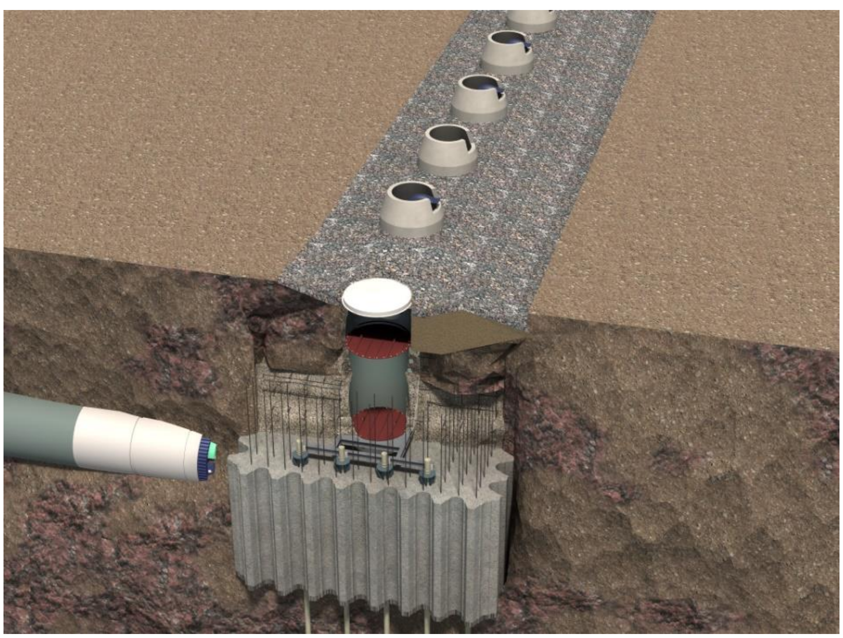
APPENDIX K
BC MINISTRY OF ENVIRONMENT EIS

Part B: Appendix A
Multiport Diffuser Design and Dilution Modelling Report
Report and Attachments A to D

Annacis Island WWTP New Outfall System

Vancouver Fraser Port Authority
Project and Environmental Review Application



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CDM Smith

Golder Associates

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APPENDIX A

Multiport Diffuser Design and Initial Dilution Modeling Report (CDM Smith 2018)

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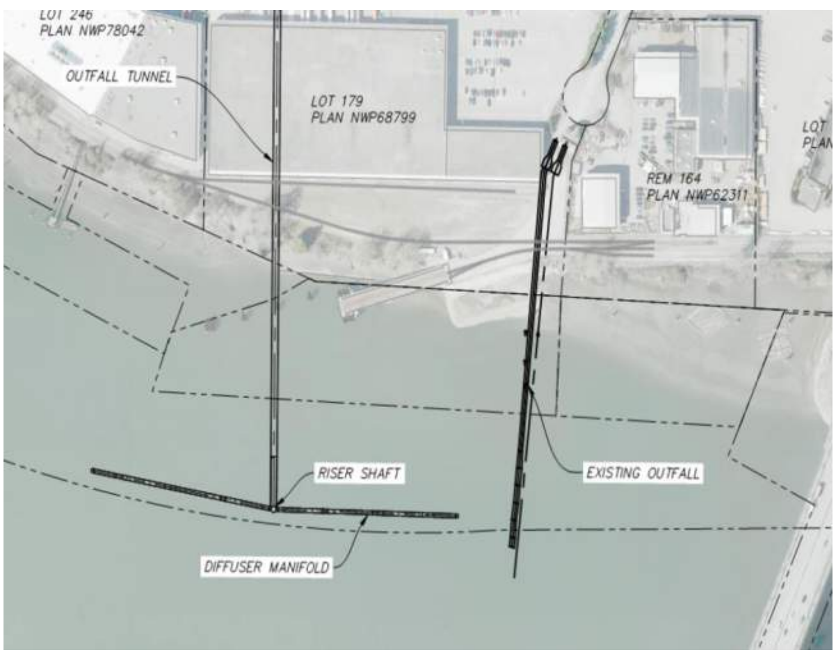
Multiport Diffuser Design and Dilution Modelling

Annacis Island WWTP
Transient Mitigation and Outfall Project

CDM Smith Canada ULC



Prepared for:

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SERVICES AND SOLUTIONS FOR
A LIVABLE REGION

March 5, 2018

CDM Smith

A Report Prepared for:

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Multiport Diffuser Design and Dilution Modelling
Annacis Island WWTP
Transient Mitigation and Outfall Project

March 5, 2018

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Section 1

Introduction

1.1 Purpose

This draft report presents the second stage of a multiport diffuser design concept and initial dilution Modelling for the terminus (diffuser) of the outfall system for the Annacis Island Wastewater Treatment Plant (AIWWTP) to identify what can be achieved in terms of dilution and mixing within the physical constraints of the project site.

Early Modelling 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 be required several decades in the future, CDM Smith recommends the diffuser design be optimized for Stage V flows using available gravity head. The diffuser is also designed, and will be constructed, so its configuration can be modified to accommodate higher future flows. Initial dilution modelling was then performed using the Stage V diffuser configuration to estimate achievable dilution and mixing in the Fraser River. Future plant capacity expansions are likely to require pumping to augment the available hydraulic head.

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

1.2 Project Background

1.2.1 Outfall Project

Metro Vancouver (MV) is currently implementing Stage V improvements to the AIWWTP that will increase the peak wet weather capacity of the plant from 12.6 m^3/s to 18.9 m^3/s, and has future (Stage VIII) plans to further increase the peak wet weather capacity to 25.3 m^3/s. A new outfall/diffuser system is needed because the current outfall does not have sufficient hydraulic capacity to discharge planned flow increases at high river levels, and is not able to provide sufficient dilution and mixing.

Metro Vancouver defined a target design for the outfall/diffuser system as:

- 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 GD without impacting the hydraulic gradeline of the treatment plant.
- To achieve a minimum dilution ratio of 20:1.

1.2.2 Scope of Work

Conceptual design and preliminary concepts development for the outfall project were completed by others (Black and Veatch, 2015). CDM Smith was retained by Metro Vancouver to review the previous work, refine design concepts, and perform options analysis to achieve the project objectives. The project was executed in two phases: Phase A – Pre-Design was completed in July 2016 (CDM Smith, 2016)., and the current Phase B – Detail Design.

Specific to the outfall system, the Phase A scope of work included:

- An analysis to look at various options for conveying effluent to the river (one or more routes), diffuser arrays in the river (single or multiple), and pumping (now or in future).
- Preliminary design for the recommended outfall system option, including dilution modelling to confirm that the outfall design meets all relevant regulations and guidelines at the initial dilution zone (IDZ).
- An Environmental Impact Study (EIS) conducted for the recommended outfall system pursuant to the Environmental Management Act and the Municipal Wastewater Regulations.

At the end of Phase A, a concept design was recommended, but questions remained about diffuser length and port spacing, and the degree of salinity that would be found at the project site due to seasonal changes in river flow, tidal forcing and factors affecting the location of the salt wedge in the Fraser River, thus affecting initial mixing of the treated effluent in the river.

In the current work (Phase B), the scope of work includes:

- A physical model of the Annacis Island diffuser to finalize the diffuser concept design.
- Additional salinity data collection in the Fraser River to refine the understanding the presence of the salt wedge at the project site.
- Re-analysis of initial dilution for the selected design to confirm that the outfall design meets all relevant regulations and guidelines at the IDZ.
- Far-field model of the Fraser River to assist with the understanding of salinity and to allow for prediction of effluent concentrations beyond the IDZ.
- A Stage 2 EIS conducted for the recommended outfall system pursuant to the Environmental Management Act and the Municipal Wastewater Regulations.

Both project phases were supported by a variety of additional studies, including fluvial geomorphological, geotechnical, environmental and archaeological services (and preparing necessary permit applications and approvals associated with the field investigations).

1.2.3 Environmental Impact Study

British Columbia's Municipal Wastewater Regulations require an EIS before expanding or making a material change to a wastewater treatment facility. The EIS includes provisions for controlling environmental impacts during the construction and operation of the wastewater facility considering:

- Potential cumulative effects of the discharge on the receiving environment
- Additional municipal effluent quality requirements if necessary to protect public health or the receiving environment
- A receiving environment monitoring program
- Demonstration that the system and its discharges will not adversely affect public health or the receiving environment
- Impact on the receiving environment both when the effluent quality requirements are met and when effluent quality is degraded

Golder Associates Ltd., as a subcontractor to CDM Smith, is leading the EIS preparation in stages per provincial guidance that included a Stage 1 assessment of available data and a pre-discharge monitoring program completed in July 2016, followed by the current Stage 2 refined evaluation of potential effluent-related impacts on the receiving environment and public health.

The results of the initial dilution modelling for the final concept diffuser design presented in this report is used to create predictions of effluent concentrations at the edge of the initial dilution zone for use in the Stage 2 EIS.

1.3 Concept Design Development

MV's project definition and the preliminary outfall system concept development (Black and Vetch, 2015) established various physical parameters and constraints that were used in CDM Smith's options analysis and preliminary diffuser design.

1.3.1 Outfall and Diffuser System Location

The new outfall is to be located opposite the AIWWTP in the Fraser River. The general area is in the Annieville Channel of the main arm of the Fraser River lying south of Annacis Island and west of the Alex Fraser Bridge as shown on **Figure 1-1**. At this location, the Fraser River is a complex tidal estuary located approximately 20 km upstream from the mouth at the Georgia Strait. At the mouth at Georgia Strait, the river drains approximately 230,000 km^2 of British Columbia.

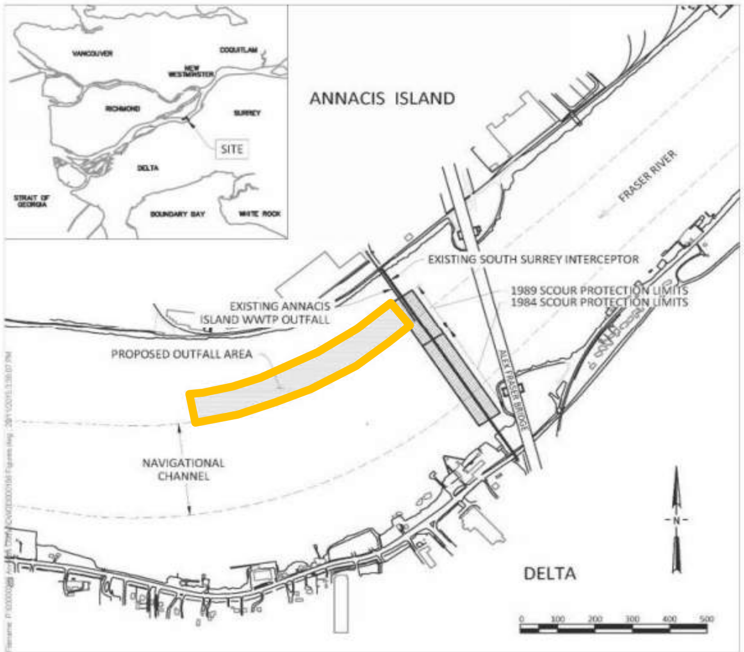

Figure 1-1. Site Map (NHC, 2015)

During the Stage 1 concept development, a decision was made to locate the diffuser system outside the Fraser River Navigation Channel to minimize dredging and shipping impacts. To maximize the diffuser depth and separation from the shoreline, the diffuser ports need to be located immediately adjacent to the edge of the shipping channel. Considering various possible routes for the effluent conveyance to the river, the general area where the outfall diffuser can be located, referred to as the project study area, is highlighted on **Figure 1-1**.

