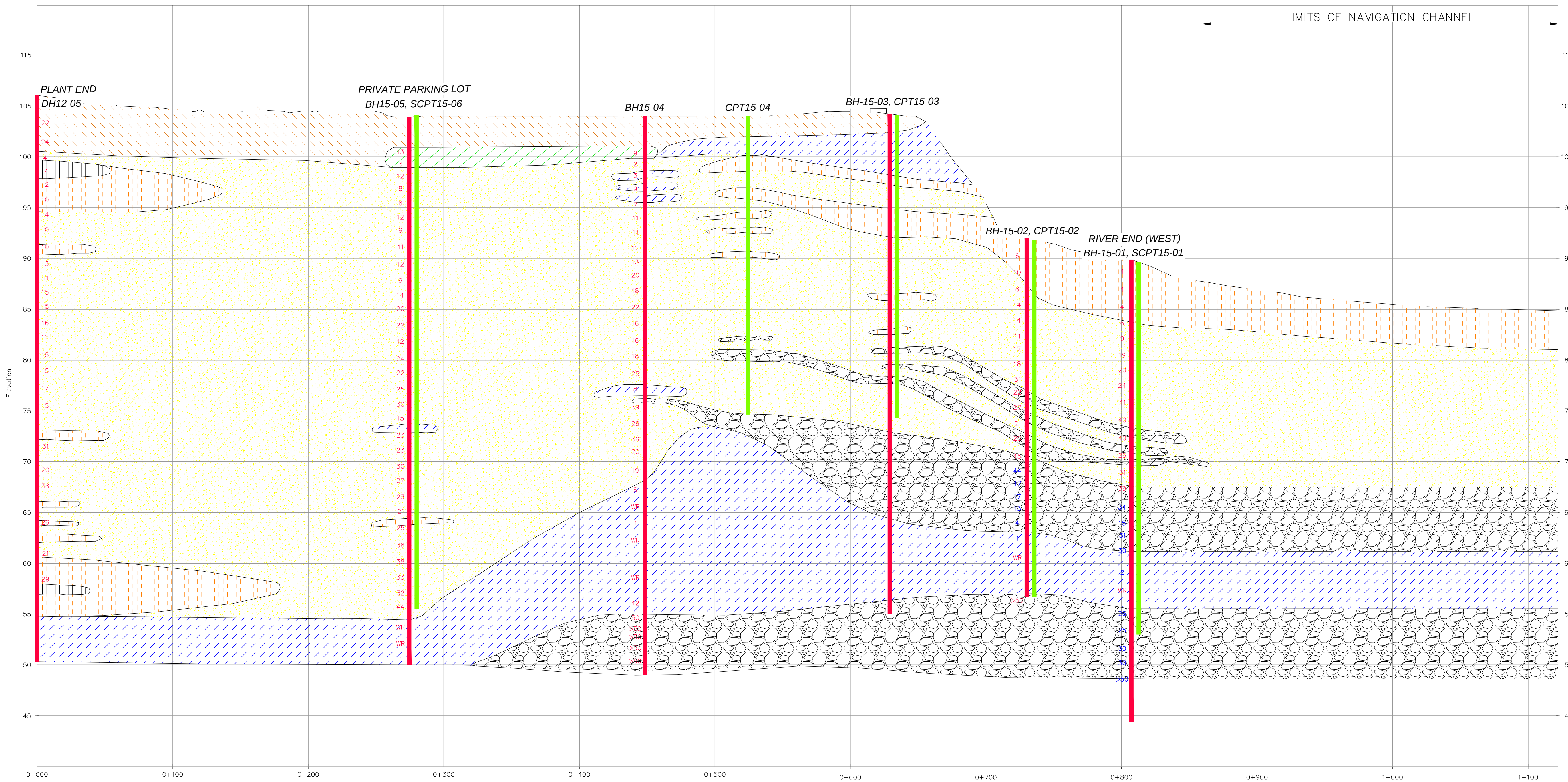
2015-10-09 GVRD 30Civil Template.dwg

xref files:



PROFILE

VERTICAL SCALE 1:200

3 0 15 METERS

HORIZTONAL SCALE 1:1500

20 0 80 METERS 160

LEGEND

- FILL
- PEAT
- SAND
- SILTY SAND/SILT
- SILT/ORGANIC SILT
- GRAVEL
- CLAYEY SILT
- 4 SPT N-VALUE
- 30 UNCORRECTED LPT BLOW COUNTS

PRELIMINARY - NOT FOR CONSTRUCTION

CDM Smith

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Professional Seal

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Design: INT.
Drawn: INT.
Checked: INT.
INT. Approved
INT. Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

ENLARGED SUBSURFACE PROFILE ALONG WEST ALIGNMENT CORRIDOR

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 2-3

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2015-10-09 GVRD 30Civil Template.dwg

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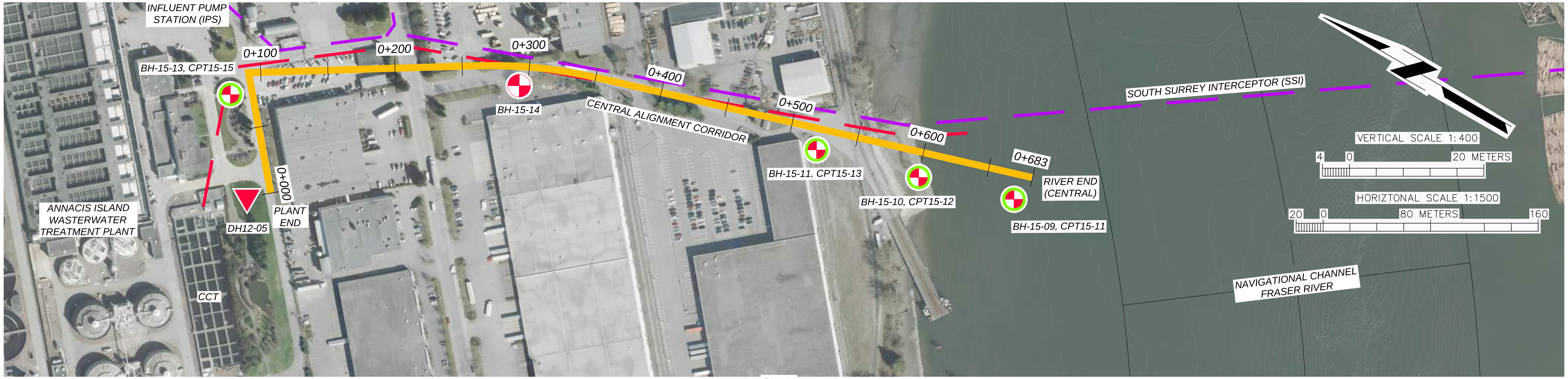
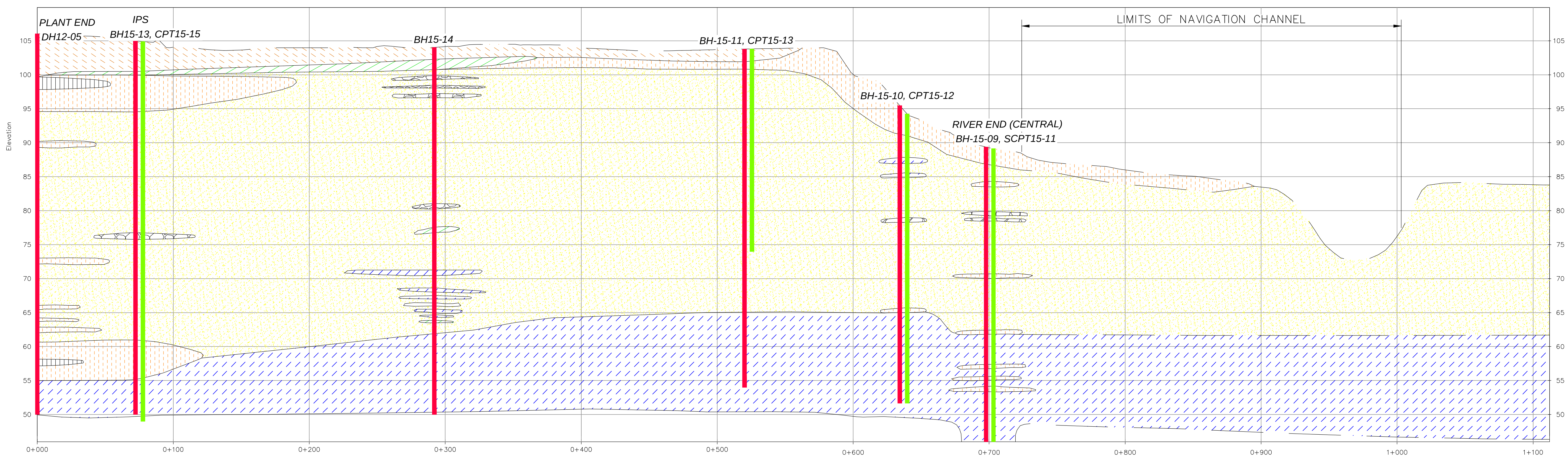


PLAN

1:1500

A
–



PROFILE

PRELIMINARY - NOT FOR CONSTRUCTION

LEGEND

- BORINGS DRILLED IN 2013
- BORINGS DRILLED IN 2015
- CPT LOGGING CONDUCTED IN 2015

CDM Smith

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Professional Seal

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Drawn: INT.
Checked: INT.
INT. Approved
INT. Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

SUBSURFACE PROFILE ALONG CENTRAL ALIGNMENT CORRIDOR

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 2-4

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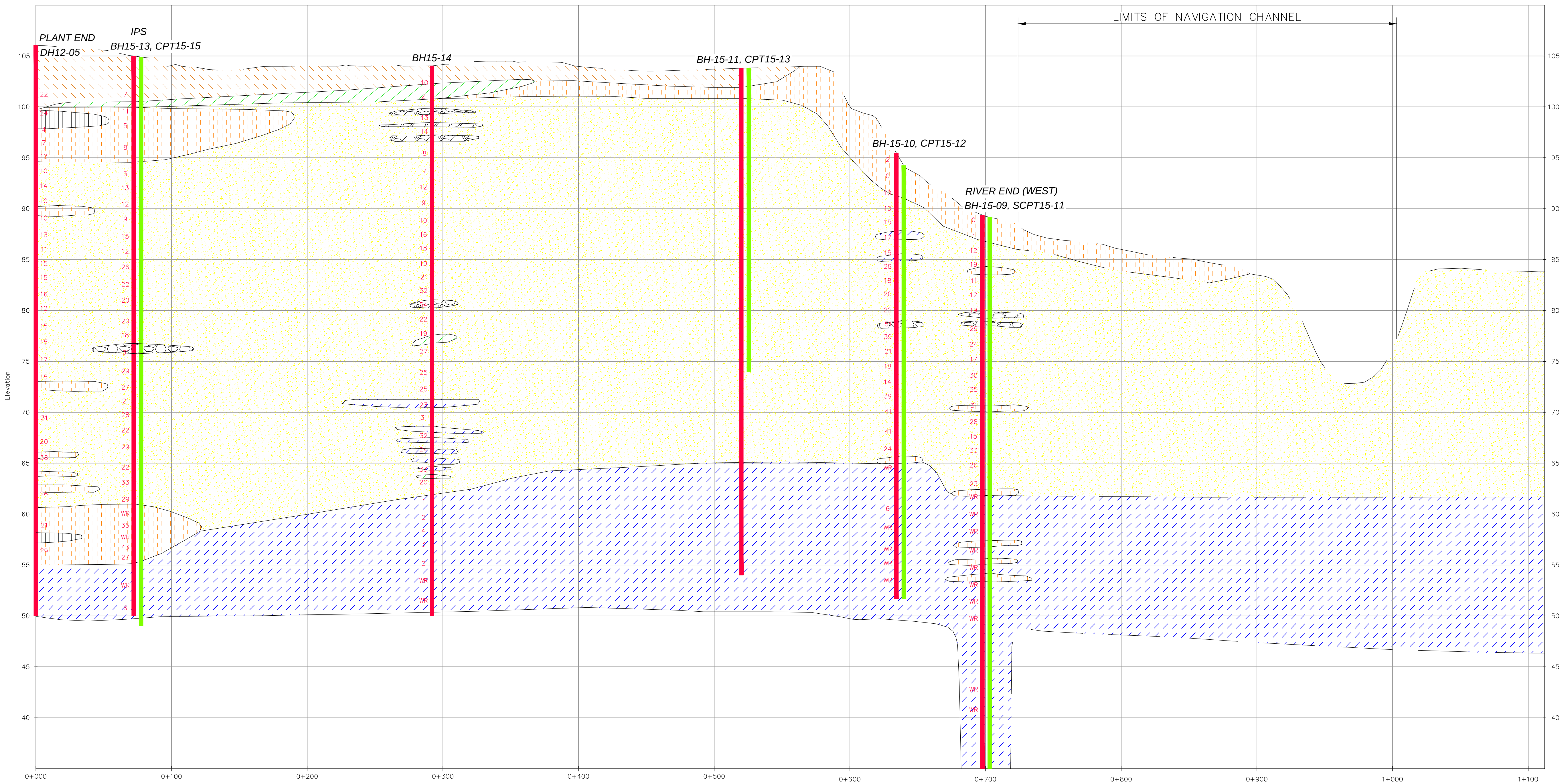

PROFILE

VERTICAL SCALE 1:200

3 0 15 METERS

HORIZTONAL SCALE 1:1500

20 0 80 METERS 160

LEGEND

- FILL
- PEAT
- SAND
- SILTY SAND/SILT
- SILT/ORGANIC SILT
- GRAVEL
- CLAYEY SILT
- 4 SPT N-VALUE

PRELIMINARY - NOT FOR CONSTRUCTION

CDM Smith

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Drawn: INT.
Checked: INT.
INT. Approved
INT. Manager

ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

ENLARGED SUBSURFACE PROFILE ALONG CENTRAL ALIGNMENT CORRIDOR

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 2-5

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Section 3

Options Selected for Analysis

3.1 Overview

As discussed in **Section 2**, two excavation methods were considered for tunnel excavation – use of a microtunnel boring machine (MTBM) with a jacked pipe or use of a tunnel boring machine (TBM).