1.3.2 Elevations and Bathymetry

Hydraulic and riverbed elevations that control or constrain the outfall diffuser design are summarized in **Table 1-1**.

Table 1-1. Outfall Design Elevations

Item	Elevation GD + 100 (m)	Chart Datum	Description
Chlorine Contact Tanks (CCT)	105.70	7.29	Maximum Stage VIII water surface elevation in CCTs[1]
Design River Stage w/ SLR	104.18	5.77	Design river level + 1.0 m for sea level rise
Design River Stage	103.18	4.77	Design river level, 200-yr peak winter flood level
High Water	102.00	3.59	High water datum at Alex Fraser Bridge
Geodetic Datum (GD)	100.00	1.59	CVD28GVRD2005 Geodetic Datum
Chart Datum	98.41	0.00	Per Port of Vancouver, varies +/- 0.01 m across area
Top of Riser Protection	89.70	-8.71	Maximum permanent elevation in Safety Area
Dredging Grade	87.51	-10.90	Navigation channel dredging elevation +/- 0.01 m
Dredging Subgrade	85.56	-12.85	Maintenance dredging elevation +/- 0.16 m

[1]Record drawing CCT surface elevation of 106.01 m less historic and predicted settlement through 2067 of 0.31 m

For the Design River Stage, the available hydraulic head for effluent flow under gravity conditions is 2.52 m (105.70-103.18 GD + 100 m) assuming a freshwater ambient river condition. This available head is reduced by 0.18 m when a saltwater wedge is present during winter flow water levels.

A bathymetric survey was performed in 2013 as part of the preliminary concept development (Fugro, 2014) with contours shown on a GD + 100 m datum. Bathymetric surveys of the Fraser River are conducted on a regular basis by the Canadian Coast Guard (CCG) based on a Local Low Water Datum, which is used for navigation charts (Chart Datum). CCG surveys of the navigation channel typically extend to safety setback lines established by Port of Vancouver and occasionally closer to the shore. An image of a recent (January 2016) bathymetric survey is shown in **Figure 1-2**. The Fugro 2013 elevation contours are shown as light grey lines in the figure.

A fluvial geomorphology study for this area of the Fraser River was performed for this project by Northwest Hydraulics Consultants (NHC, 2016). This study indicates that the ship protection peninsulas built for the Alex Fraser Bridge and armor rock placed over the existing Annacis WWTP Outfall and South Surry Interceptor pipelines have created an area of sediment scour immediately downstream of these features. This scour prevents or minimizes the formation of sand waves, which develop during freshet river flows, in the eastern portion of the study area. It is possible that existing, vertical diffuser discharge may also influence sedimentation immediately downstream of the diffuser by adding to turbulence there; this effect is believed to be secondary. Subsequent CFD modelling of the existing outfall's vertical discharge (NHC, 2017) indicates that it produces no noticeable change in the bed shear stresses; therefore, the existing outfall discharge does not contribute to the apparent relative stability of the river bed elevation. The sediment shadow effect is evident for several hundred meters downstream of the existing outfall. However, sand waves up to 1-m high have historically developed in this area. Further downstream sediment accumulates in the river bottom on the north side of the navigation channel. Port of Vancouver reports they must dredge the inside of the river bend in this area every two years due to sediment accumulation of up to 2 m or more.

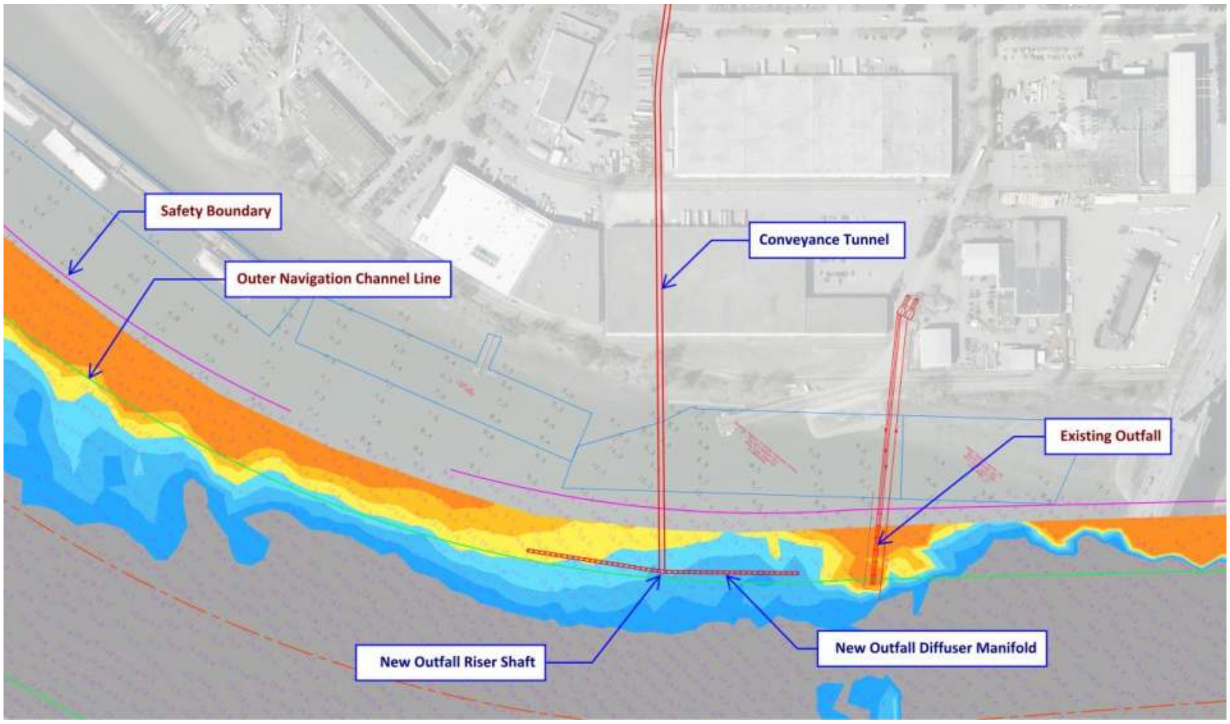

Figure 1-2. Project Study Area with January 2016 CCG Bathymetric Survey Chart

1. Magenta Line is Safety Boundary
2. Green Line is Edge of Dredged Navigation Channel
3. Contour shading is at 0.5 m intervals with blue greater that 10.5 m below Chart Datum

The color shading on **Figure 1-2** highlights the fact that: (1) the river bottom elevation in January 2016 is shallower than the Dredging Grade for much of the northern limits of the navigation channel in the proposed diffuser area and (2) dredging deeper than the Dredging Grade for the new diffuser would create a depression that would quickly fill with sediment.

1.3.3 Diffuser Layout

Preliminary concept development (Black and Veatch, 2015) suggested that two separate diffuser sections ("two outfalls") near the west and east limits of the proposed diffuser area might result in better overall dilution and diffusion of the effluent into the river. The validity of this concept was part of the dilution modelling studies carried out during the outfall system options analysis as described in this report (**Section 5.2**).

1.4 General Approach and Limitations

The general approach used for the diffuser concept design and physical, initial dilution, and far-field modelling presented in this report is as outlined below:

1. Identify regulatory requirements the project must meet that affect the design of the AIWWTP outfall/diffuser system (**Section 2**), which include:
    a. Municipal Wastewater Regulations (MWR) including those of dilution ratio, IDZ boundaries, municipal effluent quality requirements, and outfall design requirements, and
    b. Provincial water quality guidelines (WQGs) and site-specific water quality objectives (WQOs).
2. Review and analyze available data to support the analyses including Fraser River ambient conditions (flow, tide, current, temperature, salinity, pH, and ambient background concentrations) and effluent flow and quality data for the AIWWTP (**Sections 3 and 4**).
3. Develop a concept design for the diffuser system(s) that optimizes initial dilution for the Stage V flows using the available gravity hydraulic head at the Design River Stage, present the results of physical modelling to finalize the concept design and refine the method for predicting initial dilution, and discuss necessary dredging volumes, predicted sedimentation rates, maintenance dredging, and other diffuser inspection and maintenance requirements (**Section 5**).
4. Define an approach to determine the concentration at the IDZ boundary including selecting of initial dilution and far-field modelling approaches, establishing input parameters for modelling, and performing initial dilution simulations to predict concentrations at the edge of the IDZ used to assess regulatory endpoints, and performing far-field modelling to predict concentrations at far-field assessment nodes in the Fraser River (**Section 6**).
5. Present the predictions for edge of IDZ concentrations for both the optimized gravity flow design for Stage V flows, the back-calculations of allowable ammonia concentrations and predictions of IDZ temperatures, and predicted dilutions for a future pumped flow design for Stage VIII flows (**Section 7**).

This report does not include calculations to determine ambient (Fraser River) background calculations for individual parameters that are used in the predictions of concentrations at the edge of the IDZ nor the screening process used to select the list of contaminants of potential concern (COPCs) for which predictions are made; these are presented in the Stage 2 EIS.

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Section 2

Regulatory Requirements

2.1 Municipal Wastewater Regulations

2.1.1 Calculation of Dilution Ratio

According to the Municipal Wastewater Regulations, Part 1 (1) (2) (2): "The dilution ratio is calculated by dividing the 2-year return period 7-day low flow in the receiving stream by the maximum weekly (7-day) municipal effluent flow…"

Daily stream flow records are not available at the project site; however, long-term daily flow records since 1912 are available for the Fraser River at Hope (described further in **Section 3.4**). Hope is about 130 km upstream of the project study area adjacent to Annacis Island. Downstream inflows to the river between Hope and Annacis Island add to the total flow, even during low flow conditions at Hope (based on Northwest Hydraulic Consultants (NHC) Fraser River flow models). A conservative, initial estimate of outfall dilution ratio was calculated using the Hope flow data.

Using the entire record of flow at Hope (1912-2015), the 2-year return period 7-day low flow (7Q2) was calculated using the US Environmental Protection Agency (USEPA) DFLOW 3.11. DFLOW uses daily stream flow records and calculates hydrologically-based design flows. The calculation is based on a climatic year of April 1 through March 31 and yields a 7Q2 flow for the Fraser River of 652 m^3/s at Hope. The AIWWTP outfall will discharge into the Annieville Channel of the Fraser River, the main arm of the river downstream of the trifurcation above Annacis Island. Seventy-eight percent (78%) of the river flows through the Annieville Channel (NHC, 2008). Therefore, the 7Q2 flow in the Annieville Channel is 78% of 652 m^3/s, or 509 m^3/s.

Using the 2001-2014 AIWWTP record of average daily flow, a maximum weekly flow of 9.8 m^3/s was calculated by taking the maximum of the running averages of seven daily average flows. Therefore, the current minimum dilution ratio is 51.9 (509 m^3/s divided by 9.8 m^3/s). The actual dilution ratio would be somewhat higher due to inflows downstream of Hope. Future minimum dilution ratios were estimated by assuming the maximum weekly municipal effluent flow as a proportion of the peak wet weather flow (PWWF) remains consistent (at 78%) with future plant expansions. These minimum dilution ratios are shown in **Table 2-1**.

Table 2-1. Estimated Dilution Ratio

Expansion	PWWF (m3/s)	Max. Weekly Flow Proportion	Max. Weekly Effluent Flow (m3/s)	Min. 7Q2 River Flow at Annacis Is. (m3/s)	Minimum Dilution Ratio
Stage IV	12.6	78%	9.8	508.6	51.9
Stage V	18.9	78%	14.7	508.6	34.6
Stage VI/VII	22.1	78%	17.2	508.6	29.6
Stage VIII	25.3	78%	19.7	508.6	25.8

[1] http://www.epa.gov/waterdata/dflow

Part 6 (1)(94) (4) indicates that a director may approve the use of secondary treatment if there is a minimum dilution ratio of 20:1 and Part 6 (1)(94) (5) prohibits discharge if the dilution ratio is less than 10:1. The AIWWTP effluent discharge into the Fraser River meets the minimum dilution ratio criterion for all projected future flows.