Although, the MTBM method may have some length limitations due to the proposed tunneling lengths, which very between 683 m and 852 m; such limitations can be overcome by using intermediate jacking stations (IJS) which are jacking units installed within the line of pipes being jacked. However, this limitation does not apply to conventional tunneling and the proposed tunneling length for this project is achievable with conventional tunneling method.

The proposed tunnel diameters for the proposed outfall options vary between 3.0 m and 4.2 m. Microtunneling is typically performed for tunnels with internal diameters of 2 m or smaller, but the recent advances in microtunneling allow MTBM units to be custom made as big as 3.2 m in inside diameter. Microtunneling is not practical for larger tunnels. For the purposes of the option analysis, only the larger diameter tunnels were considered for consistency and discussed in this report. Microtunnels could possibly be used under Options 2 and 4. If so, the cost could be reduced some; however, risk issues were identified that would tend to offset the cost difference.

Thus, it was assumed that a TBM will be used for the excavation and it was also assumed that TBM will be abandoned at the end of construction as retrieving the entire TBM machine "in the wet" is a risky operation. Such operation would require daylighting the tunnel in the river bottom or construction of a large retrieval shaft extending into the river bed. Given the local geologic conditions, CDM Smith does not believe daylighting is practical. Constructing a retrial shaft in river is very expensive and considered to more than offset the cost of abandoning the TBM. For the option of abandoning the TBM in place, it was assumed that the contractor would "gut out" the useful parts inside the TBM basically leaving the shield in place.

Regardless, the contracting strategy will include providing options for the contractor with regard to the TBM including: a range of possible larger tunnel diameters to possibly facilitate using a factory refurbished used TBM as well as potential cost saving options for TBM abandonment or retrieval.

Based on a preliminary evaluation, CDM Smith believes that the two of the four outfall options (Options 1 and 4) required by the RFP should be expanded into three (3) sub options, resulting in a total of eight (8) options. These sub options are: 'a' – West Alignment Corridor with a combination of buried conduit and tunnel; 'b' – West Alignment Corridor with mined tunnels only; and 'c' – Central Alignment Corridor.

The West Alignment Corridor and West Alignment Corridor (Modified) are considered to be similar and not considered independently. However, sub option 'a' and 'b' were considered independently since a combination of a buried conduit (open-cut installation) segment and a mined tunnel segment might yield cost savings for MV as compared to only mined tunnel segments. A buried conduit segment was only considered along for the West Alignment Corridor, as an open-cut installation within the plant section of the Central Alignment Corridor would be extremely difficult due to the need for relocation of the existing outfall, South Surrey Interceptor (SSI) and New Westminster Interceptor (NWI).

Table 3-1 summarizes these eight (8) options selected for the Outfall System Options Analysis. These options are also illustrated in **Figure 3-1** and they are further described in subsequent sections of this report.

Table 3-1: Outfall Options and Estimated Dimensions

Outfall Options	Estimated Dimensions	Description
Option 1a: West Corridor or West Corridor (Modified) with buried conduit & mined tunnel	Buried conduit: ~4 m x 3.5 m Mined tunnel: ~4.2 m ID	A buried conduit from the CCTs to a launch shaft located in the private parking lot and a mined tunnel from the launch shaft to river riser (West)
Option 1b: West Corridor or West Corridor (Modified) with mined tunnel	Mined tunnel: ~4.2 m ID	A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft near the CCTs and a mined tunnel from the launch shaft to the river riser (West)
Option 1c: Central Corridor with mined tunnel	Mined tunnel: ~4.2 m ID	A mined tunnel from a launch shaft located in the vicinity of IPS to a receiving shaft near the CCTs and a mined tunnel from the launch shaft to the river riser (Central)
Option 2: West Corridor or West Corridor (Modified) and Central corridors with mined tunnels	Mined tunnel: ~3.4 m ID	West: A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft near the CCTs and a mined tunnel from the launch shaft to the river riser Central: A mined tunnel from a second launch shaft located in the vicinity of IPS to the same receiving shaft near the CCTs and a mined tunnel from the second launch shaft to the river riser
Option 3: West Corridor or West Corridor (Modified) mined tunnel & the existing outfall	Mined tunnel: ~3.6 m ID	A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft near the CCTs and a mined tunnel from the launch shaft to the river riser to supplement the existing outfall
Option 4a: West Corridor or West Corridor (Modified) with buried conduit, mined tunnel, and pump station	Buried conduit: ~3.5 m x 2.1 m Mined tunnel: ~3.0 m ID Pump station: 25 m by 20 m	A buried conduit from the CCTs to a launch shaft located in the private parking lot and a mined tunnel from the launch shaft to a river riser (West) with a pump station near the CCTs
Option 4b: West Corridor or West Corridor (Modified) with mined tunnel and pump station	Mined tunnel: ~3.0 m ID Pump station: 25 m by 20 m	A Mined Tunnel from a Shaft located in the Private Parking Lot to Plant End and a Mined Tunnel from the shaft to River End (West). A pump station would be located near the CCTs
Option 4c: Central Corridor with mined tunnel and pump station	Mined tunnel: ~3.0 m ID Pump station: 25 m by 20 m	A mined tunnel from a launch shaft located in the vicinity of IPS to a receiving shaft near the CCTs and a mined tunnel from the launch shaft to the river riser (Central). A pump station would be located near the CCTs

3.2 Option Descriptions

3.2.1 Option 1 - One New Gravity Outfall

3.2.1.1 Option 1a – West Corridor with Buried Conduit & Mined Tunnel

Option 1a includes a buried conduit and a mined tunnel through the West Alignment Corridor or West Corridor (Modified) as illustrated in **Figure 3-2**. This option includes the construction of one launch shaft in the private parking lot and ground improvement or pile foundations along the proposed buried conduit alignment. The anticipated construction includes:

1. Ground improvement or pile installation followed by excavation and construction of a buried conduit from WWTP in the vicinity of the CCTs to a launch shaft located in the private parking lot;
2. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
3. One riser pipe (3.8 m ID) installed at the end of the outfall; and
4. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The buried conduit is anticipated to be approximately 4.0 m x 3.5 m and the internal diameter of the mined tunnel is anticipated to be approximately 4.2 m. The length of the buried conduit is about 295m and the approximate length of the tunnel is 491 m or 567 m, along the West Alignment Corridor and the West Alignment Corridor (Modified), respectively.

The invert of the buried conduit is anticipated to be at El. 99. It is also anticipated that the subgrade along the buried conduit will have to be improved (i.e., ground improvement or pile foundations) in order for the buried conduit to meet post disaster requirement. It is anticipated that ground improvement would extend to a depth of 30 m (El. 74.5) below the ground surface. In addition, installation of an excavation support system and a dewatering system are anticipated to be required to facilitate construction of the buried conduit.

Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the west corridor conducted by CDM Smith, the tunnel invert is anticipated to be placed at El. 69 (ground surface is at ~El. 104.5) or below, which requires the bottom of the launch shaft to be at about 36 m (i.e., ~El. 68.5). The internal diameter of the shaft is anticipated to be 16 m.

However, implementation of buried conduit as a part of the outfall system may trigger a number of issues. These include, but are not limited, to the following:

- Extreme difficulties associated with relocating at-or-below-grade utilities to facilitate constructions within the WWTP;
- Potential conflicts with future development associated with the WWTP;
- Potential conflicts with on-going Stage V construction and planned Co-Gen construction in the near future; and
- Higher head loss through buried conduit portion of the outfall.

3.2.1.2 Option 1b – West Corridor with Mined Tunnel

Option 1b includes a mined tunnel that runs through the West Alignment Corridor or West Corridor (Modified) as illustrated in **Figure 3-3**. This option includes the construction of a launch shaft in the private parking lot and a receiving shaft located in the vicinity of the CCTs. The anticipated construction includes:

1. A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft located near the CCTs;
2. A mined tunnel from the launch shaft out to the riser pipes located in the Fraser River with the TBM abandoned in place;
3. One riser pipe (3.8 m ID) installed at the end of the outfall; and
4. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is anticipated to be approximately 4.2 m and the approximate total length of the tunnel is 786 m or 862 m, along the West Alignment Corridor and the West Alignment Corridor (Modified), respectively. Based on the preliminary liquefaction evaluation and an evaluation of subsurface conditions along the west corridor, the tunnel invert is anticipated to be placed at El. 69 or below. Thus, the bottom of the launch shaft is anticipated to be at about 36 m and the internal diameter to be approximately 16 m. The receiving shaft diameter and depth are anticipated to be 9 m and 36 m, respectively.

3.2.1.3 Option 1c – Central Corridor with Mined Tunnel

Option 1c includes construction of one mined tunnel that runs through the Central Alignment Corridor as illustrated in **Figure 3-4**. This option includes construction of a launch shaft in the vicinity of the IPS and a receiving shaft in the vicinity of the CCTs. The anticipated construction includes:

1. A mined tunnel from a launch shaft located in the vicinity of IPS lot to a receiving shaft located near CCTs;
2. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
3. One riser pipe (3.8 m ID) installed at the end of the outfall; and
4. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is anticipated to be approximately 4.2 m and the approximate total length of the tunnel is 683 m. Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the central corridor, the tunnel invert is anticipated to be placed at El. 69 or below. Thus, the bottom of the launch shaft is anticipated to be at a depth of about 36 m, and the internal diameter is to be approximately 16 m. The receiving shaft diameter and the depth are anticipated to be 9 m and 36 m, respectively.

However, tunneling through the Central Corridor may encounter a number of constraints associated with the area between the Plant End and the River End. These include, but are not limited, to the following:

- Extreme difficulties associated with shaft construction in the vicinity of the IPS due to the need for relocating the existing outfall, South Surrey Interceptor, New Westminster Interceptor;
- Difficulties associated with relocating at-or-below-grade utilities to facilitate constructions within the WWTP; and
- Potential settlements in the subgrade along the existing outfall and South Surrey Interceptor due to tunneling in the close proximity.

3.2.2 Option 2 – Two New Gravity Outfalls

Option 2 includes two mined tunnels; one runs through the West Alignment Corridor or West Corridor (Modified) and the other one runs through the Central Alignment Corridor as illustrated in **Figure 3-5**. This option includes construction of two launch shafts: one in the private parking lot and the other in the vicinity of the IPS for the West and Central Alignment Corridors, respectively. A single receiving shaft for both tunnels is anticipated to be located in the vicinity of the CCTs. The anticipated construction includes:

3.2.2.1 West Alignment Corridor

The anticipated construction includes:

1. A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft located near the CCTs;
2. A mined tunnel from the launch shaft to a receiving shaft in the Fraser River where the TBM would be recovered;
3. Installation of a riser pipe (3 m ID) in the receiving shaft followed by shaft backfilling; and
4. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is anticipated to be approximately 3.4m and the approximate total length of the tunnel is 786 m or 862 m, along the West Alignment Corridor and the West Alignment Corridor (Modified), respectively. Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the west corridor the tunnel invert is anticipated to be placed at El. 69 or below. Thus, the bottom of the Launch Shaft is anticipated to be at a depth of about 36 m, and the internal diameter anticipated being 11 m. The receiving shaft located in the vicinity of the CCT is anticipated to be used for both tunnel drives. Its internal diameter and the depth are expected to be 8 m and 36 m, respectively. A receiving shaft with an internal diameter of 8 m is anticipated at the riser pipe location in the river at the end of west end in order to recover the TBM for the use in the Central Alignment Corridor tunnel construction.

3.2.2.2 Central Alignment Corridor

The anticipated construction includes:

1. A mined tunnel from a launch shaft located in the vicinity of IPS lot to a receiving shaft located near CCTs;
2. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
3. One riser pipe (3 m ID) installed at the end of the outfall; and
4. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is also anticipated to be approximately 3.4 m and the approximate total length of the tunnel is 683 m. Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the central corridor, the tunnel invert is anticipated to be placed at El. 69 or below. Thus, the bottom of the launch shaft is anticipated to be at a depth of about 36 m.

However, tunneling through the Central Corridor may encounter a number of constraints associated with the area between the Plant End and the River End. These include, but are not limited, to the following:

- Extreme difficulties associated with shaft construction in the vicinity of the IPS due to the need for relocating the existing outfall, South Surrey Interceptor, New Westminster Interceptor;
- Difficulties associated with relocating at-or-below-grade utilities to facilitate constructions within the WWTP; and
- Potential settlements in the subgrade along the existing outfall and South Surrey Interceptor due to tunneling in the close proximity.

3.2.3 Option 3 – One New Gravity Outfall & the Existing Outfall

Option 3 includes one mined tunnel that runs through the West Alignment Corridor or West Corridor (Modified) to supplement the existing outfall as illustrated in **Figure 3-6**. This option includes construction of a launch shaft in the private parking lot and a receiving shaft in the vicinity of the CCTs to facilitate the mined tunnel construction while keeping the existing outfall at the current operation level (i.e., no improvement to the outfall).

As discussed in **Section 1.1**; the existing outfall was constructed in 1974 and is not capable of:

1. Meeting discharge mixing and dilution objectives (20:1) for the current or future design flows or
2. Meeting MV's seismic design criteria which require new wastewater facilities to be designed as post-disaster level facilities.

Option 3 would not meet the project objectives unless reconstruction of the existing outfall is undertaken (similar to the Option 2 outfall construction). These efforts may include, but are not limited to, the following:

1. A thorough evaluation on the current conditions of the existing outfall (both on land and offshore segments), which may require taking the outfall out of service for a short period of time;
2. Additional offshore geotechnical investigation in the vicinity of the offshore segment of the outfall;
3. Significant modelling efforts to evaluate options for improving the dilution ratio from 7:1 to 20:1; and
4. Significant seismic design efforts to make the existing outfall meet the current seismic requirements.