2.1.2 Initial Dilution Zone (IDZ)

The Municipal Wastewater Regulations at Part 6 (1) (91) (1) define the IDZ as:

- The 3-dimensional zone around the point of discharge where mixing of the municipal effluent and the receiving waters occurs.

Water quality guidelines must be met at the edge of the IDZ. For guidelines that protect from the potential for short-term toxicity impacts, the objectives must be met at all times. For those that protect from the potential for long-term impacts, the guidelines must be met at monthly average conditions.

In addition, the edge of the IDZ must be at least 300 m away from recreational areas, shellfish harvesting areas, domestic or agricultural water intakes, or other sensitive areas requiring protection. None of these areas are located within 300 m of the project study area as defined in **Section 1.3**.

The key clauses relating to the spatial extent of the IDZ are found in Section 93(1): "For the purpose of calculating the initial dilution zone for a stream, river or estuary, all of the following, measured from the point of discharge and from mean low water, apply:

(a) the height is the distance from the bed to the water surface;
(b) the width, perpendicular to the path of the stream, is the lesser of
  (i) 100 m, and
  (ii) 25% of the width of the stream or estuary;
(c) the length, parallel to the path of the stream, is the distance between a point 100 m upstream and a point that is the lesser of
  (i) 100 m downstream, and
  (ii) a distance downstream at which the width of the municipal effluent plume equals the width determined under paragraph (b)."

The regulations also state the initial dilution zone must not extend closer to shore than mean low water. Following these regulations, a conceptual IDZ for a multiport diffuser at the project site is shown **Figure 2-1**. The target initial dilution will be determined at the edge of an IDZ located 100 m in all directions from any edge of the diffuser, since 100 m is less than 25% of the river width at this location (147.5 m).

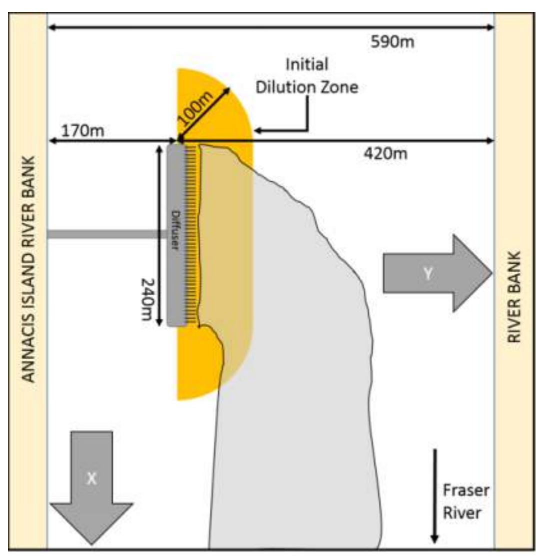

Figure 2-1. Conceptual Initial Dilution Zone

2.1.3 Municipal Effluent Quality Requirements

Part 6 (1) Sections 94-97 of the British Columbia Municipal Wastewater Regulation (B.C. Reg. 87/2012) defines the municipal effluent quality requirements. Those relevant to the AIWWTP discharge include:

- Section 94 defines end-of-pipe limits for the following parameters: biochemical oxygen demand (BOD_5), total suspended solids (TSS), pH, total phosphorus and orthophosphate, and Section 96 defines edge-of-the-IDZ limits on coliform bacteria. These limits are evaluated in the main report of the Stage 1 EIS.
- Section 95 requirements are in effect if the maximum daily effluent flow is greater than 50 m^3/day, which is the case for the AIWWTP discharge. Subsection 6 requires analysis related to the design of the diffuser, and states:

  "A discharger must determine the maximum allowable municipal effluent ammonia concentration at the "end of pipe" by a back calculation, from the edge of the initial dilution zone that considers:

  (a) the ambient temperature and pH characteristics of the receiving water, and
  (b) water quality guidelines for chronic ammonia."

There are two additional federal effluent ammonia regulations, summarized in **Table 2-2**.

- Pursuant to subsection36(5) of the Fisheries Act, the Wastewater Systems Effluent Regulations (WSER) defines a maximum allowable at the end of the pipe effluent unionized ammonia concentration of 1.25mg-N/L at 15°C ± 1°C, as calculated by the equation listed in **Table 2-2**.
- The Canadian Environmental Protection Act (CEPA) classified total ammonia dissolved in water as a toxic substance. Pursuant to that classification, a guideline for the release of total ammonia dissolved in wastewater effluent was established in 2004. The guideline sets a pH dependent maximum allowable effluent ammonia concentration, which is calculated using the equation listed in **Table 2-2**.

Table 2-2. Federal Effluent Ammonia End-of-Pipe Regulations

Regulation	Requirement
WSER Unionized Ammonia	Unionized ammonia must be <1.25 mg-N/L at 15°C ± 1°C and calculated using the following equation: $$NH_3 = \frac{\text{Total Ammonia}}{[1 + 10^{(9.56 - pH_{eff})}]}$$ Where: Total ammonia is the sum of unionized ammonia and ionized ammonia pH is the initial pH of the effluent at 15°C ± 1°C 9.56 is the logarithmic dissociation constant of ammonia at 15°C The concentration of total ammonia in the effluent is determined using an aliquot of the effluent from which the pH of the effluent is determined.
CEPA Total Ammonia Guideline	Maximum allowable total ammonia concentration is: $Total\ Ammonia\ (\text{mg/L as N}) = 306{,}132{,}466.34 * 2.7183^{(-2.0437 * pH_{eff})}$ Where pH_{eff} is the measured pH of the effluent

2.1.4 Outfall Design and Minimum Depth Requirement

Sections 99 and 100 include requirements that define important design considerations for any outfall/diffuser system. These include that the outfall/diffuser system must meet initial dilution requirements; prevent air entrapment; is adequately weighted to prevent movement; is protected from corrosion, wave, boat and marine activity; is located at sufficient depth to maximize the frequency of trapping the plume; intercept the predominant current and avoid currents that move the plume to the shoreline; and is designed to achieve maximum dilution where most of the water flows in the water body.

Additional requirements specific to siting an individual outfall/diffuser system include:

- 99(2)(c)(i) and (ii): "Each diffuser section will provide at least a 10:1 dilution within the IDZ" and "Outside the IDZ the discharge does not cause water quality parameters to fail to meet water quality guidelines."
- 99(3)(b)(ii): "A qualified professional must ensure that outfalls are located at a depth of at least 10m below mean low water in estuaries."
- 100(1) and 100(2), which confirm that the minimum 10m depth below mean low water level applies to the shallowest diffuser port.
- 89(2)(a) "'mean low water' means, for marine waters, the datum provided on the most recently published marine chart published by the Canadian Hydrographic Service for the location."

2.2 Water Quality Guidelines and Objectives

The Municipal Wastewater Regulations stipulate that the discharger must not discharge municipal effluent unless, at the edge of the IDZ, applicable WQGs are met. For this project, Fraser River WQOs also need to be met at the edge of the IDZ. The Stage 2 EIS screens against applicable guidelines (listed below) from all relevant jurisdictions.

- Water Quality Assessment and Objectives for the Fraser River from Hope to Sturgeon and Roberts Banks First Update, Freshwater, Estuarine or Marine Water Quality Criteria for the Fraser River Main Arm from the New Westminister Trifurcation to the Banks. Accessed May 2017. Available online at http://www.dfo-mpo.gc.ca/Library/272539.pdf.
- British Columbia Ministry of Environment Approved Water Quality Guidelines (BC WQG) (2017) for freshwater/estuarine/marine aquatic life. Accessed August 2017. Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-quality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf. Where approved guidelines were not available, working guidelines were used for screening. Accessed August 2017. https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-quality/wqgs-wqos/bc_env_working_water_quality_guidelines.pdf.
- Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life freshwater and marine water quality guidelines. Accessed August 2017. Available online at: http://st-ts.ccme.ca/en/index.html.

- The USEPA criteria that were used were: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-june-2017. Accessed August 2017.

Most of the comparisons to WQGs and WQOs are performed in the main report of the Stage 1 EIS. The calculations for comparison to the interim guideline for temperature (which limits changes in the river to a +/- 1°C temperature variation at any time, location or depth in marine and estuarine waters) and the back calculation of ammonia discussed in **Section 2.1.3** are included in **Section 7.6.2**

2.2.1 Ammonia Specific Receiving Water Guidelines and Objectives

Short- and long-term total ammonia water quality objectives exist at the provincial level, and are set as a function of ambient pH and temperature. Attachment J shows the maximum and average 30-day total ammonia water quality objectives for the Fraser River from Hope to Sturgeon Banks.

Additionally, if a discharger's effluent is found to be acutely toxic due to concentrations of unionized ammonia, the WSER authorizes such discharger to apply for a temporary permit to continue discharging if the concentration of unionized ammonia in the water at any point that is 100 m from the point of entry where effluent is deposited in that water via the final discharge point is less than or equal to 0.016 mg-N/L, and if:

- The effluent is acutely lethal, as determined in accordance with Reference Method EPS 1/RM/13 using the procedure set out in Section 6 of that Method and the Procedure for pH Stabilization EPS 1/RM/50, primarily due to the concentration of unionized ammonia; or
- The effluent is acutely lethal because the concentration of unionized ammonia in the effluent deposited via the final discharge point is greater than or equal to 1.25 mg-N/L, at 15°C ± 1°C.

Table 2-3. Ammonia Receiving Environment Regulations

Regulation	Requirement
British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Maximum concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-1 in Attachment J
British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Average 30-day nitrogen concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-2 in Attachment J
WSER & Canadian Water Quality Guidelines for the Protection of Aquatic Life	For effluent that is acutely lethal due to unionized ammonia concentrations, the unionized ammonia at any point 100 m from the point of entry where effluent is discharged must be less than or equal to 0.016 mg-N/L. Unionized ammonia is calculated using the following equation: $$NH_3 = \frac{Total\ Ammonia}{\left[1 + 10^{\left(0.09018 + \frac{2729.92}{(273.15+T)} - pH\right)}\right]}$$

2.3 Port of Vancouver Requirements

Discussions with Dave Hart, Dredging Specialist, Operations for Port of Vancouver, indicated they would have the following conditions for placing the diffuser in the Fraser River at the project study area:

- A diffuser could be placed between the boundary of the navigation channel and the safety setback lines.
- A diffuser in the above area should not have any infrastructure extend above 6 m water depth at MLW (Chart Datum).

2.4 Summary of Regulatory Requirements

The following is a summary of the regulatory requirements and their application to the proposed outfall/diffuser system design for the AIWWTP discharge.

- A dilution ratio greater than 20:1 determined from the 7Q2 flow and maximum weekly effluent flow is met for the current effluent discharge and all anticipated future effluent flow rates.
- The project study area can accommodate a diffuser location and its IDZ does not overlap with the shoreline.
- The diffuser should be located at a depth of at least 10 m (measured at the shallowest port), and achieve a minimum dilution of 10:1 with the IDZ.
- The discharge from the diffuser should not cause water quality parameters outside the IDZ to fail to meet water quality guidelines or objectives, and should meet end-of-pipe regulations for ammonia and other parameters

Section 3

Fraser River Data

3.1 Available Monitoring Data

Data from several monitoring stations along the Fraser River inform this study. **Table 3-1** describes the data used to understand ambient conditions in the Fraser River and as input data for initial dilution modelling. The stations are shown on **Figure 3-1**.

Table 3-1. Monitoring Data Considered in this Study

Station	Data Available	Data Frequency	Coverage	Approximate River km from Mouth
Fraser River Water Quality Buoy at Gravesend Reach	Temperature, pH, conductivity, current speed, water quality	Continuous Hourly	4/2008 – 10/2016	13.1
		Grab Samples	9/2001 – 12/2015	
AIWWTP	Flow and water quality	Described in Section 4		20.1
AIWWTP Receiving Environmental Monitoring (REM) at the IDZ	Effluent and river water quality, conductivity and temperature with depth (CTD) profiles (only 2016)	Grab Samples for Winter and Summer Season	2011 – 2016	20.1
Shoreline of Annacis Island: Brewery Pier	Salinity, temperature, turbidity	Continuous	3/2016 – 4/2016 9/2016 – 3/2017	20.1
Proposed Diffuser Site: QuadPod	Salinity, temperature, turbidity, current speed and direction.	Continuous	2/2017 – 3/2017	20.1
Near Proposed Diffuser Site	CTD profiles	Synoptic (5 different days)	2/2017 – 3/2017	20.1
Fraser River at New Westminster	Tide Elevation	Hourly	1970 – 2017	26
Upstream Reference Station for AIWWTP REM Monitoring	Water quality	Grab Samples for Winter and Summer Season	2011 – 2016	26.3
Fraser River at Hope	Flow, water quality	Daily	1912 – 2017	151

The remainder of this section presents a summary of the data that were considered. The data are used in two ways: (1) input data for initial dilution modelling and (2) to characterize the parameters measured in treated effluent (**Section 4.0**) and the Fraser River to predict concentrations at the edge of the IDZ.

The initial dilution model requires input data on the effluent, ambient river conditions and the diffuser configuration:

- Effluent – flow and density (temperature)
- Fraser River – water depth, current speed, and vertical density structure (temperature and salinity)
- Diffuser – length and orientation of manifold; and number, diameter, orientation and spacing of ports

Section 6.4 describes how the data are used to develop input parameters for the initial dilution model. **Section 5.0** describes the development of conceptual diffuser designs.

Water quality data used to calculate the concentration at the edge of the IDZ are:

- Ambient background concentrations – the REM reference area station, supplemented with data collected at the water quality buoy at Gravesend Reach and FRAMP Tilbury Island data (see Stage 2 EIS for calculations).
- Effluent – 2012-2016 effluent data

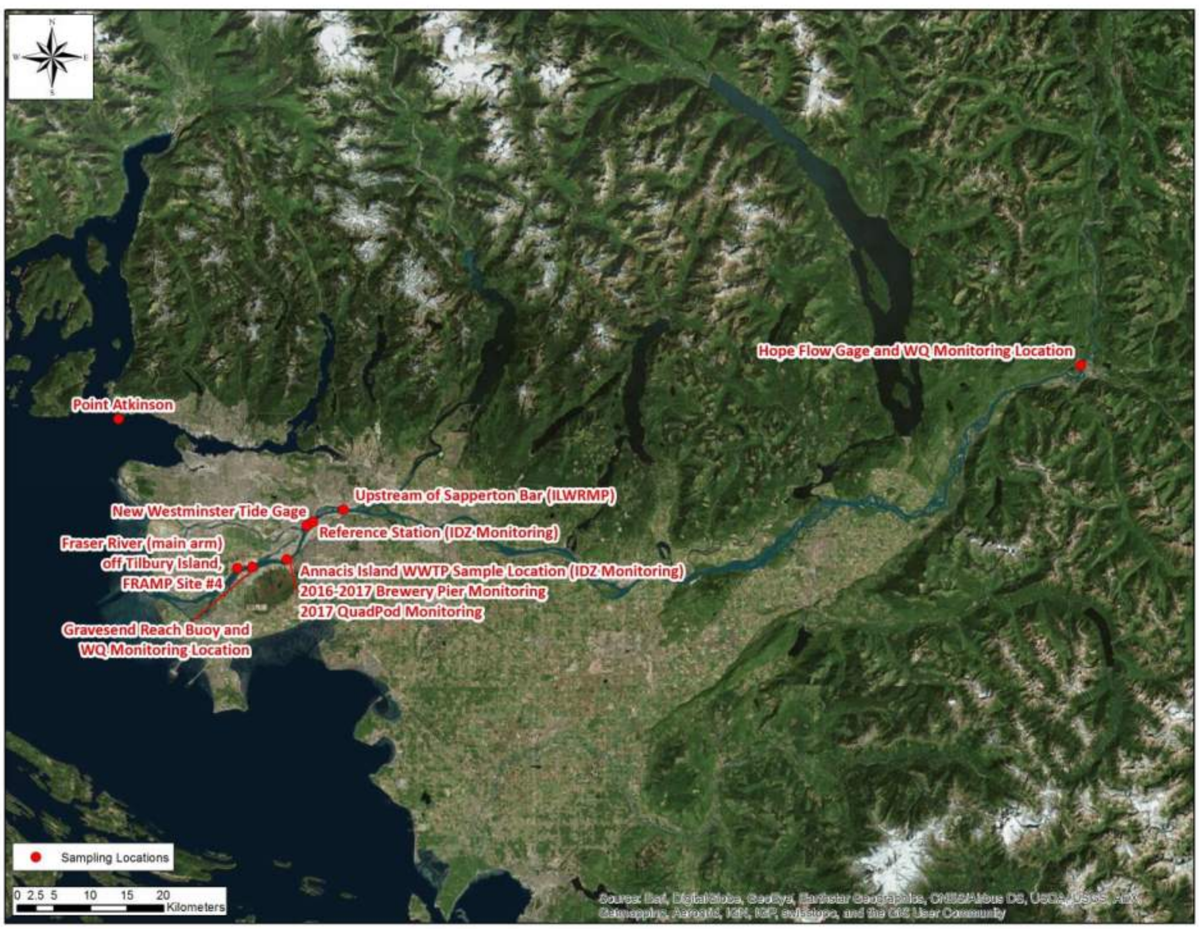

Figure 3-1. Locations of Monitoring Stations along the Fraser River

3.2 Fraser River Characteristic Data

Readily available sources of data from the efforts in Stage 1 are updated for Stage 2, including physical data from the Gravesend Reach buoy, water surface elevation data from the tide gage at New Westminster, and daily flow estimates for the Fraser River at Hope.

During Stage 1, two data collection efforts occurred:

- Continuous monitoring of temperature and salinity from March 9-April 13, 2016 at a location on the Brewery Pier on the north bank of Annacis Island, approximately 200 m downstream of the proposed outfall; two meters were deployed but only the bottom meter, located just above the river bottom at water depths ranging from about 3 to 5 m provided usable data, and
- Water column profiling of CTD using acoustic backscatter at select tidal conditions during March 22-23, 2016.

Based on recommendations from Stage 1, CDM Smith retained Golder Associates to provide continuous and synoptic ambient measurements to better understand the physical conditions at the project site during low flow conditions at flows less than 1,000 m^3/s, when salinity may be present. A second field campaign was conducted from September 2016 – March 2017:

- Continuous monitoring of temperature and salinity at a single-point, relatively shallow, moored instrument from September 2016-March 2017 located on the Brewery Pier,
- Continuous monitoring of near-bed temperature, salinity turbidity, and current speed and direction through the water column near the center of the proposed diffuser manifold from a seabed frame (QuadPod) for a 30-day period, and
- Water column profiling of CTD during select tidal conditions over five days at six specified sampling locations.

The Golder Associates field report, *Annacis Island WWTP Salinity Monitoring Program*, is found in **Attachment E**.

3.2.1 Temperature

Ambient river temperature in the Fraser River varies seasonally. **Figure 3-2** depicts temperature at the Gravesend Reach water quality buoy about 7 km downstream of Annacis Island. The readings at the buoy are taken at 1 m below the water surface. These data are used in **Section 6** to develop long-term average temperatures for river flow conditions as input to the initial dilution modelling.

Starting in 2016, continuous temperature data were also recorded at the Brewery Pier, a fixed pier site on Annacis Island. A mooring line was suspended from a railing on the Brewery Pier and the measurement device was installed at an elevation of -4.28 m CGVD28. During the September 2016 to March 2017 deployment, the Brewery Pier instruments measured an average temperature of 6.8°C.

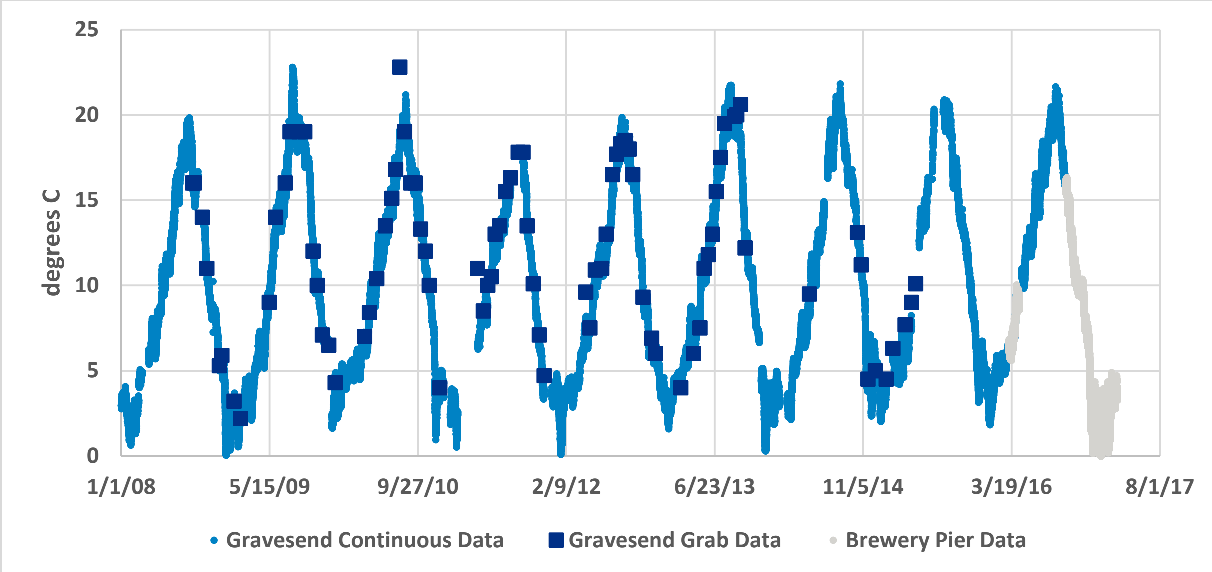

Figure 3-2. Time Series of Water Temperature (2008-2017)

3.2.2 pH

The Gravesend Reach water quality buoy also measures pH at 1 m below the water surface. **Figure 3-3** is a time series graph of available continuous data. The data quality appears questionable (it is unclear if a QA review by Environment Canada was completed). While the data is between 7 and 8.5, consistent with expectations for potential ranges in fresh water, unexplained linear shifts in observations occur as well as spurious data points (those well out of expected bounds were removed from this graph), but without verified QA review from Environment Canada, the data are considered preliminary.

Continuous pH was also measured at the Brewery Pier. During biweekly site visits to download data, an independently calibrated pH meter was used to verify the continuous sensor measurements. Drift and inconsistencies with the independent pH meter meant the continuous pH data from the sonde could not be verified and thus, the data are not used.