Despite the understanding on the Option 3 that does not meet MV's project objectives, this option will be carried forward for the outfall system option analysis only for the purpose of comparison of all 8 options. Also, CDM Smith anticipates this option will be shown to be not favorable for MV early in the process and it will not be developed to the same extent as the other options.

3.2.4 Option 4 – One New Outfall with a New Pump Station

3.2.4.1 Option 4a – West Corridor with Buried Conduit and Mined Tunnel

Option 4a includes construction of a pump station in the vicinity of the CCTs and construction of a buried conduit and mined tunnel in the West Alignment Corridor or West Corridor (Modified) as illustrated in **Figure 3-7**. This option also includes construction of a launch shaft in the private parking lot, and ground improvement or piles along the proposed buried conduit alignment. The anticipated construction includes:

1. Ground improvement or pile foundations to support the pump station;
2. Construction of a pump station;
3. Ground improvement or pile installation followed by excavation and construction of a buried conduit from the pump station to a launch shaft located in the private parking lot;
4. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
5. One riser pipe (3.8 m ID) installed at the end of the outfall; and
6. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The buried conduit is anticipated to be approximately 3.5 m x 2.1 m and the internal diameter of the mined tunnel is anticipated to be approximately 3.0 m. The length of the buried conduit is about 295m and the approximate length of the tunnel is 491 m or 567 m, along the West Alignment Corridor and the West Alignment Corridor (Modified), respectively. . The pump station is anticipated to occupy an area of approximately 25 m x 20 m.

Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the west corridor, the tunnel invert is anticipated to be placed at El. 69 (ground surface is at ~El. 104.5) or below. The bottom of the launch shaft is anticipated to be at a depth of 36 m (~El. 68.5). The internal diameter of the shaft is anticipated to 11 m. The invert of the buried conduit invert is anticipated to be at El. 100. It is also anticipated that the subgrade along the buried conduit will have to be improved (i.e., ground improvement) in order for the buried conduit to meet the post disaster requirements. It is anticipated that ground improvement would extend to a depth of 30 m (El. 74.5) below the ground surface. In addition, installation of an excavation support system and a dewatering system are anticipated to be required to facilitate construction of the buried conduit.

However, implementation of buried conduit as a part of the outfall system may trigger a number of issues. These include, but are not limited, to the following:

- Extreme difficulties associated with relocating at-or-below-grade utilities to facilitate constructions within the WWTP;
- Potential conflicts with future development associated with the WWTP;
- Potential conflicts with on-going Stage V construction and planned Co-Gen construction in the near future; and
- Higher head loss through buried conduit portion of the outfall.

3.2.4.2 Option 4b – West Corridor with Mined Tunnel

Option 4b includes construction of a pump station in the vicinity of the CCTs and construction of a mined tunnel through the West Alignment Corridor or West Corridor (Modified) as illustrated in **Figure 3-8**. This option also includes construction of a launch shaft in the private parking lot and a receiving shaft at the pump station location. Consideration will be given to construction of the pump station within a larger diameter receiving shaft if it is determined to be advantageous. The anticipated construction includes:

1. Ground improvement or pile foundations to support the pump station if it is not supported by the receiving shaft structure;
2. A mined tunnel from a launch shaft located in the private parking lot to a receiving shaft located near the CCTs;
3. Construction of the pump station;
4. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
5. One riser pipes (3.8 m ID) installed at the end of the outfall; and
6. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is anticipated to be approximately 3.0 m and the approximate length of the tunnel is 786 m or 862 m, along the West Alignment Corridor and the West Alignment Corridor (Modified), respectively. The pump station is anticipated to occupy an area of 25 m x 20 m.

Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the west corridor, the tunnel invert is anticipated to be placed at ~El. 69 (ground surface is at ~El. 104.5) or below. Thus, the bottom of the launch shaft and the receiving shaft is anticipated to be at a depth of about 36 m (~El. 68). The internal diameters of the launch and receiving shafts are anticipated to be at 11 m and 8 m, respectively.

3.2.4.3 Option 4c – Central Corridor with Mined Tunnel

Option 4c includes construction of a pump station in the vicinity of the CCTs and construction of one mined tunnel that runs through the Central Alignment Corridor as illustrated in **Figure 3-9**. This option also includes construction of a launch shaft in the vicinity of the IPS and a receiving shaft at the pump station location. Consideration will be given to construction of the pump station within a larger diameter receiving shaft if it is determined to be advantageous. The anticipated construction includes:

1. Ground improvement or pile foundations to support the pump station if it is not supported by the receiving shaft structure;
2. A mined tunnel from a launch shaft located in the vicinity of IPS lot to a receiving shaft located near CCTs;
3. Construction of the pump station;
4. Mining a tunnel from the launch shaft out to riser pipes located in the Fraser River with the TBM abandoned in place;
5. One riser pipe (3.8 m ID) installed at the end of the outfall; and
6. Installation of distribution pipe(s) and diffuser sections buried in the river bottom and protected by armor rock.

The internal diameter of the mined tunnel is anticipated to be approximately 3.0 m and the approximate length of the tunnel is 683 m. The pump station is anticipated to occupy an area of 25 m x 20 m.

Based on a preliminary liquefaction evaluation and an evaluation of subsurface conditions along the central corridor, the tunnel invert is anticipated to be placed at ~El. 69 (ground surface is at ~El. 104.5) or below. Thus, the bottom of the launch shaft and the receiving shaft is anticipated to be at a depth of about 36 m (~El. 68). The internal diameters of the launch and receiving shafts are anticipated to be at 11 m and 8 m, respectively.

However, tunneling through the Central Corridor may encounter a number of constraints associated with the area between the Plant End and the River End. These include, but are not limited, to the following:

- Extreme difficulties with shaft construction in the vicinity of the IPS due to the need for relocating the existing outfall, South Surrey Interceptor, New Westminster Interceptor;
- Difficulties with relocating at-or-below-grade utilities to facilitate constructions within the WWTP; and
- Potential settlements in the subgrade below the existing outfall and South Surrey Interceptor due to tunneling in the close proximity.

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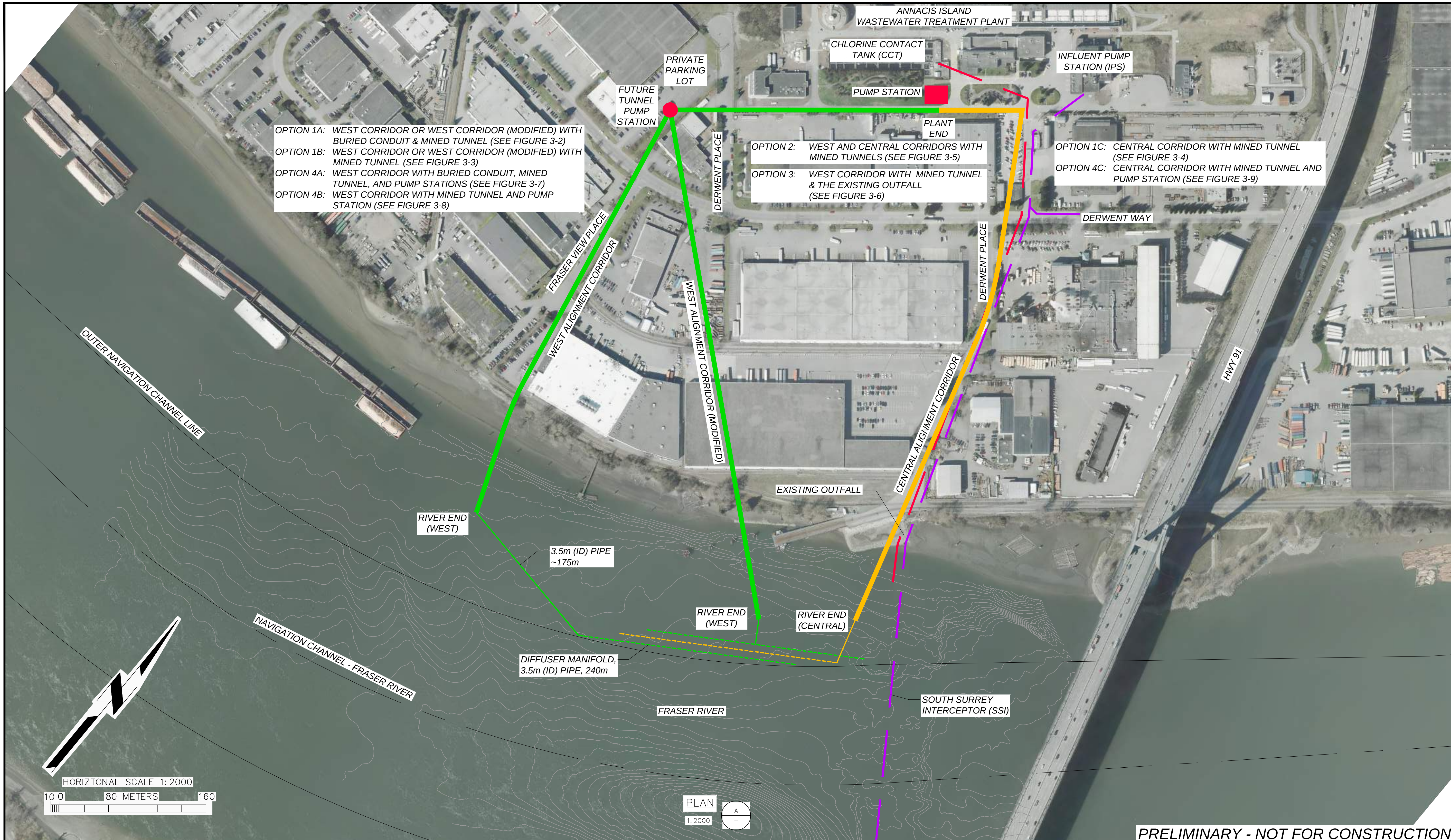

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

OVERALL OUTFALL OPTIONS

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3-1

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2013-10-09 GVRD 3DCivil Template.dwg

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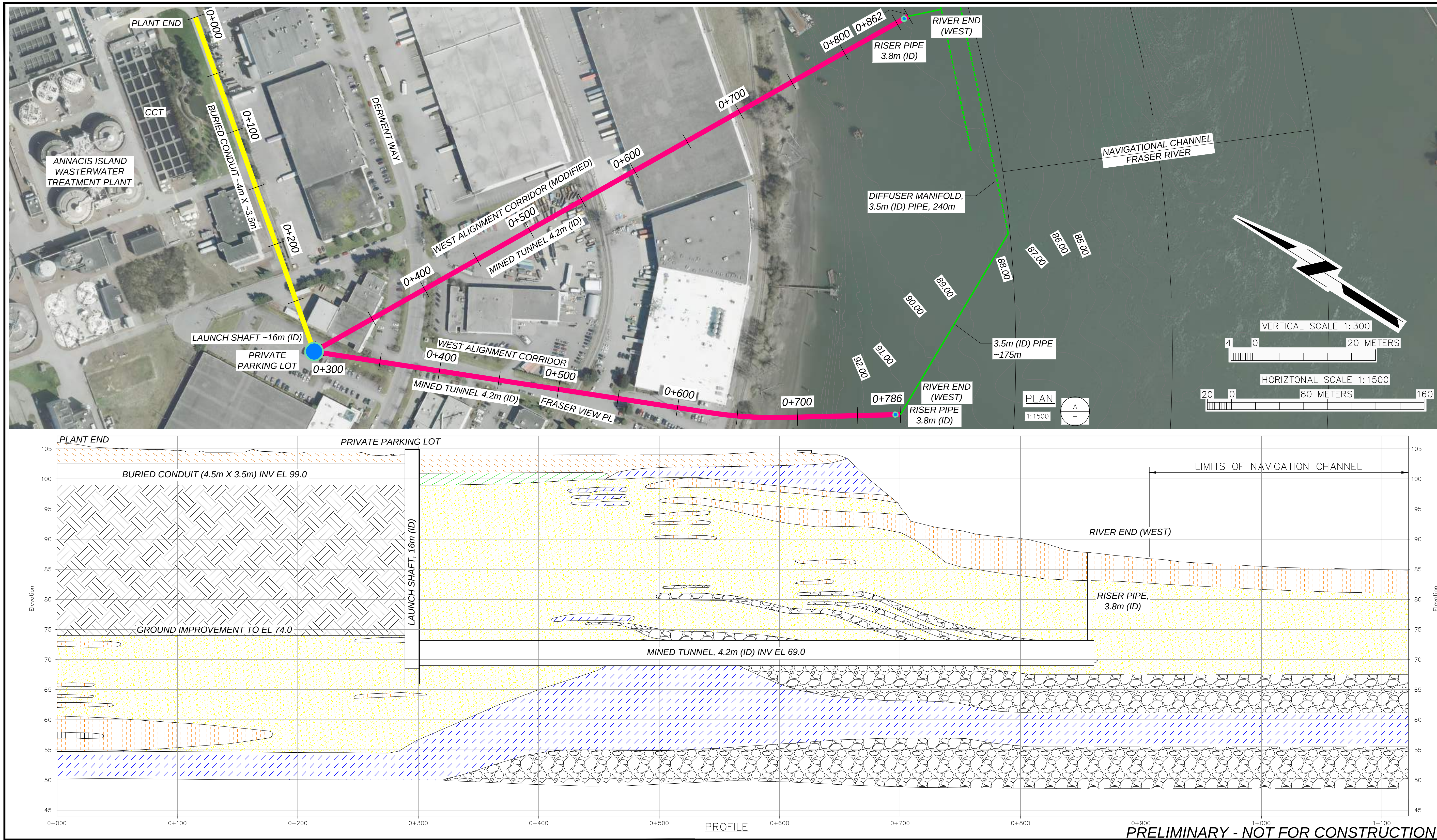

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL ALIGNMENT (WEST) – OPTION 1A

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3-2

SUPERSEDES PRINTS OF THIS DRAWING NUMBER WITH LETTERS PREVIOUS TO A

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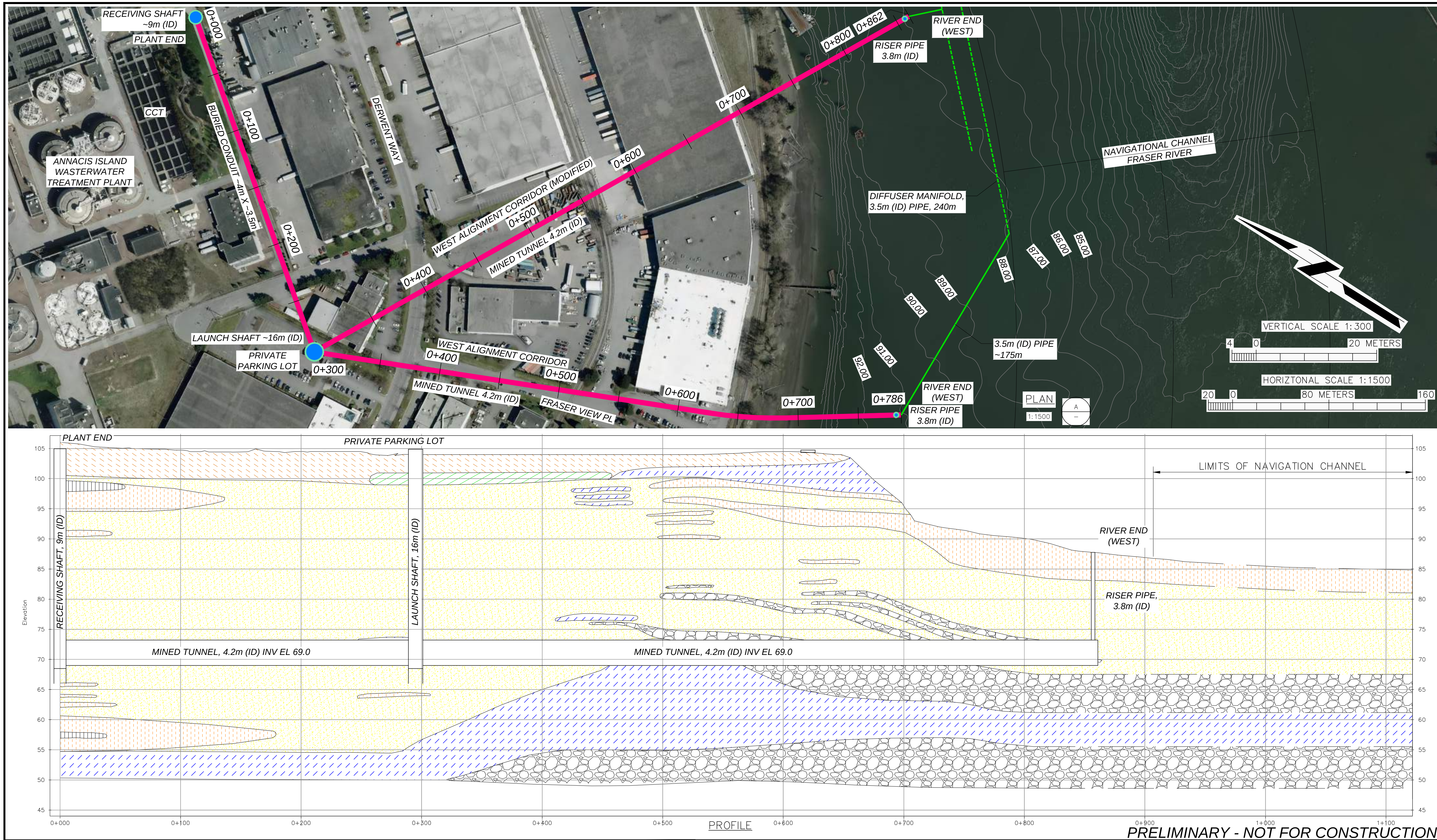

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL ALIGNMENT (WEST) – OPTION 1B

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3-3

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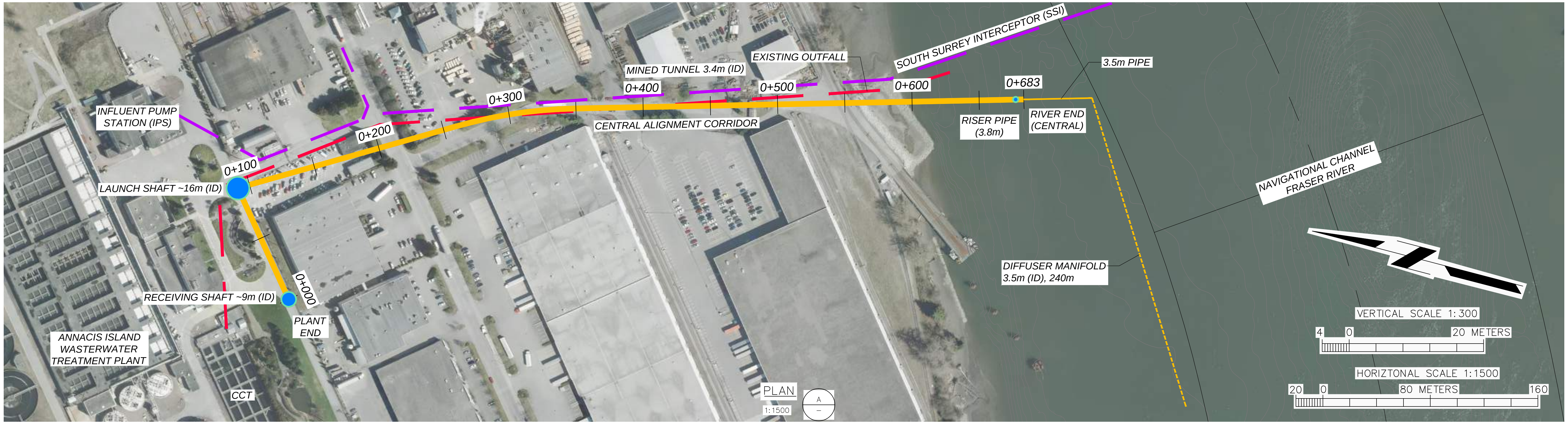

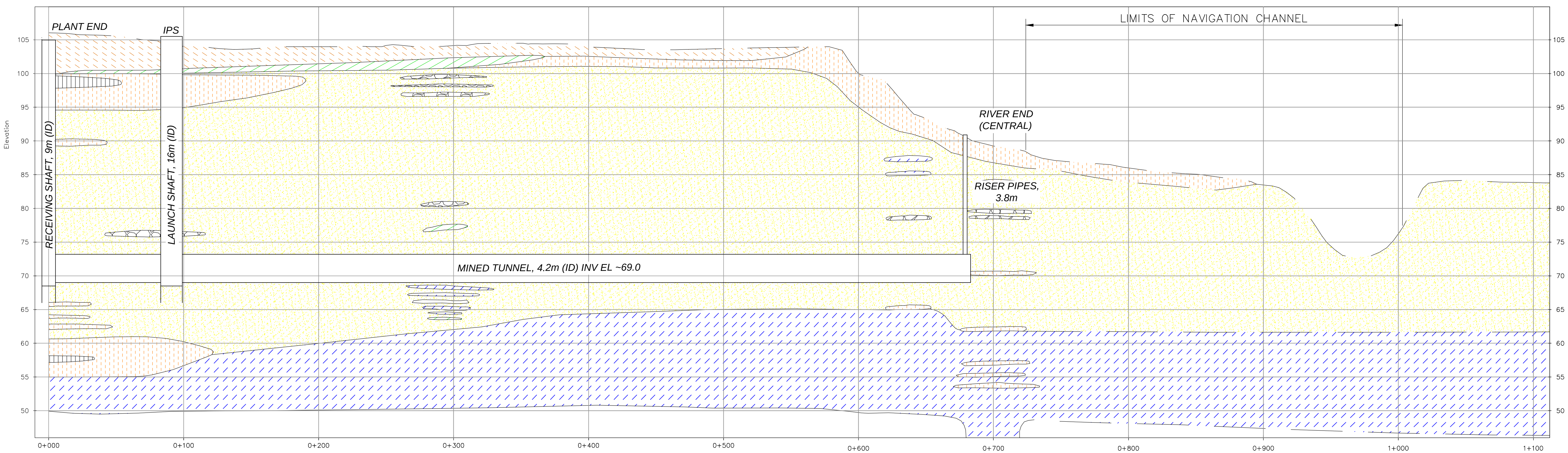

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ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL ALIGNMENTS (CENTRAL) – OPTION 1C

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3-4

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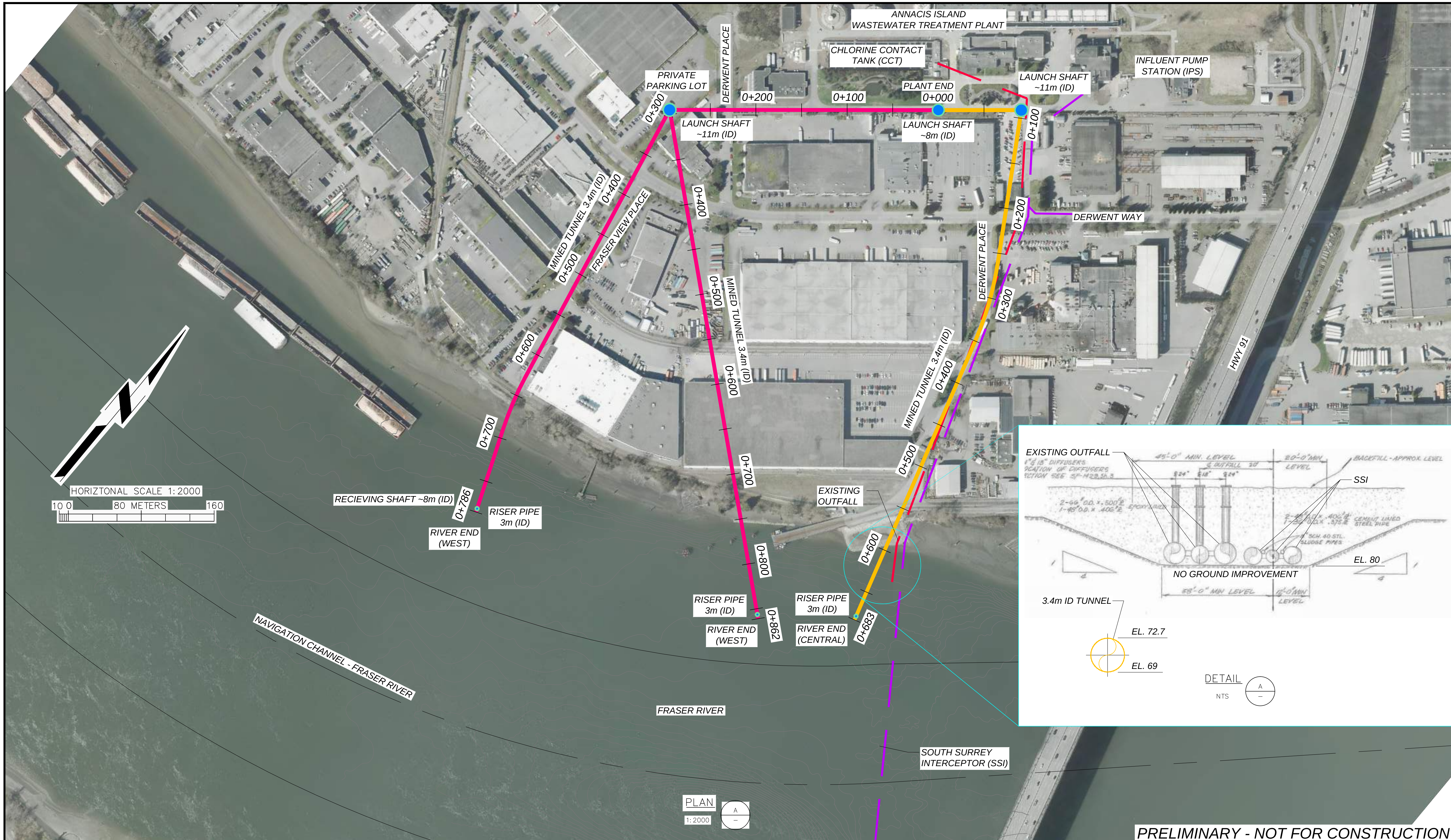

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL ALIGNMENTS – OPTION 2

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3–5

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ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL ALIGNMENTS – OPTION 3