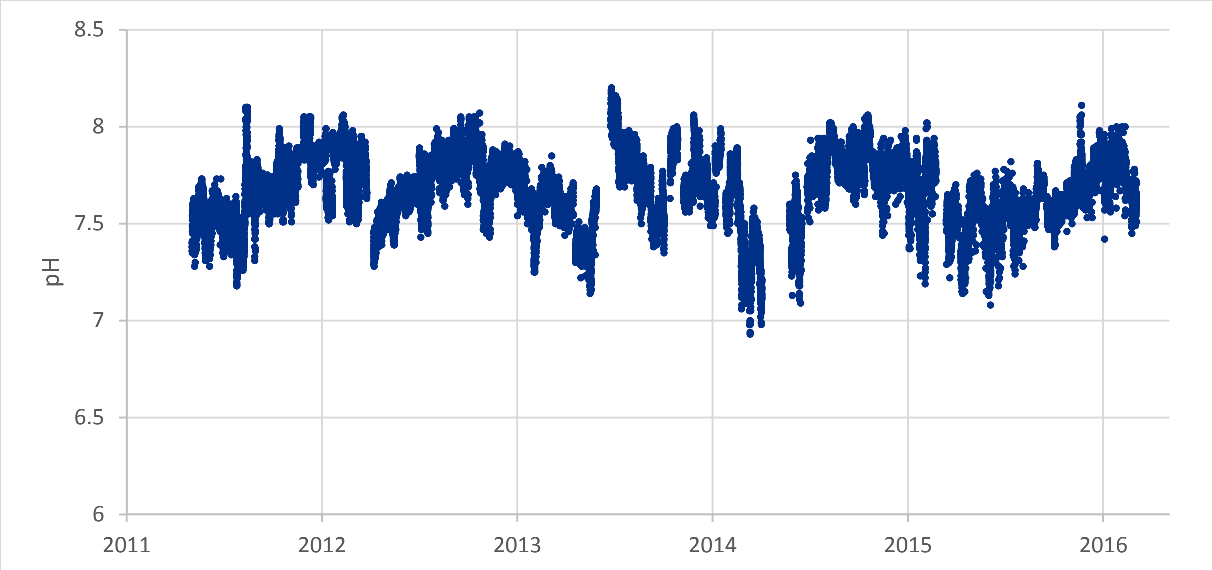

Figure 3-3. Time Series of pH Measurements at the Gravesend Reach Buoy

3.2.3 Salinity

The presence of salinity at the project site and its distribution with depth will have a significant influence on the predicted initial dilution from a submerged diffuser. Typically, ambient temperature and salinity observations are used to develop density profiles as an input to the initial dilution modelling. Density profiles are of critical importance to the initial dilution calculations because the amount of salinity influences the buoyancy flux impacting dilution, and the shape of the density profile will influence how high the effluent plume will rise before it is trapped. While salinity can increase dilution through buoyancy flux, a trapped effluent plume can lower dilution by limiting the volume of water that can be entrained.

3.2.3.1 Recent Monitoring for Stratification (March-April 2016)

The goals of the program were to obtain temperature and salinity information at low flow to support the hypothesis that salinity only occurs at low river flow and obtain additional information on the vertical density differences. Measured data from the bottom-moored meter (Golder Associates, 2016) are presented in **Figure 3-4.** During the deployment, average flow in the Fraser River at Hope was 1,450 m^3/s, which is above the low flow of 1,000 m^3/s that the Stage 1 analysis had identified as a threshold for the salt wedge having the potential to reach Annacis Island. The results show several instances where salinity briefly rose to above 0.1 psu, with a peak value of about 1.8 psu, and 6 hours as the longest duration of salinity above 0.1 psu. The data suggest salinity occurrence at the project site is driven by complex interactions of multiple cycles of strong asymmetrical tides followed by a strong flood tide. The data also identified the presence of relatively low salt concentrations (about 2 PSU) in shallow water when the river flow was above 1,000 m^3/s, indicating the need for additional data collection to better understand the presence, magnitude and duration of salt at the project site.

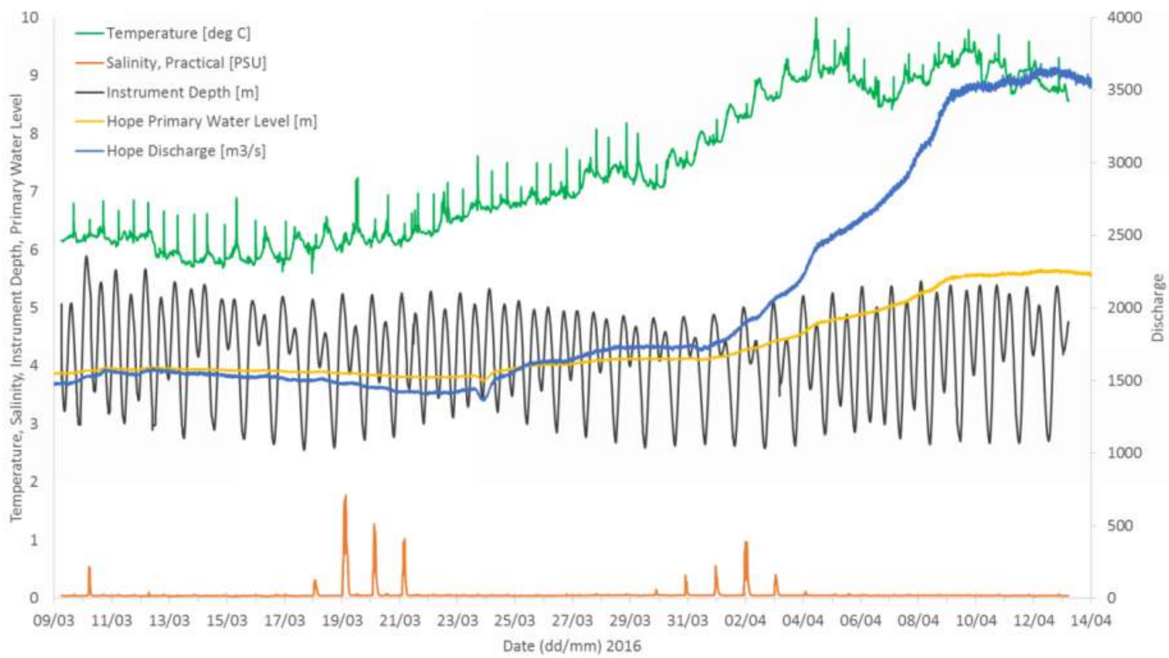

Figure 3-4. Time Series of Temperature, Salinity, and Instrument Depth near AIWWTP

3.2.3.2 Recent Monitoring for Stratification (September 2016-March 2017)

Based on recommendations from Stage 1, a field campaign was initiated in September 2016 and continued into March 2017 to measure the ambient density properties (i.e., temperature and salinity) during low flow conditions.

Continuous measurements were taken at the Brewery Pier (shallow, nearshore conditions) and at the QuadPod (at the proposed diffuser depth and location). The monitoring periods at both measurement sites overlap during the QuadPod deployment (30 days) to capture any variability in salinity depth, occurrence, magnitude and to better understand any temporal and spatial synchronization as the salt wedge moves upriver. **Figure 3-5** is a time series graph of salinity for several days in February 2017 from the Brewery Pier and QuadPod when salt is present and flows in the river are about 1200 m^3/s.

Peak salinity of 19.9 ppt was observed at the QuadPod on February 19, 2017 when the flow in the Fraser was approximately 1,225 m^3/s. This measurement is greater than any previously observed at a flow greater than 1,000 m^3/s. Salinity of >1 ppt was observed at the site when flows were between 797 and 1930 m^3/s (maximum flow occurred in October 2016). Tidal asymmetry at the site, in the form of diurnal inequality caused by smaller differences between the higher high water of the tidal cycle and higher low water, tend to coincide with the occurrence of the salinity at the site (along with low river flows). A salinity of greater than 1 ppt persisted for almost 24 hours on February 19-20, 2017, but is ephemeral under other tidal and flow conditions. This monitoring data also shows that the salt wedge evacuates the site during each tidal cycle.

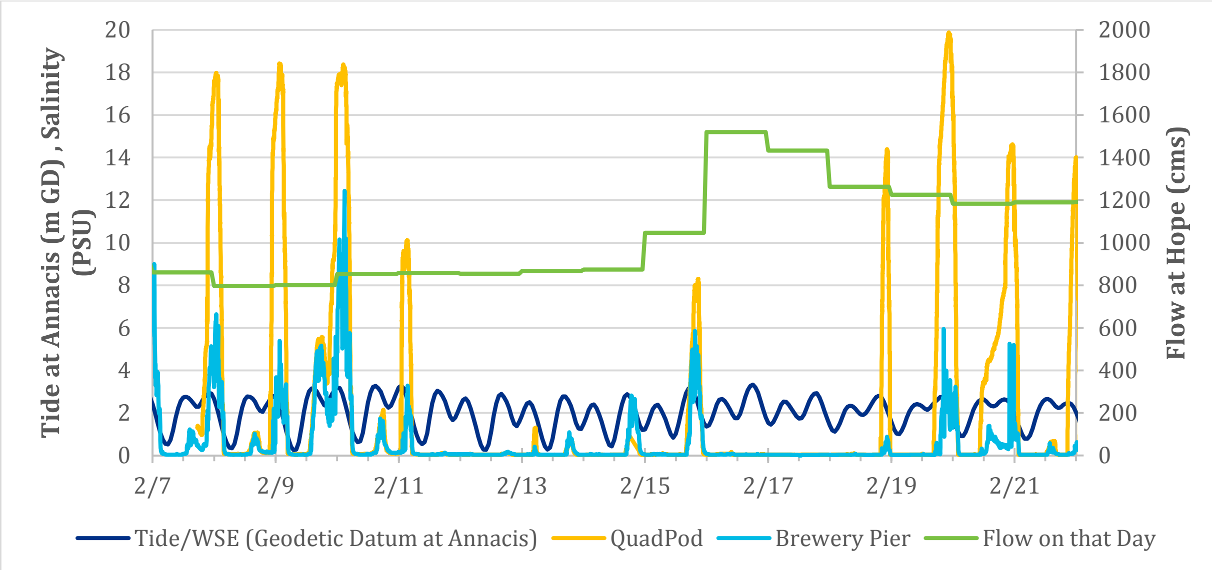

Figure 3-5. Time Series of Salinity Measurements in February 2017 at the QuadPod and Brewery Pier Locations

3.2.3.3 IDZ Boundary Data (2007-2016)

Figure 3-6 presents salinity data measured at the IDZ boundary from Metro Vancouver's REM program from 2007 to 2016. Sampling occurs during low flow periods, and occurs in February-March and in August-September. Measurements are summarized in yearly IDZ monitoring reports (e.g., Smith, 2013a). As the measurement program consists of a grab sample at depth and are designed to capture the effluent plume, they do not represent ambient river conditions. Therefore, we can only use these data to determine whether salinity was present at Annacis Island and at what concentration. The grab samples were collected from depths ranging from 10 m to nearly 20 m below the water surface, depending on the location along the IDZ boundary and the sampling period (winter vs. summer, ebb vs. slack vs. flood). Nearly 80% of the recorded measurements report less than 1 psu of salt in the water column during either of the summer or winter sampling periods (**Figure 3-6**) with a maximum concentration of 15 psu occurring at a Fraser Flow of 1,220 m^3/s.