SCALE: AS NOTED
DISTRICT FILE ##-####
DRAWING NUMBER FIGURE 3-6

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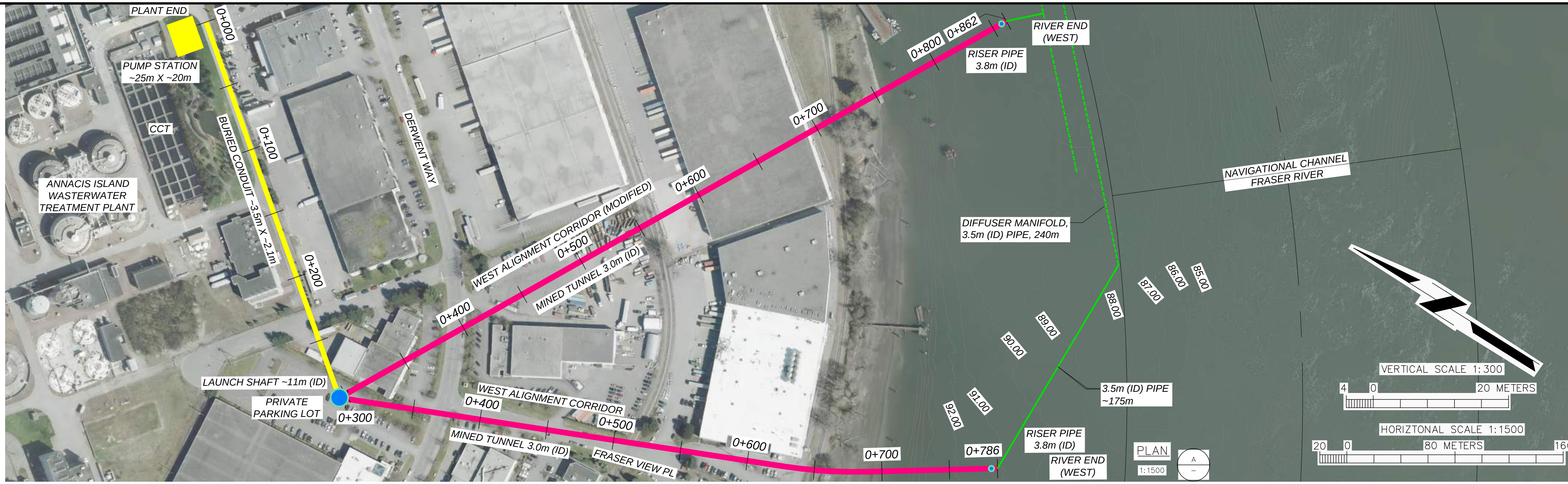

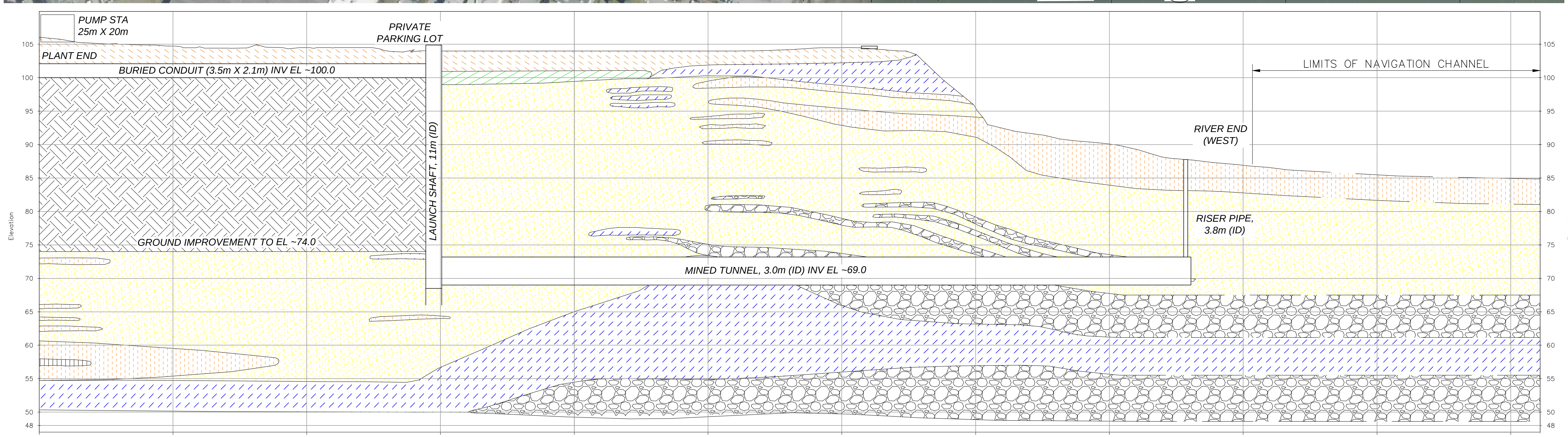

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL
ALIGNMENT (WEST) – OPTION 4A

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 3-7

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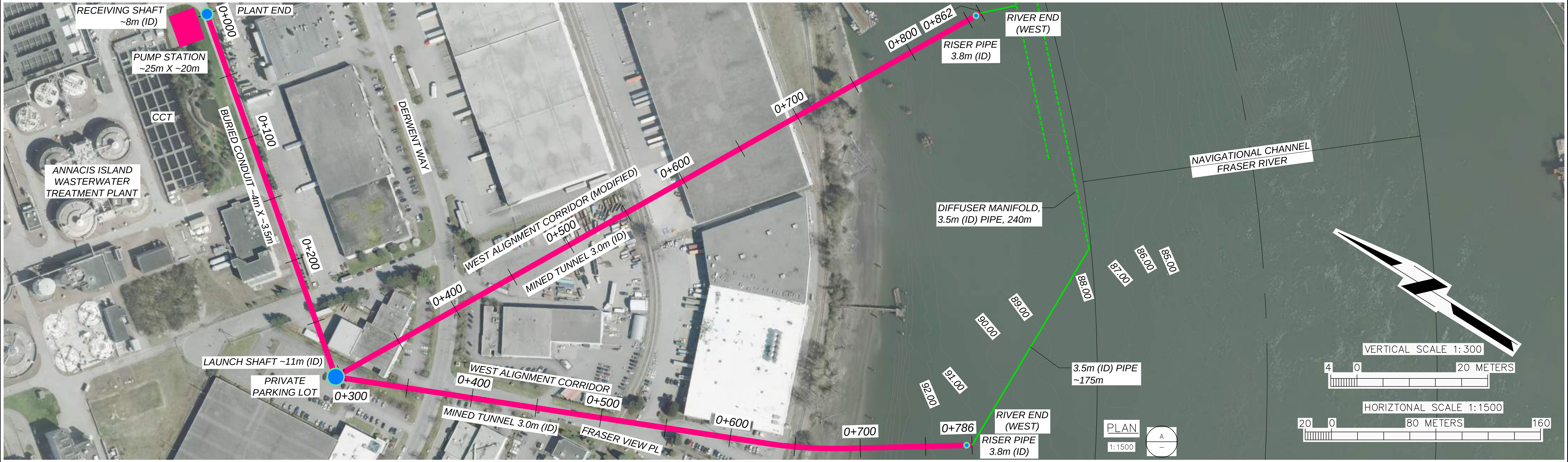

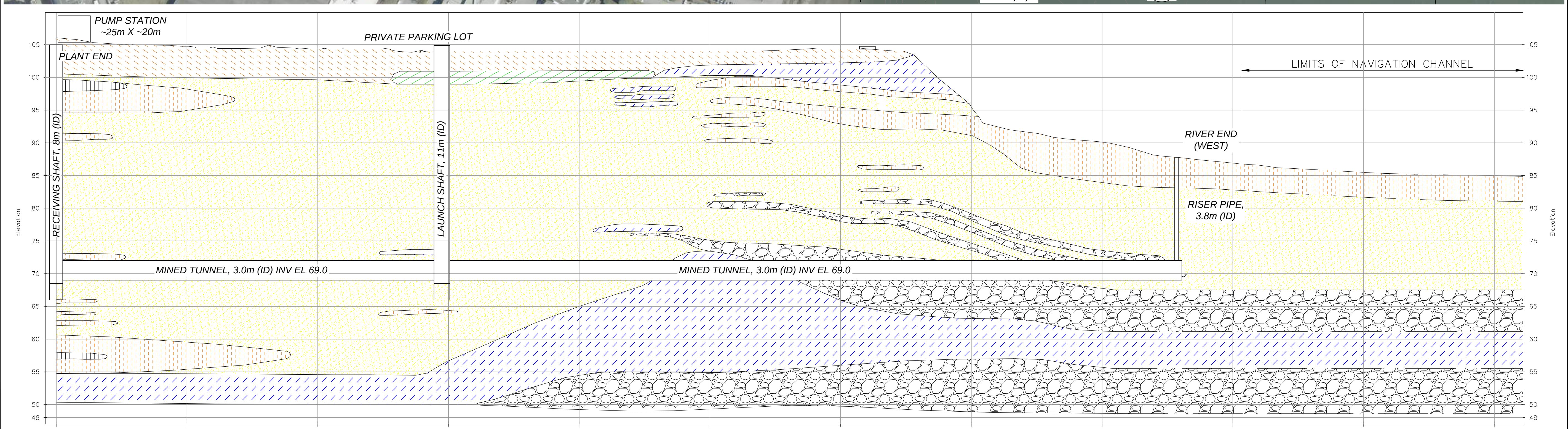

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ANNACIS ISLAND WWTP
ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL
ALIGNMENT (WEST) - OPTION 4B

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 3-8

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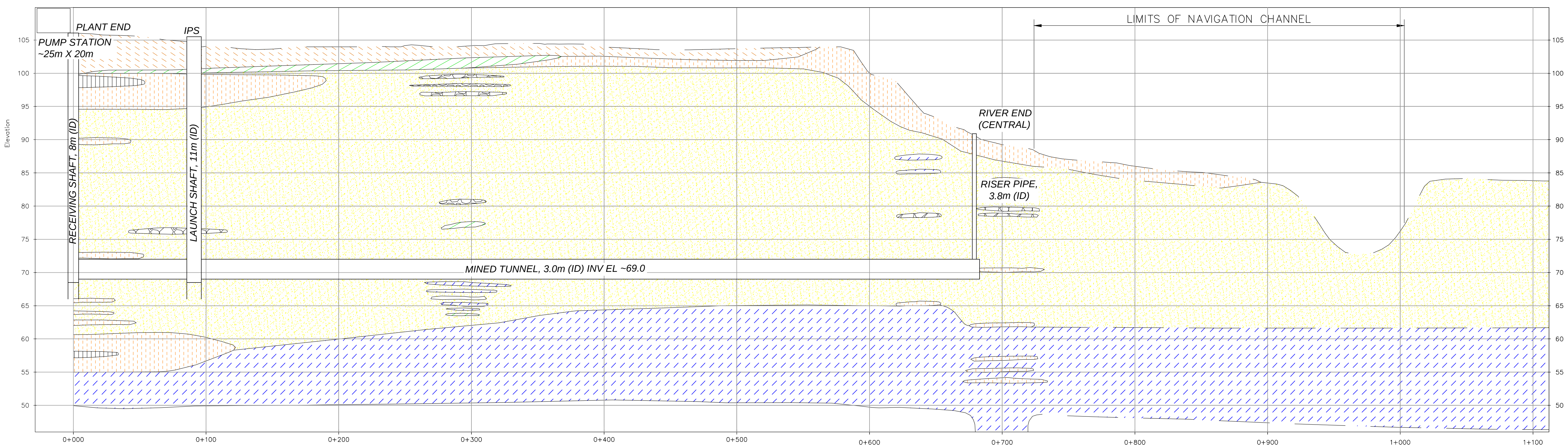

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ANNACIS INFLUENT & OUTFALL UPGRADE

HORIZONTAL AND VERTICAL ALIGNMENTS (CENTRAL) – OPTION 4C

SCALE: AS NOTED

DISTRICT FILE ##-####

DRAWING NUMBER FIGURE 3-9

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Section 4

Opinion of Probable Construction Cost

The opinion of probable construction cost[2] presented in this report is a Class 5 cost evaluation which is developed for the purpose of Outfall Option screening. The Class 5 cost evaluation expects a variation of accuracy as tight as -20% to +30%or as loose as -50% to +100%. An opinion of probable cost for each option discussed above is presented in tables below. The Class 5 cost evaluation may be conservative at this point in time, but appropriate for alternative comparison. However, recent local tunnel projects with similar size and geology support the unit cost estimate. **Table 4-1** below presents a summary of costs for options discussed in the report and a breakdown for each option is presented in the following sections:

Table 4-1: A Summary of Opinion of Probable Construction Cost

Outfall Options	Total Probable Cost; $ mil
Option 1a: West Corridor with buried conduit & mined tunnel	**$105.3**
Option 1b: West Corridor with mined tunnel	**$114.5**
Option 1c: Central Corridor with mined tunnel	**$107.4**
Option 2: West and Central corridors with mined tunnels	**$160.2**
Option 3: West Corridor mined tunnel & the existing outfall	**$138.7**
Option 4a: West Corridor with buried conduit, mined tunnel, and pump station	**$123.7**
Option 4b: West Corridor with mined tunnel and pump station	**$136.8**
Option 4c: Central Corridor with mined tunnel and pump station	**$130.6**

Table 4-2 through **Table 4-9** present additional detail on the opinion of probable construction cost for each of the eight (8) options. For the West Alignment Corridor options, the longer tunneled alignment (modified) was used as a consistent assumption with the expectation that the cost for the longer tunnel alignment would be offset by the cost for an in-river pipeline between the riser and the diffuser manifold.

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[2] All construction costs have been estimated in general accordance with AAEC Class 5 requirements (with an accuracy of -50% and +100%). Construction costs have not been escalated to the mid-point of construction and do not include contactor markup and overhead, property acquisition or easement, environmental mitigation, engineering, procurement, contract administration, or construction management costs. These construction cost estimates should only be used for comparative purposes among the presented options and not for capital planning purposes.

Table 4-2: Opinion of Probable Construction Cost for Option 1a

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Ground Improvement from Plant End to the Launch Shaft	Depth - 35 m Length - 295 m	1	$5.3
Construction of Buried Conduit	4.5 m x 3.5 m Length - 295 m	1	$11.5
Construction of Launch Shaft in the Private Parking Lot	16 m (ID) Depth - 36 m	1	$22.0
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Purchase/Assembly/ Launching/Parts Removal	4.2 m (ID) Length - 567 m	1	$42.5
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.8 m	1	$7.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
		Total	**$105.3**

Table 4-3: Opinion of Probable Construction Cost for Option 1b

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Construction of Launch Shaft in Private Parking Lot	16 m (ID) Depth - 36 m	1	$22.0
Construction of Receiving Shaft near CCTs	9 m (ID) Depth - 36 m	1	$14.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	4.2 m (ID) Length - 295 m	1	$31.8
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	4.2 m (ID) Length - 567 m	1	$22.7
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.8 m	1	$7.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
		Total	**$114.5**

Table 4-4: Opinion of Probable Construction Cost for Option 1c

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Construction of Launch Shaft in Private Parking Lot	16 m (ID) Depth - 36 m	1	$22.0
Construction of Receiving Shaft near CCTs	9 m (ID) Depth - 36 m	1	$14.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	4.2 m (ID) Length - 91 m	1	$23.7
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	4.2 m (ID) Length - 592 m	1	$23.7
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.8 m	1	$7.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
		Total	**$107.4**

Table 4-5: Opinion of Probable Construction Cost for Option 2

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Activities on the West Alignment Corridor			
Construction of Launch Shaft in Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Construction of Receiving Shaft near CCTs	8 m (ID) Depth - 36 m	1	$12.0
Construction of Receiving Shaft in Fraser River	8 m (ID) Depth - 36 m	1	$20.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	3.4 m (ID) Length - 295 m	1	$26.7
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	3.4 m (ID) Length - 567 m	1	$20.5
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	1.9 m	1	$4.0
Dredging and Construction of Diffuser Sets	Length - 140 m	1	$7.5
Activities on the Central Alignment Corridor			
Construction of Launch Shaft in Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Launching/Removal	3.4 m (ID) Length - 91 m	1	$3.5
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	3.4 m (ID) Length - 592 m	1	$21.5
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	1.9 m	1	$4.0
Dredging and Construction of Diffuser Sets	Length - 140 m	1	$5.5
		Total	**$160.2**

Table 4-6: Opinion of Probable Construction Cost for Option 3

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Activities on the West Alignment Corridor			
Construction of Launch Shaft in Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Construction of Receiving Shaft near CCTs	8 m (ID) Depth - 36 m	1	$12.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	3.6 m (ID) Length - 295 m	1	$29.2
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	3.6 m (ID) Length - 567 m	1	$21.5
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.8 m	1	$7.5
Dredging and Construction of Diffuser Sets	Length - 140 m	1	$14.0
Activities on the Central Alignment Corridor			
On-Land Ground Improvement / Pile Foundations	Depth - 35 m Length – 450 m	1	$9.0
In-River Ground Improvement / Pile Foundations	Depth - 35 m Length – 160 m	1	$8.0
On-Land Conduit Structural Reinforcement	Length - 450 m	1	$10.0
In-River Pipe Structural Enhancement or Replacement	Length - 160 m	1	$7.0
Improvements to Diffusers or Replacement	Length - 100 m	1	$3.0
		Total	**$138.7**

Table 4-7: Opinion of Probable Construction Cost for Option 4a

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Ground Improvement from Plant End to the Launch Shaft	Depth - 35 m Length - 295 m	1	$5.3
Construction of Buried Conduit	3.5 m x 2.1 m Length - 295 m	1	$5.6
Construction of Launch Shaft in the Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Purchase/Assembly/ Launching/Parts Removal	3.0 m (ID) Length - 567 m	1	$33.3
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.0 m	1	$5.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
Construction of Pump Station with Ground Improvement	25 m x 20 m	1	$25.0
Pump Station Operation and Maintenance	35 years	1	$17.5
		Total	**$123.7**

Table 4-8: Opinion of Probable Construction Cost for Option 4b

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Construction of Launch Shaft in Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Construction of Receiving Shaft near CCTs	8 m (ID) Depth - 36 m	1	$14.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	3.0 m (ID) Length - 295 m	1	$24.0
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	3.0 m (ID) Length - 567 m	1	$19.3
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.0 m	1	$5.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
Construction of Pump Station with Ground Improvement	25 m x 20 m	1	$25.0
Pump Station Operation and Maintenance	35 years	1	$17.5
		Total	**$136.80**

Table 4-9: Opinion of Probable Construction Cost for Option 4c

Description of Activity	Dimensions / Length	Units	Total Probable Cost $ mil
Construction of Launch Shaft in Private Parking Lot	11 m (ID) Depth - 36 m	1	$15.0
Construction of Receiving Shaft near CCTs	8 m (ID) Depth - 36 m	1	$14.0
Mined Tunnel from Launch Shaft to Receiving Shaft (Plant End); TBM Purchase/Assembly/ Launching/Removal	3.0 m (ID) Length - 91 m	1	$17.0
Mined Tunnel from Launch Shaft to Riser River End (West); TBM Launching/Parts Removal	3.0 m (ID) Length - 592 m	1	$20.1
Shaft Drop Structure Installation	6 m (ID) Depth - 30 m	1	$2.5
Construction of Riser Pipe and Connection to Tunnel	3.0 m	1	$5.5
Dredging and Construction of Diffuser Sets	Length - 240 m	1	$14.0
Construction of Pump Station with Ground Improvement	25 m x 20 m	1	$25.0
Pump Station Operation and Maintenance	35 years	1	$17.5
		Total	**$130.6**

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Section 5

Evaluation of Option Risk

A risk is an uncertain event or condition that, if it occurs, has an uncertain positive or negative effect on a project's objectives. Risks may be inherent characteristics or conditions of the project or external influences, events, or conditions such as weather or economic conditions. Risks may have an effect on many types of project objectives including cost, schedule, operational performance, working conditions and environmental sustainability.

The methodology used for evaluating outfall system options based on risk consists of two primary and interrelated processes: (1) qualitative risk analysis and (2) risk-based option evaluation. The methodology used and results of qualitative risk analysis and risk-based option evaluation are described in the following subsections. Recommendations are also provided.

5.1 Methodology

5.1.1 Qualitative Risk Analysis

Qualitative risk analysis is the process of prioritizing risks for further analysis or action by assessing and combining their likelihood of occurrence and consequences. The qualitative risk analysis process is intended to identify individual project risks and then rank them in regard to potential severity. The results of the qualitative risk analysis process are typically documented in a project risk register.

A risk register is a document that generally provides a list of all project risks and summarizes the results of both qualitative risk analysis and risk response (e.g., mitigation) planning. A full risk register - that includes risk response planning results - will be developed and maintained for the preferred option in the future as part of the design management process.

To support risk-based evaluation of the outfall system options, a subset of risks sufficient to provide differentiation between and among the options was developed and provided the basis for the decision process risk registers prepared for each option. Two risk registers were developed for each option: (1) a risk register for risks with consequences that can be quantified in terms of cost and (2) a risk register for risks with consequences that cannot easily be quantified in terms of cost.

As stated above, a risk is an uncertain event or condition that, if it occurs, has an uncertain positive or negative effect on a project's objectives. This definition includes two key dimensions of risk: (1) uncertainty and (2) effect on a project's objectives. When assessing the importance of a risk, these two dimensions are both considered. The uncertainty dimension is described using the term likelihood and the effect is called consequence.

Several techniques were utilized to identify and rank individual project risks, including:

- Formal risk register development meetings
- Project documentation review
- Historical information analysis
- Professional judgment

Guidelines were developed to help ensure consistency in the process of qualitatively prioritizing risks and rating them in regard to both likelihood and consequence. Identified risks were categorized as to the likelihood of occurrence using the guidelines in **Table 5-1**.

Table 5-1: Likelihood of Occurrence Category Guidelines

Likelihood Category	Guideline for Qualitative Analysis
Almost Certain	90% ≤ Probability ≤ 100%
Likely	50% ≤ Probability < 90%
Possible	10% ≤ Probability < 50%
Unlikely	1% ≤ Probability < 10%
Improbable	Probability <1%

Identified risks were categorized as to potential consequences using the guidelines in **Table 5-2** for risks with consequences that can be quantified in terms of cost and **Table 5-3** for risks with consequences that cannot easily be quantified in terms of cost.

Table 5-2: Consequence Category Guidelines for Risks Quantified in Terms of Cost

Consequence Category	Guideline for Qualitative Analysis
Catastrophic	Cost Impact > $20.0 million
Major	Cost Impact > $10.0 million to ≤ $20.0 million
Significant	Cost Impact > $2.5 million to ≤ 10.0 million
Minor	Cost Impact > $0.5 million to ≤ $2.5 million
Insignificant	Cost Impact ≤ $0.5 million

Table 5-3: Consequence Category Guidelines for Risks Not Easily Quantifiable in Terms of Cost

Consequence Category	Guideline for Qualitative Analysis		
	Environmental Impacts	**Operational Impact**	**Reputational Impact**
Catastrophic	Long-term environmental harm to the river and/or shoreline. Significant additional Greenhouse Gas (GHG) emissions occurring as a consequence of use of grid-supplied electricity AND significant additional GHG emissions from sources within the plant boundary. Discharge routinely exceeds WQ criteria and has less than a 10:1 dilution ratio.	Protracted non-operational period for the plant.	Long duration of negative media coverage and numerous complaints to government officials. Loss of confidence in the plant and organization.
Major	Major release of pollutants to the river and/or shoreline with mid-term recovery period. Significant additional GHG emissions from sources within the plant boundary. Discharge frequently exceeds WQ criteria and has less than a 10:1 dilution ratio.	Plant non-operational for days.	Moderate duration of negative media coverage of event and several complaints to governmental officials. Reputation of the plant and confidence of the organization are adversely impacted.
Significant	Significant release of pollutants with mid-term environmental recovery period. Minor additional GHG emissions occurring as a consequence of use of grid-supplied electricity AND minor additional GHG emissions from sources within the plant boundary. Discharge may exceed WQ criteria but has greater than a 10:1 dilution ratio.	Plant non-operational for hours.	Short duration of negative media coverage of event and a few complaints to governmental officials. Reputation of the plant is adversely impacted.

Consequence Category	Guideline for Qualitative Analysis		
	Environmental Impacts	Operational Impact	Reputational Impact
Minor	Minor release of pollutants to the river and/or shoreline with short-term environmental recovery period. Minor additional GHG emissions occurring as a consequence of use of grid-supplied electricity. No additional GHG emissions from sources within the plant boundary. Discharge occasionally exceeds WQ criteria but has greater than a 20:1 dilution ratio.	Plant operations are impaired but not disrupted.	Short duration of negative media coverage of event and no complaints to governmental officials.
Insignificant	Brief pollution to the river and/or shoreline but no environmental harm. No additional GHG emissions during operations. Discharge meets WQ requirements 99.99% of time.	Impact can be dealt with by routine operations.	One-time, non-negative media coverage of event and no complaints to governmental officials.

A Risk Breakdown Structure (RBS) was developed to organize project risks into categories and develop descriptive project risk statistics for the risk registers. The RBS includes the following risk categories:

- Design
- Permitting and Approvals
- Construction
- Operation and Maintenance

After categorizing risks in regard to likelihood and consequence, a risk matrix was used to prioritize individual risks for presentation in the project risk register using a color coding and numerical score. The numerical scores range from 1 to 5 and are based on a system where relatively lower scores are assigned to risks that are relatively larger threats to project objectives (i.e., a risk with a score of 1 poses a greater threat than a risk with a score of 5). The risk scoring matrix is presented as **Figure 5-1**.

Figure 5-1: Risk Scoring Matrix

Likelihood Category	Insignificant	Minor	Significant	Major	Catastrophic
Almost Certain	4	3	2	1	1
Likely	4	3	2	2	1
Possible	4	3	3	2	2
Unlikely	5	4	3	3	3
Improbable	5	5	4	4	4

Consequence Category

5.1.2 Risk-Based Option Evaluation

Each outfall system option was evaluated independently for (1) risks with consequences that can be quantified in terms of cost and (2) risks with consequences that cannot easily be quantified in terms of cost. The same evaluation methodology was used for both cost-quantifiable risks and risks not easily quantified in terms of cost (i.e., the methodology described below applies to both types of risks).

An identical set of risks was used to evaluate each option using the numerical risk scores documented in the risk registers. The risk scores (ranging from 1 to 5) for each individual risk were summed to create a total risk score for each option. The minimum and maximum total risk scores for all options were used to identify a range of total risk scores. The range of total risk scores was then divided into 5 equal sub-ranges (quintiles).

The outfall system options were evaluated by assigning each with an option score based upon in which quintile the total risk score for the option was located, as follows:

- **Option Score 5**: An option score of 5 was assigned to options in the fifth quintile of total risk scores for all options. Options in the fifth quintile are associated with the least amount of risk relative to all other options.
- **Option Score 4**: An option score of 4 was assigned to options in the fourth quintile of total risk scores for all options. Options in the fourth quintile are associated with a greater amount of risk relative to options in the fifth quintile.
- **Option Score 3**: An option score of 3 was assigned to options in the third quintile of total risk scores for all options. Options in the third quintile are associated with a greater amount of risk relative to options in the fourth quintile.

- **Option Score 2**: An option score of 2 was assigned to options in the second quintile of total risk scores for all options. Options in the second quintile are associated with a greater amount of risk relative to options in the third quintile.
- **Option Score 1**: An option score of 1 was assigned to options in the first quintile of total risk scores for all options. Options in the first quintile are associated with the greatest amount of risk relative to all other options.

5.2 Results

5.2.1 Qualitative Risk Analysis

A total of 20 project risks were identified and are documented in the option risk registers which are provided in **Appendix A.** Of the 20 risks identified, 14 risks (70 percent) were categorized as cost-quantifiable and 6 risks (30 percent) were categorized as not easily quantified in terms of cost. **Table 5-4** depicts the number of risks identified in each of the four RBS categories. Seventy-five percent of risks identified are in the categories of (1) Construction and (2) Operations and Maintenance.

Table 5-4: Distribution of Risks by Category

Risk Category	Number of Risks	Percent of Total
Construction	8	40%
Operations and Maintenance	7	35%
Design	3	15%
Permitting and Approvals	2	10%
TOTAL	20	100.0%

5.2.2 Risk-Based Option Evaluation

Table 5-5 presents results of risk-based option evaluation for risks that are quantifiable in terms of cost. The table presents the individual risk scores, total risk score and option score for each option. Option 1b has an option score of 5 and is the only option in the fifth quintile of total risk scores. Option 1b is associated with the least amount of cost quantifiable risk relative to all other options. Options 1a, 1c, 4a and 4b have option scores of 4 and are associated with lower cost quantifiable risk levels relative to Options 2, 3 and 4c.