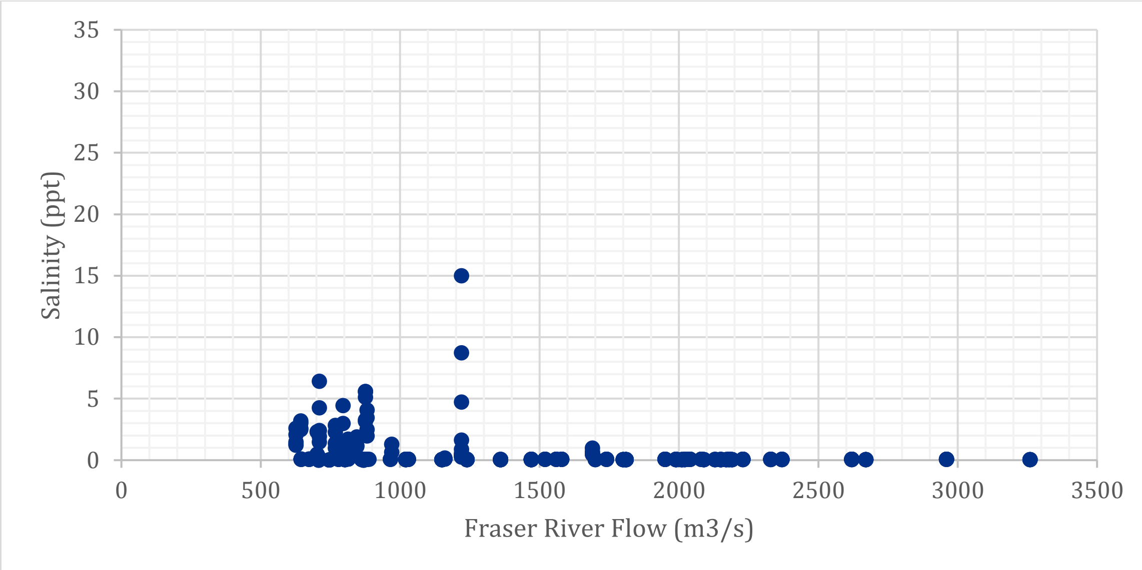

Figure 3-6. Salinity Measurements from Grab Samples

3.2.3.4 Ages and Woolard (1976) Estimates

As in Stage 1, the Stage 2 dilution analysis still considered similar observations presented in Ages and Woolard (1976) with respect to the presence of the salt water wedge near Annacis Island. They report that during periods of low flow in the Fraser River (typically during the winter), the salt wedge associated with the flood tide has been recorded to reach Annacis Island and near the project site. Ages and Woolard performed their study during a period of low flow, when flow in the Fraser River was approximately 850 m^3/s, but also before dredging to deepen the navigation channel of the Fraser River occurred in the early 1980s, which may now allow the salt wedge to penetrate further upstream than was measured in 1976.

3.2.3.5 AIWWTP Pre-Discharge Dilution Study (1997) Vertical Profiles

Vertical profiles of temperature and salinity are presented in the ***Annacis Island Wastewater Treatment Plant Pre-Discharge Monitoring Dilution/Dispersion Study*** (LWMP Environmental Monitoring and Assessments Technical Committee, 1997). During a detailed field survey in November 1995, the Fraser River flow was sufficiently high such that the salt wedge was held below the AIWWTP. Profiles of temperature and salinity were measured through the flood cycle on February 13 and 14, 1996 when the Fraser River flow at Hope on those two days were 865 and 922 m^3/s, respectively [NB: the location of the profiles are not recorded, but are assumed to be in the navigation channel near Annacis Island). **Figure 3-7** presents the temperature and salinity profiles from the beginning of the salt water intrusion (top) and at the fullest intrusion (bottom) during the 1996 study. The vertical profiles indicate that the water column is stratified with a surface layer of freshwater extending down 4 to 6 m, and then a linearly increasing salinity level extending below the freshwater 'lens' with maximum observed salinities of 6 to 12 psu at the bottom.

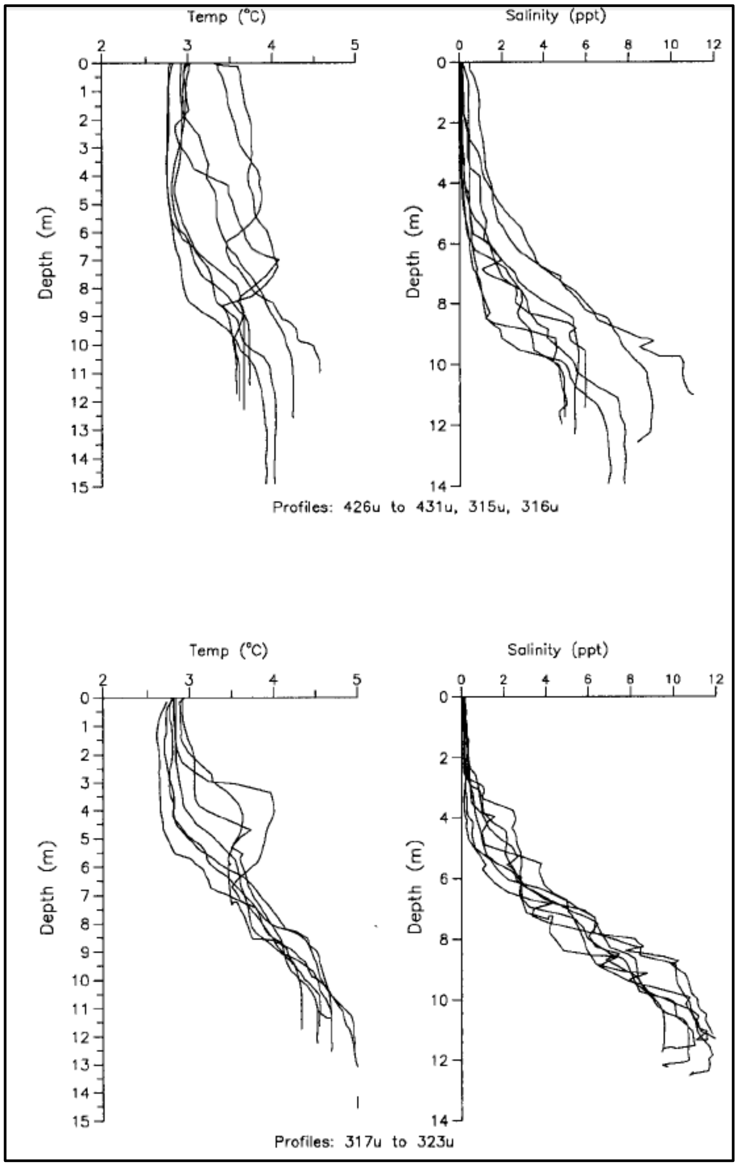

Figure 3-7. Vertical Profiles of Temperature and Salinity
Beginning of Saltwater Intrusion (top) and at the Fullest Extent of Intrusion (bottom) (LWMP, 1997)

3.2.3.6 IDZ Boundary Data (2016)

Metro Vancouver also collected vertical profiles of temperature and salinity just downstream of the IDZ near the western boundary of the project's study area during the 2016 low flow REM program. Most of the profiles did not indicate the presence of saline water, except for a profile on March 2, 2016, when the river flow as measured at Hope was 1,220 m^3/s. **Figure 3-8** depicts two salinity profiles from the 2016 IDZ monitoring program, along with graphs of the location along the tidal cycle when they were collected.

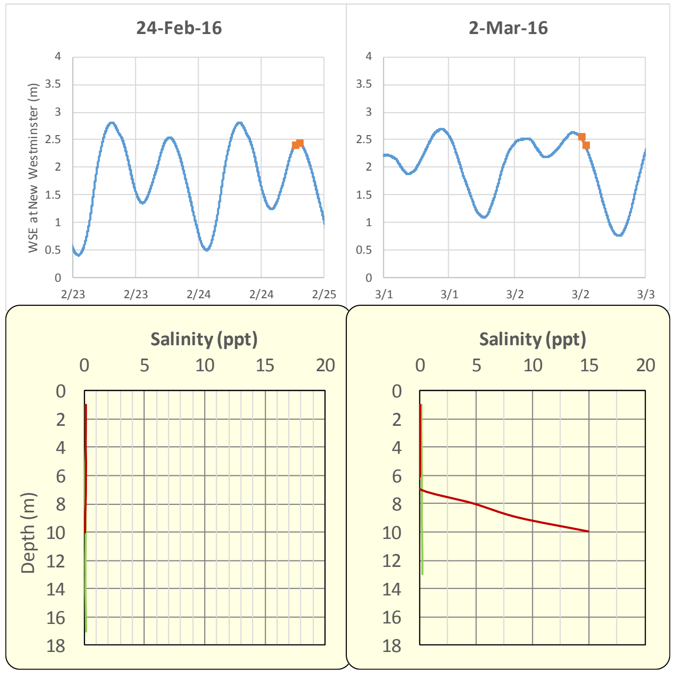

Figure 3-8. Profiles from the IDZ Monitoring on February 24, 2016 and March 2, 2016
Bottom two figures are salinity profile with depth: green (at the upstream reference station) and red (at the IDZ boundary) on two different dates (note the diurnal inequality).

3.2.3.7 Recent Monitoring for Stratification: CTD Profiles

A CTD instrument and an acoustic Doppler current profiler (ADCP) were used to collect data on the vertical structure of salinity in the river on March 22-23rd, 2016. On the dates of the survey, no salinity was found at the project site as river flow and tidal conditions were not suitable. The survey team traveled down river and located the inward extend of the salt wedge near Tilbury Island.

The 2016-2017 continuous monitoring at the Brewery Pier and the QuadPod is complemented by cotemporaneous CTD water column profiling at locations within 300 m of the proposed diffuser site. **Figure 3-9** is a compilation of CTD profiles taken within about an hour of each other on February 9, 2017. Of the five different days where selected tidal conditions were monitored, two days showed significant stratification near and at the site (February 7, 2017 and February 9, 2017). Additional information regarding the measurement techniques, CTD locations, and other CTD profiles are found in the Golder field report in **Attachment E**.

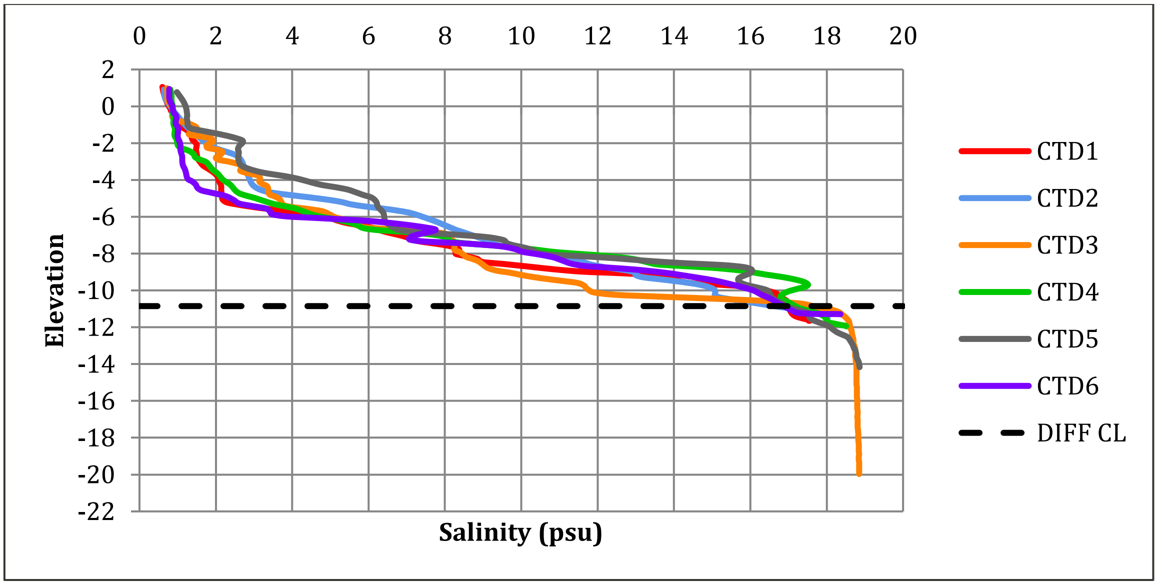

Figure 3-9. CTD Profiles near the Project Site on February 9, 2017

3.2.4 Currents

River currents on the Fraser River are measured at the Gravesend Reach buoy. Current speed and current direction are measured at 1-m below the water surface. The hourly data record used for this project begins in April 2008 and ends in mid-December 2014 with some periods of missing data. According to correspondence with Environment Canada, the current meter at the Gravesend Reach buoy was removed between January 2015 and October 2016.