Table 5-5: Option Scores for Risks Quantifiable in Terms of Cost

Risk Type	Risk Number	Risk Name	OPTION NUMBER							
			1a	1b	1c	2	3	4a	4b	4c
Quantifiable in Terms of Cost	x.01	Outfall Inspection/Maintenance Serviceability/Repair Access	3	3	3	3	3	3	3	3
	x.02	Operational Complexity/Conflict with Future WW System Improvement	1	4	1	1	2	1	2	1
	x.03	Hydraulic Capacity/Sedimentation	1	3	3	3	3	1	4	4
	x.04	Turn up and Turn Down Flexibility/Attaining Dilution Criteria	2	3	3	3	2	2	4	4
	x.05	Increased O&M Cost - Pump Station	5	5	5	5	5	2	2	2
	x.06	Hydraulic Performance	2	3	3	3	3	4	4	4
	x.07	Attaining Dilution Criteria - Capital Cost	2	2	2	2	1	4	4	4
	x.08	Marine Habitat Restrictions	4	4	4	4	4	4	4	4
	x.09	Seismic Hazard Mitigation	3	3	3	2	1	3	2	3
	x.10	Tunnel Alignment	3	3	4	3	3	3	3	3
	x.11	Shaft Location Conflicts - Constructability	5	5	3	3	5	5	5	3
	x.12	Greater Number of Tunnel Shafts	5	3	3	3	3	5	3	3
	x.13	Greater Number of Mined Tunnels	5	3	3	2	3	5	3	3
	x.14	Capital Cost Estimate Uncertainty	4	3	4	1	2	3	2	2
TOTAL QUANTIFIABLE RISK SCORE:			45	47	44	38	40	45	45	43
OPTION SCORE:			4	5	4	1	2	4	4	3

Table 5-6 presents results of risk-based option evaluation for risks that are not quantifiable in terms of cost. The table presents the individual risk scores, total risk score and option score for each option. Option 1b has an option score of 5 and is the only option in the fifth quintile of total risk scores. Option 1b is associated with the least amount of risk that is not cost quantifiable relative to all other options. Options 1c and 2 have option scores of 4 and are associated with lower levels of risk that is not cost quantifiable relative to Options 1a, 3, 4a, 4b and 4c.

Table 5-6: Option Scores for Risks Not Quantifiable in Terms of Cost

Risk Type	Risk Number	Risk Name	OPTION NUMBER							
			1a	1b	1c	2	3	4a	4b	4c
Not-Quantifiable in Terms of Cost	x.15	Pollution and Emissions	3	3	3	3	3	2	2	2
	x.16	Impact on Plant Operations	2	4	2	4	4	2	3	3
	x.17	Public Acceptance	4	4	4	4	2	4	3	3
	x.18	Traffic Disruption - Street	3	3	3	2	3	3	3	3
	x.19	Traffic Disruption - River	3	3	3	2	3	3	3	3
	x.20	Post Disaster-Level Performance	3	5	5	5	1	3	5	5
TOTAL NON-QUANTIFIABLE RISK SCORE:			18	22	20	20	16	17	19	19
OPTION SCORE:			2	5	4	4	1	1	3	3

5.3 Conclusions

The outfall system options have been evaluated using a risk-based framework for risks that are quantifiable in terms of cost and risks not quantifiable in terms of cost. The framework used a two-step process of qualitative risk analysis and risk-based option evaluation. The results of the process demonstrate significant differences in the relative favorability of the outfall system options based on potential adverse impacts to important project objectives.

The following list provides a summary of conclusions based on the results of risk-based outfall system options evaluation:

1. **Quantifiable Risks**: Option 1b has an option score of 5 and is the only option in the fifth quintile of total risk scores. Option 1b is associated with the least amount of cost quantifiable risk relative to all other options. Options 2, 3, and 4c have high cost quantifiable risk levels relative to the other options.
2. **Non-Quantifiable Risks**: Option 1b has an option score of 5 and is the only option in the fifth quintile of total risk scores. Option 1b is associated with the least amount of risk that is not cost quantifiable relative to all other options. Options 1a, 4a, and 4b have high non-quantifiable risks relative to the other options.

Section 6

Recommended Options

6.1 Recommended Option

Based on the opinion of probable construction cost and evaluation of option risk, CDM Smith recommends implementing Option 1b for the final design based on the following:

1. Options 2, 3, 4a, 4b, and 4c all have higher probable construction cost as well as higher quantifiable and non-quantifiable cost risk than Options 1a, 1b, or 1c.
2. The lower probable construction cost for Option 1a will likely be more than offset by risk costs, particularly the non-quantifiable ones associated with construction of buried conduits within the confines of the treatment plant, especially with regard to both restrictions on future plant expansion and interferences with concurrent Stage V and Co-Generation construction activities.
3. The lower probable construction cost for Option 1c will likely be more than offset by risk costs associated with constructing the new system within the same corridor as the existing outfall while keeping the existing outfall in operation.
4. Option 1b provides the most flexibility in terms of potential future pump station construction, connection with the post-disaster effluent conduit, and connection to the possible riser and diffuser locations in the Fraser River.

CDM Smith recommends design of Option 1b include:

- Selection of a preferred alignment in the West Alignment Corridor based on further evaluation in-river diffuser design and modeling in in concert with on-going discussions with the Ministry of Environment along with construction access and cost factors to be developed in concert with on-going discussions with Port Metro Vancouver.
- 30% design for a future pump station the launch shaft location, since the pumping has been confirmed to be required to facilitate a diffuser system that will meet regulatory criteria for future plant expansion beyond Stage V (see **Appendix B**). The proposed pump station configuration concepts are discussed in **Section 7**.
- Managing the design process for the preferred option using best practices for project risk management that are widely used for projects of similar size and complexity both in British Columbia and internationally. A risk management best practice is a strategy, approach, method, tool or technique that is particularly effective in helping organizations achieve objectives for managing risk. Risk management methodologies and processes are recommended to be consistent with CAN/CSA ISO 31000: Risk Management - Principles and Guidelines. CAN/CSA ISO 31000 is the international standard for risk management and has been adopted by the government of British Columbia.

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Section 7

Pump Station Conceptual Configurations

7.1 Introduction

As discussed in **Section 2**, modeling of the outfall and dispersion of effluent into the river indicates that pumping will be required in the future; the timing will be dependent on how quickly plant flows increase in the future. Although the timing of when plant and river conditions require effluent pumping is variable, it is prudent to plan for effluent pumping in terms of site space and, if cost-effective, construct some of the facilities under the current project since construction is inevitable and disruption can be avoided in the future.

This section:

- Summarizes how the sources of plant effluent will be routed to the pump station and then to the outfall; and
- Describes the four different pump station configurations considered;

7.2 Effluent Routing to the River

Under normal conditions, treated plant effluent is routed through the existing chlorine contact tanks (CCTs) where sodium hypochlorite disinfects the effluent prior to discharge to the river[3]. Currently effluent flows are discharged through an Existing Effluent Conduit (EEC) to the existing Influent Junction Chamber (IJC) and then to the existing outfall. To provide better dispersion into the river, a new outfall will be constructed under this project and flows will be routed from the CCTs to the new outfall.

A consideration regarding the conveyance existing effluent flows to the new outfall is the application of the new Canadian Building Code[4] and a review of the existing Stage IV treatment facilities determined that an earthquake event could damage these Stage IV treatment processes

[3] These flows are also dechlorinated.

[4] From Technical Memorandum No. 19 by Brown and Caldwell (January 24, 2013): Since the Stage IV upgrades to Annacis Island during the 1990s, several significant changes have been made to the National Building Code of Canada (NBCC). The change having the largest impact on the Stage V upgrade is the new requirement, first appearing in NBCC 2005, that new sewage treatment facilities built under the code be rated as Post-Disaster facilities (NBCC 2010, Table 4.1.2.1) and be operational after the major earthquake. The intensity of the design earthquake has also been increased. The definition of post-disaster comes from Commentary A on NBCC 2010 and states that: *"Buildings designed as post-disaster facilities should remain operational immediately after an emergency or disaster."*

Further, Commentary A also says: *"However, the mere application of an importance factor greater than 1.0 does not necessarily ensure the operation readiness of a facility following an emergency or disaster; this can only be determined by carrying out a detailed study of what equipment and services need to be in operation immediately after an emergency or disaster and of the anticipated behavior of equipment and structural components. Such a study should address issues like what equipment should be connected to emergency power, how long emergency generators need to be able to run, how secure the fuel supply is, whether or not a stored supply of potable water is required, etc."*

As the commentary states, the ultimate criteria in terms of treatment requirements will need to be decided by Metro Vancouver (MV). The Design Team can support this decision with technical information. Metro Vancouver has already set some of these requirements when it released an update to Standard No. CR-02- 02-DS-GEN-00100-2003 Rev C in October 2012. In this update, Metro Vancouver has acknowledged the new NBCC requirements with respect to water and wastewater structures, but has also stated that "facilities are to be treated on a case by case basis to assess the applicability of the NBCC."

leaving only the new Stage V treatment facilities in operation[5]. As the existing CCTs are not earthquake resistant, effluent flows from the new Stage V final sedimentation tanks will be routed to the new outfall using a new "post-disaster bypass" conduit. Options for the post-disaster bypass conduit are presented and discussed in a separate report being prepared under this contract: "Post-Disaster Bypass Conduit to Outfall[6]".

There are four basic options for routing of effluent flow from the treatment facilities to the outfall and they are depicted in **Figure 7-1**.

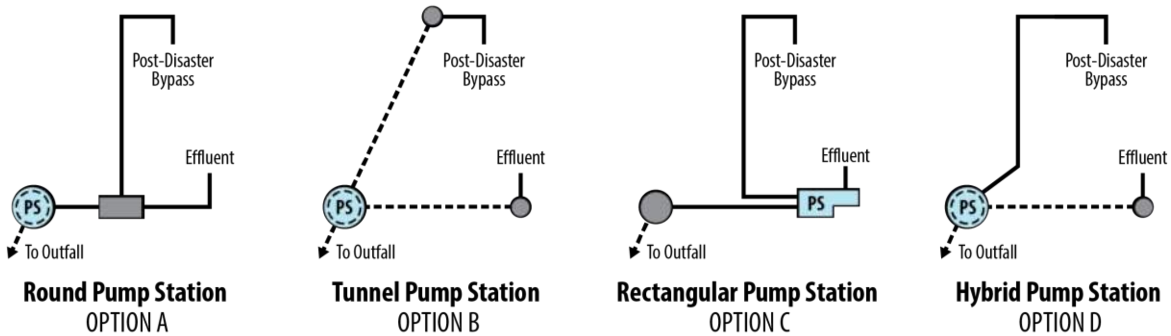

Figure 7-1 Options for Routing Effluent to the Outfall

There are four basic options for routing of effluent flow from the treatment facilities to the outfall and they are presented in **Table 7-1**. Each of these options is described in **Section 7.3** below.

Table 7-1 Effluent Routing Options

Option Name	CCT Effluent Configuration	Post-Disaster Bypass Configuration	Pump Station Configuration
Round	Buried Conduits or Pipes	Shallow – just below grade	Round Pump Station
Tunnel	Deep Tunnel	Deep Tunnel	Tunnel Pump Station
Rectangular	Buried Conduits or Flumes	Shallow – just below grade	Rectangular Pump Station
Hybrid	Deep Tunnel	Shallow – just below grade	Round Pump Station

7.3 Pump Station Configurations (4)

As presented in **Figure 7-1**, there are four pump station options which match with four arrangements of conduits buried below the surface or tunnels. Each of these configurations is discussed below. Drawings of all pump station configurations and the support building are presented in **Appendix C**, however, excerpts from these drawings are included below to better explain the pump station concepts being considered.

[5] An Annacis Outfall Workshop was held on September 08, 2015 at the Metro Vancouver Head Office. One of the decisions made by MV was that the new outfall shall be assessed as a post-disaster level facility, capable of remaining operational following a seismic event with an annual exceedance probability (AEP) of 1/2475. MV decided there would be no need for assessing the requirement for AEP scenarios of 1:979, 1:475, and seismic design.

[6] Post-Disaster Bypass Conduit to Outfall, DRAFT - December 2015, CDM Smith

7.3.1 Round Pump Station

The "Round Pump Station" configuration is presented as Site Schematics in **Figure 7-2** and sections are presented in **Appendix C**.

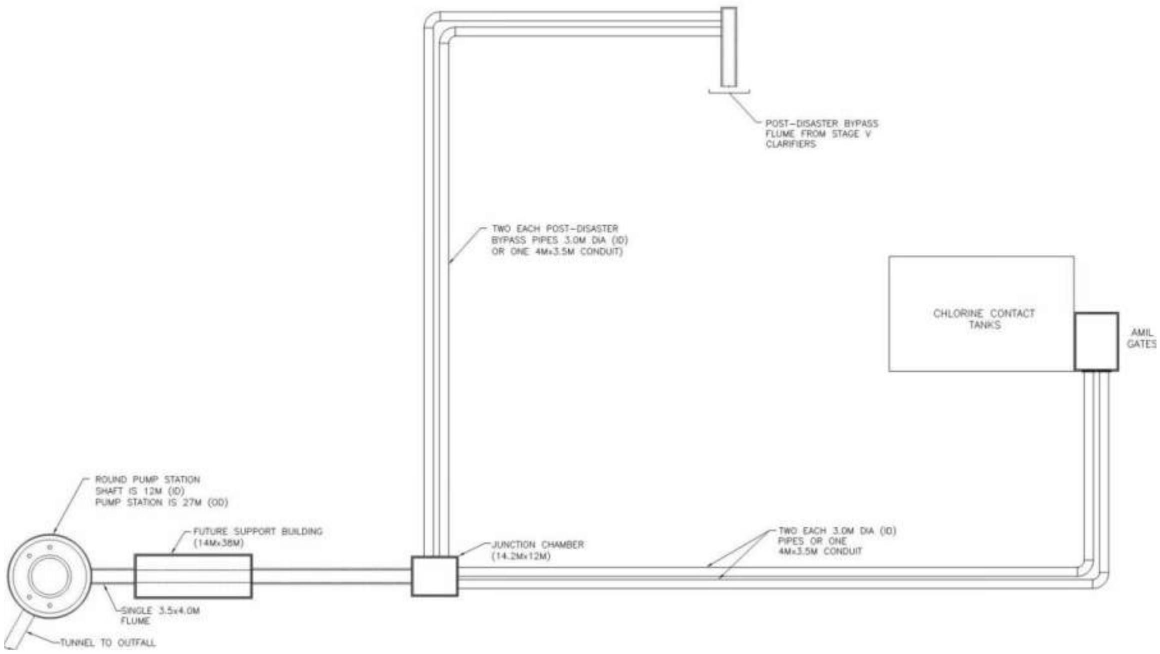

Figure 7-2 Site Schematics - Round Pump Station Plan

This pump station is constructed integral with the upper portion of the outfall shaft that used to convey effluent flows to the new outfall. At the top of the shaft is a large (5m wide) annulus channel that receives flow from two sources:

- The plant chlorine contact tanks (CCTs); and,
- The post-disaster bypass conduit.