Although the buoy is located some distance downstream of AIWWTP, the measurement conditions along the banks of the Fraser River provide a reasonable analog to a similar behavior near the proposed outfall/diffuser system. From the buoy data, the Fraser River appears to exhibit a tidal current reversal during periods of lower discharge when the direction of measured current is typically bidirectional (**Figure 3-10**, left panel with current direction [top] and current speed [bottom]; current direction >180° is flow discharging to the mouth of the river; current direction <180° is upstream flow). During higher flows in the freshet period, flow in the Fraser River is primarily unidirectional (**Figure 3-10**, right panel). The period of unidirectional vs. bidirectional flow varies from year to year and is a function of freshwater flow and tides in the Fraser River; as a general guide, unidirectional flow occurs when river flow at Hope exceeds 6,000 m^3/s. When bidirectional flow occurs, the upstream flow period is typically 5-6 hours in a day, and thus is often only associated with the highest high tide of the day. Some days, however, experience two periods of reversing tide.

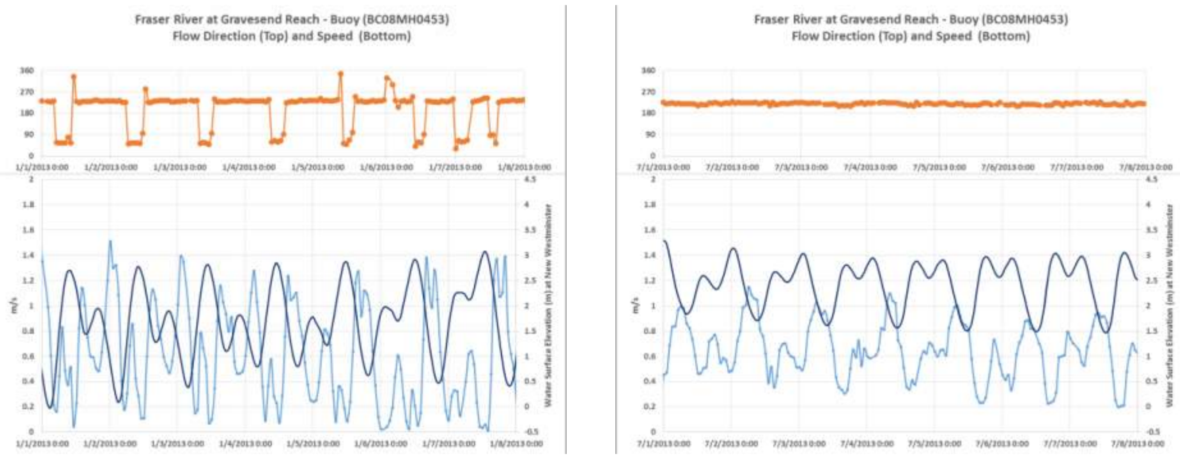

Figure 3-10. Current Speed and Direction for Low and High River Discharge
Low (left panel) and High (right panel) Periods of River Discharge

During the recent sampling period, current speed and direction were measured at the QuadPod at 1-meter above the river bottom during the month-long measurement period in 2017. Current conditions measured by the QuadPod at the project site were predominantly downriver (southwest or colored teal in **Figure 3-11**). Current measurements collected during low flow conditions showed that at least once per tidal cycle, the flow direction reversed through the water column to flow upriver (northeast or colored pink in **Figure 3-11**) during the larger flood tide of the day. When tidal asymmetry was not as strong (diurnal inequality was minimal), the flow reversal occurred twice each cycle, during both flood tides.

Mean current speeds were between 0.48 to 0.71 m/s and reached maximum values of 1.4 to 2.12 m/s through the water column from the bottom to surface, respectively. Speed and direction were relatively uniform through the water column, with speeds slightly higher near the surface and decreasing with depth. Current direction through the water column became stratified for a few salt wedge intrusion events, and current speed was slower near the bottom where the salt wedge was present. Additional information regarding the current measurement techniques are found in the Golder field report in Attachment E.

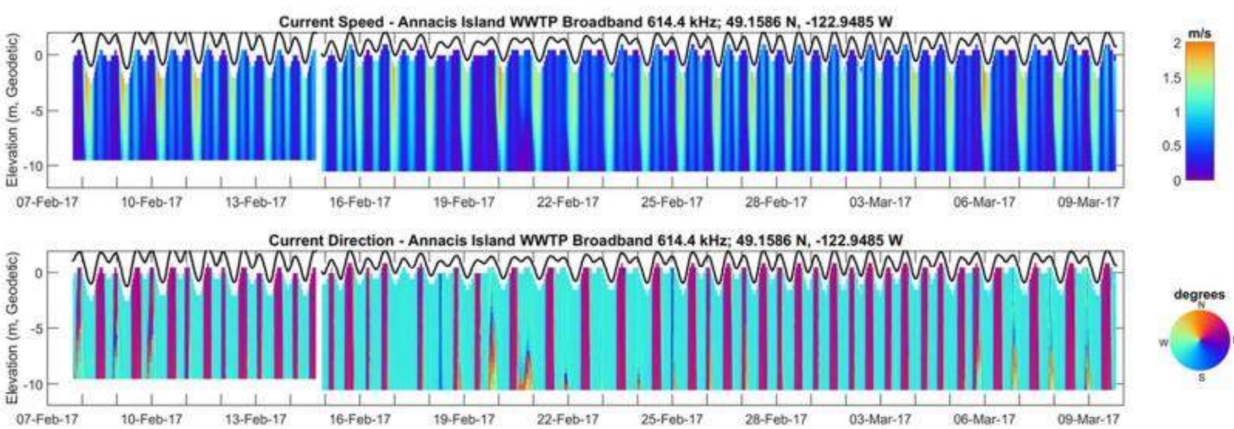

Figure 3-11. Current Speed and Direction Measured in 2017
Measured by the 600 kHz ADCP on the QuadPod station from February 7 to March 9, 2017 [Golder, 2017].

3.2.5 Water Surface Elevation at New Westminster

Canadian Hydrographic Service, Department of Fisheries and Oceans maintains a record of tidal water surface elevations at New Westminster (#7654)[2]. Hourly observations are available from 1970-2017, with the reported water surface elevation as height in m above the chart datum. **Figure 3-12** presents the tide observation at New Westminster for the 2012 calendar year. The tide signal exhibits a mixed semidiurnal tide with two high tides and two low tides occurring each day, but the twice daily high and low tides have different and irregular amplitudes. The calendar year cycle also indicates the influence of the river flows on the tidal signal. During the freshet and high flow summer months, the low tide observations are almost 2 m higher than during low flow periods. Daily water surface excursions during low flow conditions are generally 2.5-3.5 m, yet during high flows, these daily excursions can be reduced to approximately 1 m. The complexity of the semidiurnal mixed tide and large seasonal variation in Fraser River flows results in a very complex hydrodynamic situation at the project site.

Along with the observations of water surface elevation, the Department of Fisheries and Oceans provides a table that compares the water surface elevation at Point Atkinson against water surface elevations at Stevenson, Deas Island, and New Westminster based on the discharge at Hope. These data for Point Atkinson and New Westminster are presented in **Table 3-2**.

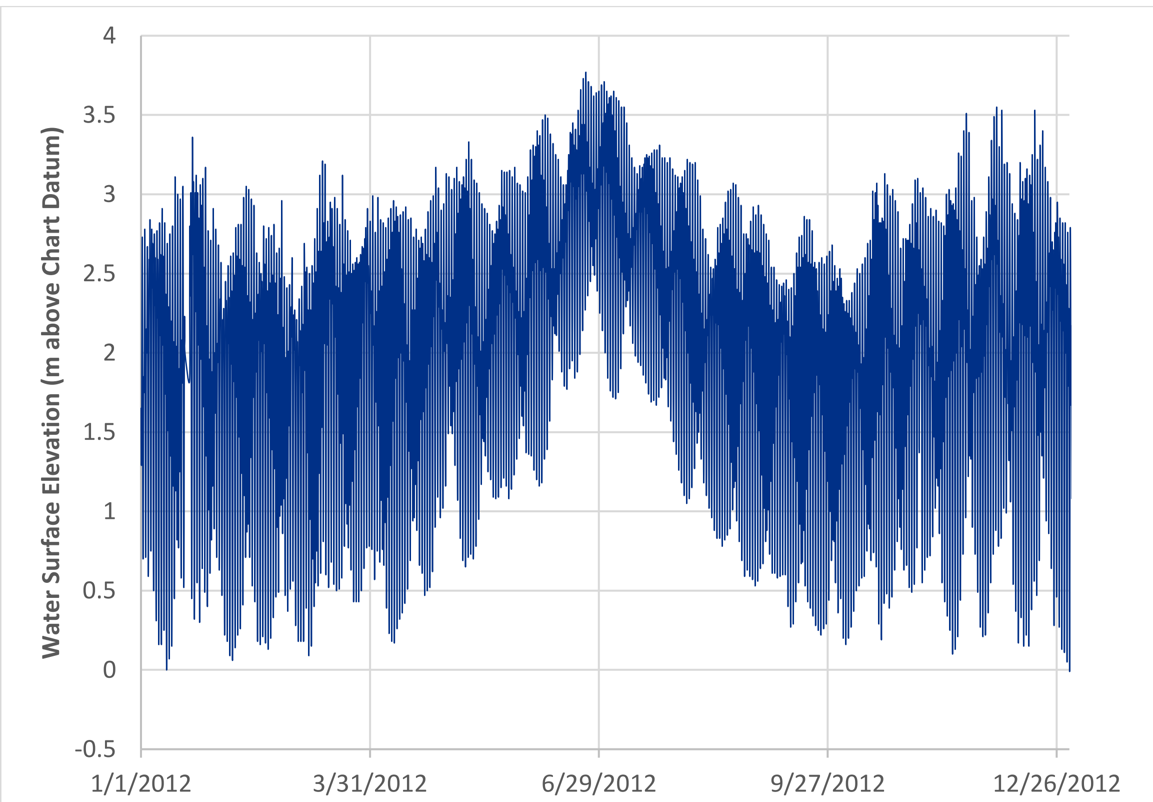

Figure 3-12. Time Series of Water Surface Elevation at New Westminster for 2012

[2]http://www.waterlevels.gc.ca/eng/station?type=1&date=2016%2F02%2F05&sid=7654&tz=PST&pres=0

Table 3-2. Water Surface Elevation based on the Discharge at Hope

Point Atkinson [m]	New Westminster [m]			
	700 m³/s	2,800 m³/s	5,700 m³/s	8,500 m³/s
5.0	3.2	3.4	3.5	3.5
4.5	2.7	3.0	3.1	3.2
4.0	2.4	2.6	2.8	3.0
3.5	1.9	2.2	2.4	2.7
3.0	1.6	1.8	2.1	2.5
2.5	1.2	1.5	1.8	2.3
2.0	0.8	1.1	1.5	2.1
1.5	0.4	0.7	1.3	1.9
1.0	0.2	0.4	1.1	1.8
0.5	0.0	0.2	1.0	1.7
0.0	-0.1	0.1	0.9	1.6

3.2.6 Fraser River Flow at Hope

Discharge in the Fraser River varies considerably from year to year and from season to season. Snow-melt, which contributes approximately two-thirds of the total runoff, begins in April and increases to a maximum in late May and early June. By late August, the flows have diminished, and the lowest flows of the year generally occur in winter (January-February).