Both of these effluent sources are conveyed to the pump station using either:

- A single rectangular conduit with inside dimensions of: 3.5M x 4.0M; or
- Twin circular pipes, each with an inside diameter of 3.0M or less[7].

Flows from the plant effluent and post-disaster bypass conduit would discharge to a Junction Chamber (see **Section 7.4.4**) and then be routed to the pump station using a rectangular flume or two concrete pipes.

A support building (see **Section 7.4.5**) would be located near the pump station to manage power and control needs at the pump station.

[7] The diameter of these pipes may be reduced depending on the outfall diffuser losses.

7.3.2 Tunnel Pump Station

The "Tunnel Pump Station" configuration is presented as Site Schematics in **Figure 7-3** and sections are presented in **Appendix C**. Note that this pump station is configured to receive flow from two tunnels, one from the plant effluent and another from the post-disaster bypass conduit.

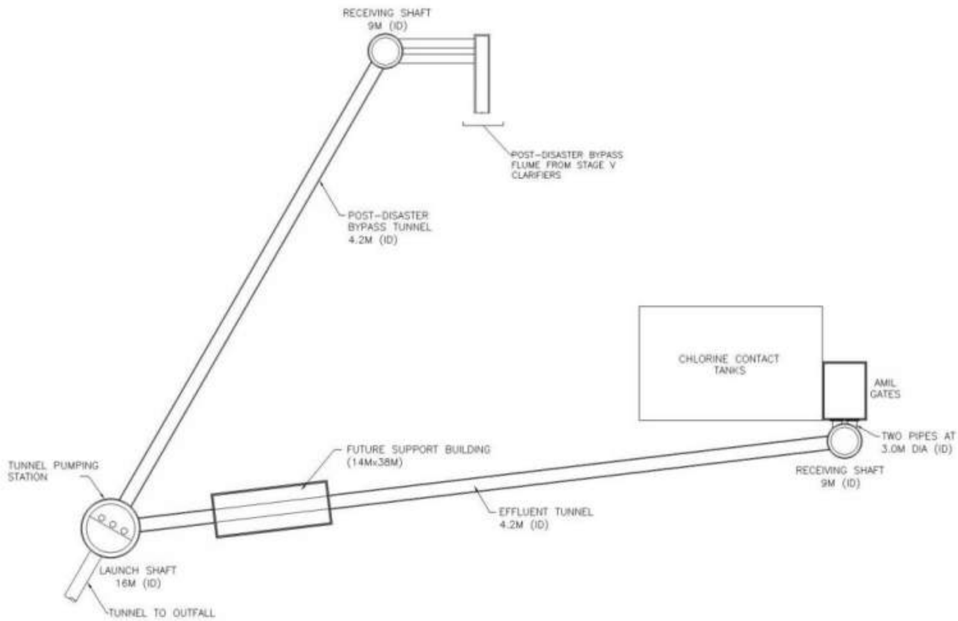

Figure 7-3 Site Schematics -Tunnel Pump Station

Effluent flows from both the chlorine contact tanks (CCTs) and post-disaster bypass conduit will enter new "receiving shafts" near the source and tunnels will be bored from these shafts to the common outfall shaft. Construction of these shafts and tunnels will be performed as follows:

- Construction of the 16 m inside diameter "launch shaft" in the private land parcel west of the plant site (this shaft also forms the outer shell of the tunnel pump station);
- Construction of a 9 m inside diameter receiving shaft" on the north side of the plant where post-disaster bypass flows will be received;
- Boring of an effluent tunnel (4.2 m inside diameter) from the outfall launch shaft to the post-disaster receiving shaft;
- Construction of an 9 m inside diameter effluent receiving shaft near the existing CCTs;
- Boring of an effluent tunnel (4.2 m inside diameter) from the outfall launch shaft to the effluent receiving shaft;

The Tunnel Pump Station would be fitted with flap gates to facilitate gravity flows from either the post-disaster bypass conduit of plant effluent to flow by gravity to the river. When increased plant flows dictate the need for pumping:

- The pumps would be procured and installed; and,
- The Support Building (see **Section 7.4.5**) would be constructed and fitted with all necessary electrical, controls and mechanical systems required.

The timing of pump procurement/installation and construction of the support building would be dependent on the timing of when increased plant flows occur.

7.3.3 Rectangular Pump Station

The "Rectangular Pump Station" configuration is presented as Site Schematics in **Figure 7-4** and sections are presented in **Appendix C**.

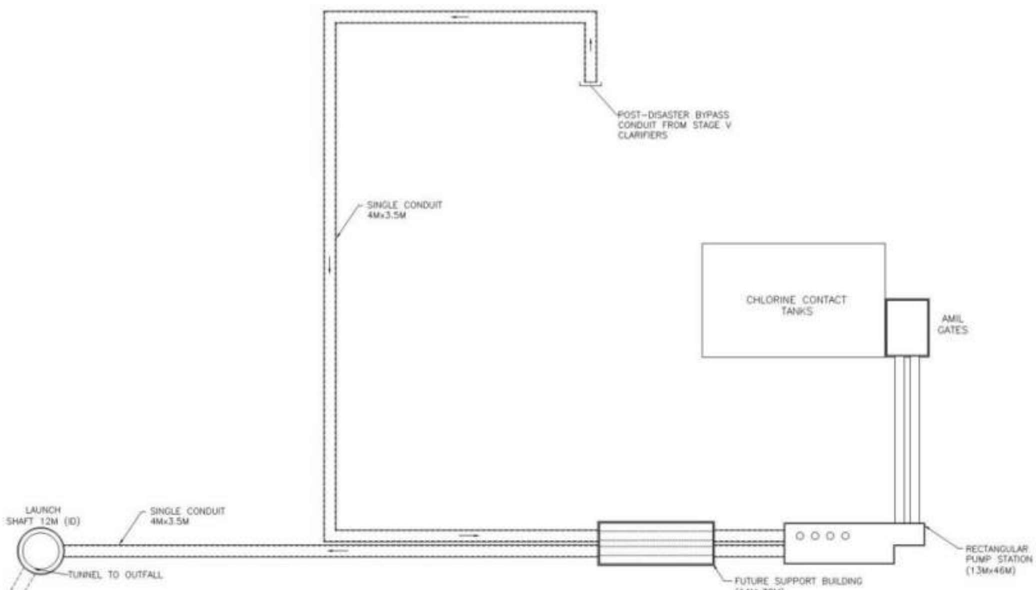

Figure 7-4 Rectangular Pump Station Plan

For the rectangular pump station, effluent flows enter a "trench style" wetwell from either end:

- Plant effluent enters from one end; and,
- Post-disaster bypass flows enter from trench wetwell the other end.

These flows are pumped to an effluent flume (single or dual chamber) which drains by gravity to the outfall shaft, and then to the river.

A support building (see **Section 7.4.5**) would be located near the pump station to manage power and control needs at the pump station.

7.3.4 Hybrid Pump Station

The "Hybrid Pump Station" configuration is presented as Site Schematics in **Figure 7-5** and sections are presented in **Appendix C**.

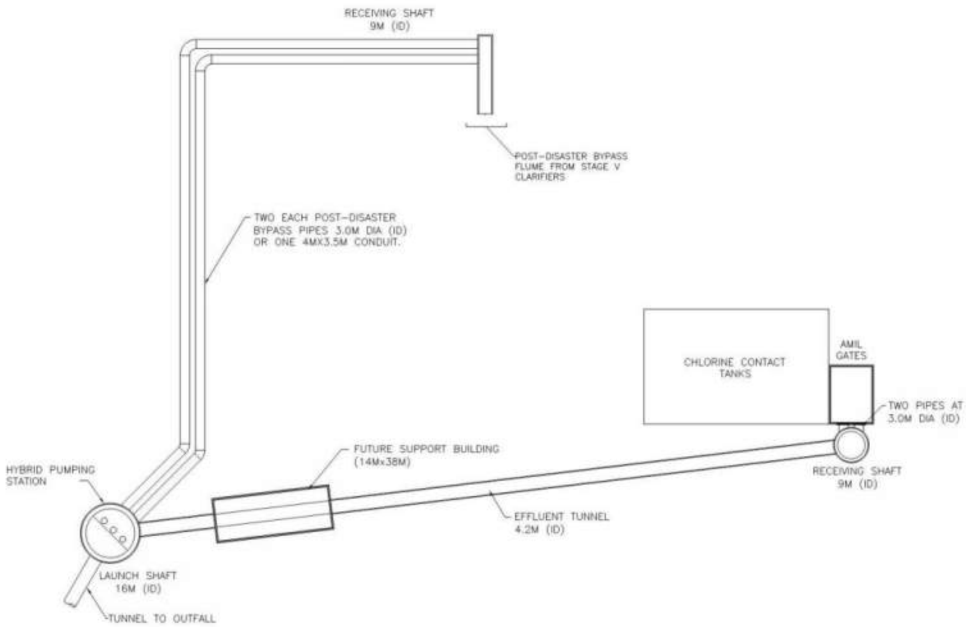

Figure 7-5 Site Schematics -Hybrid Pump Station

For the hybrid pump station, effluent flows enter the pump station:

- Normal plant effluent flows from the CCTs enter the pump station via a tunnel extending from a receiving shaft located near the AMIL gates; and,
- Post-disaster bypass flows enter just below the ground surface via two flumes that use either two pipes or a dual box culvert.
- These flows are pumped over a dividing wall to the outfall shaft, and then to the river.

A support building (see **Section 7.4.5**) would be located near the pump station to manage power and control needs at the pump station.

7.4.4 Junction Chamber

A junction chamber is required for the round pump station configuration which utilizes buried conduits and combines plant effluent flows and post-disaster flows prior to sending them to the outfall shaft. A junction chamber is presented in **Figure 7-6**.

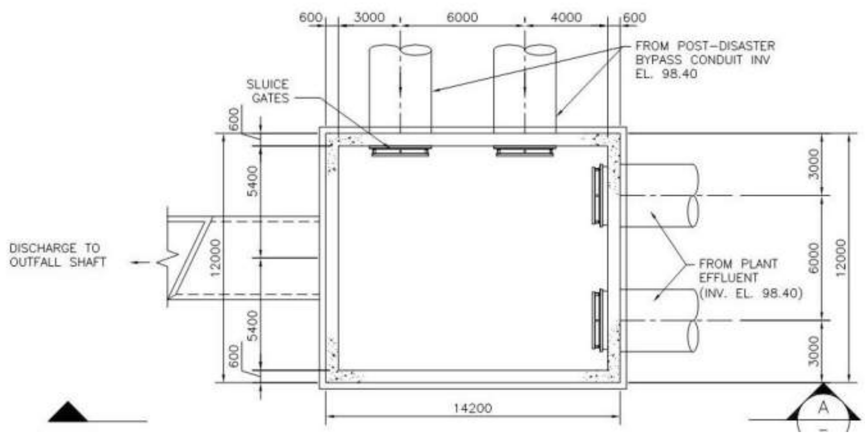

Figure 7-6 Junction Chamber for Combining Plant Effluent and Post-Disaster Bypass Conduits

7.4.5 Support Building

The Support Building houses all of the equipment needed to power and control the pump stations. The layout presented in **Figure 7-7** is generic and would be suitable for all four pump station options. The Support Building would only be constructed when pumping was needed.

Figure 7-7 Support Building Plan and Section

7.5 Recommendations

The tunnel and hybrid pump station options at the launch shaft location are consistent with the recommended outfall system Option 1b and have multiple advantages relating to cost and operability. They can be constructed in phases so that the capital investment for pumping can be delayed until effluent pumping is required. Also, they do not involve a separate facility location within the plant site in the vicinity of future potential expansion of the CCTs.

As recommended in **Section 6**, Option 1b should be expanded to include design and partial construction of pump station now as part of the outfall system and the remaining facilities can be constructed in the future when flows increase. Thus, at 30% design; CDM Smith plans to develop Class 5 cost evaluation and perform a comparison of the four pump station configuration.

Typically, Class 5 cost estimates which as defined by the Association for the Advancement of Cost Engineering (AACE)[8] have a cost range of from -50% to +100%. In order to present a reasonable comparison, the costs should be included for the: a) Pump Station or Outfall Shaft and Slurry Walls, b) Effluent Receiving Shafts, c) Tunnels (excluding outfall), d) Pump Station Civil Works, e) Pump Procurement, and f) Junction Chamber/Support Building. This comparison is necessary because the pump station cost differences could be a relatively small contributor to the overall cost for an effluent routing option. Then select a pump station configuration for the final design. It is anticipated that the design work would include only civil/structural components that are sufficient enough for the partial construction of the pump station.

[8] AACE International Recommended Practice No. 18R-97; COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

Section 8

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