Measured upstream of Annacis Island at Hope, BC, the flow record starts in 1912 and thus extends more than 100 years. The minimum daily flow of 340 m^3/s on record was documented on January 8, 1916. More recently, a minimum daily discharge of 470 m^3/s occurred on December 17, 2000. The average daily discharge over the entire data record is approximately 2,700 m^3/s. The maximum recorded daily discharge was 15, 200 m^3/s on May 31, 1948.

Hope is about 130 km upstream of the AIWWTP outfall adjacent to Annacis Island. As discussed in **Section 2.1.1**, downstream inflows to the river between Hope and Annacis Island can add to the total flow, even during low flow conditions at Hope, based on NHC Fraser River flow models. However, flow data at Hope was considered representative of the Fraser River flows at Annacis Island for the purposes of characterizing when the river current is high enough to overcome tidal currents.

The flow data at Hope was combined with current data at Gravesend Reach to elucidate the relationship of flow and current at the project site. **Figure 3-13** depicts time histories of two representative years (2009 and 2013) where complete, cotemporaneous current direction and flow data exist. Note that current data from the Gravesend Reach buoy were filtered and limited to speeds below 2 m/s based on what appears to be meter drift or periods of instrument maintenance. The buoy data quality appears questionable (it is unclear if a QA review by Environment Canada was completed).

This figure shows that when the Fraser River flow at Hope is greater than 6,000 m^3/s, the current is predominately unidirectional. When flow is less than 6,000 m^3/s, the current is bidirectional. The direction of the current during the tide cycle determines whether a local buildup effluent occurs (called background buildup) that will reduce instantaneous dilution predicted by the initial dilution model. The 6,000 m³/s value becomes a threshold, and is used in **Section 6.0** to establish one of the flow classifications for the complex estuary.

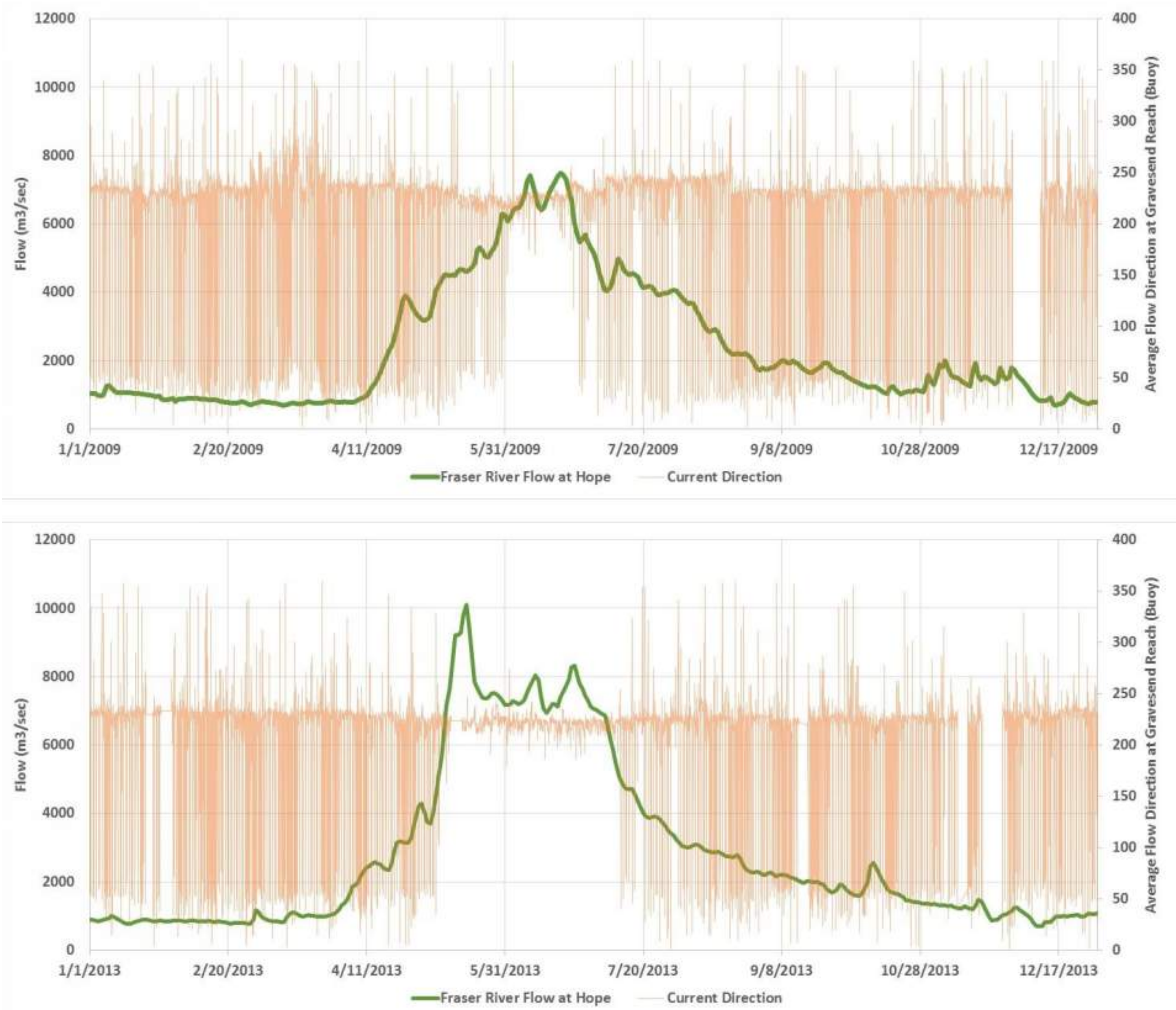

Figure 3-13. 2009 and 2013 Time Histories of Fraser River Flow and Current Direction
Flow at Hope and Current Direction at Gravesend Reach Buoy

3.3 Ambient Background Water Quality Data

Additional water quality data are measured at the Gravesend Reach buoy, which include nutrients, major ions and metals. These data are used to supplement water quality data from the reference station of the REM monitoring program to define ambient background levels in the river as the measurements could be influenced by the discharge from the AIWWTP. Interestingly, observational comparison of the ambient background levels at this location and the reference sampling site used by Metro Vancouver during the IDZ monitoring indicate concentrations are quite similar at the two sites, suggesting the signature of the AIWWTP is not seen at the Gravesend Buoy. As the samples are not contemporaneous, a more rigorous statistical analysis was not performed.

3.3.1 Water Quality Data at Hope

Water quality samples are collected at the Federal-Provincial monitoring station at Hope, located about 130 km upstream of Annacis Island; the data record begins in July 1979. Hope is the farthest downstream of five long-term monitoring stations on the Fraser River. Samples are collected twice monthly and analyzed for physical parameters, major ions, nutrients (nitrogen and phosphorus), dissolved, extractable and total metals.

The water quality data at Hope were not used as part of this project. They were reviewed for use in establishing ambient background concentrations, but were found to vary significantly for some parameters when compared to MV monitoring data upstream of the project site.

3.3.2 Monitoring of the Fraser River Upstream of Sapperton Bar

As part of the Integrated Liquid Waste Management and Resource Management Plan (ILWRMP), Metro Vancouver has an ambient monitoring program "in areas where water quality (as indicated by water quality objective criteria) is potentially affected by wastewater and/or stormwater" (e.g., ENKON, 2014). The water quality monitoring program repeats on a 5-year cycle with water quality monitored in every year, while sediment sampling and of fish tissue/fish health survey are conducted in one year of the cycle. The water quality monitoring program has been in place since 2003; the most current cycle began with monitoring in 2013. Seven sites are monitored as part of the ILWRMP. Sampling is designed to collect during periods of low flows in the Fraser River with 5 surveys conducted at one-week intervals for compliance with average water quality objectives (5 samples within a 30-day period).

To understand ambient background concentrations, this project considered data from Site 3 – Upstream of Sapperton Bar. This location is about 6.2 km upriver of the AIWWTP discharge. The water quality monitoring includes laboratory testing for bacteriological parameters, nutrients, ions, physical parameters, dissolved oxygen, total and dissolved metals, total and reactive silica, and nonylphenol + octylphenol and nonylphenol ethoxylates. Field measurements consist of pH, conductivity, dissolved oxygen, temperature, salinity, and turbidity.

The Sapperton Bar data are not used to characterize the ambient background as there is sufficient low flow data at the reference area location from the REM program.

3.3.3 MV Receiving Environment Monitoring Program

Metro Vancouver conducts a Receiving Environment Monitoring (REM) program to assess the potential for impacts from the AIWWTP on the receiving environment. Water column monitoring has been conducted at the IDZ boundary annually since 2003. For this project, we have considered the data collected from 2012 to 2017 (Smith, A., 2013a 2013b, 2015; data from the 2014 and 2016 monitoring program were provided digitally by Metro Vancouver).

Since 2011, Metro Vancouver has collected data twice a year to assess compliance of the discharge of the AIWWTP with site-specific WQOs and provincial WQGs. Winter sampling occurs during low flow in February-March, while summer sampling targets summer low flow conditions in September. For each sampling period, five surveys are conducted at one-week intervals to determine compliance with 30-day water quality objectives; when needed a sixth survey is added. Sampling dates and times are selected for each sampling period to reflect specific tide conditions at the IDZ boundary. Each week, samples are collected from within the effluent plume at the edge of the IDZ boundary and at the reference area located above the New Westminster trifurcation. The location of the plume is determined in the field using an onboard color video sounder. **Figure 3-14** (left) shows the extent of the IDZ boundary and the sampling sites for slack tide on September 26, 2011. The locations of the reference area stations are shown in **Figure 3-14** (right).

Figure 3-14. IDZ Monitoring Locations in September 2011
Sampling (left panel) and Reference Area Stations (right panel)

In March 2013, a special sampling event was conducted to analyze variation in dilution with tidal cycle. High frequency samples of plant effluent and river at the IDZ boundary were collected over a day, and were analyzed for fecal coliform bacteria, *E. coli*, enterococci and ammonia.

Field measurements are taken for pH, temperature, dissolved oxygen, conductivity, and salinity. Grab samples are sent to the laboratory for bacteriological analyses (fecal coliform bacteria and enterococci) as well as pH, conductivity, total ammonia, nitrate, nitrite, and total phosphorus. If a sample is confirmed to have been collected from the effluent plume (by having elevated the fecal coliform bacteria counts or elevated ammonia levels, if the effluent is disinfected), the sample is further analyzed for chloride, total Kjeldahl nitrogen (TKN), total and dissolved organic carbon (TOC and DOC), total suspended solids (TSS), volatile suspended solids (VSS) and low-level total and/or dissolved metals by ICP-MS (NB: additional parameters vary by year). Additional organic parameters have been analyzed at a subset of both IDZ and reference sampling stations; not all parameters are analyzed for each sampling period with more samples from the winter period being analyzed for these organics: alkylphenols, 4-nonylphenols, nonylphenol, mono- and diethoxylates, octylphenol, polycyclic aromatic hydrocarbons (PAHs), pyrethoid pesticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs), and/or selected hormones and sterols.

The Stage 2 EIS describes the approach used to develop ambient background water quality data for use in the predictions of concentrations at the edge of the IDZ, and includes a statistical summary of the ambient water quality monitoring data.

Section 4

Annacis Island Wastewater Treatment Plant Effluent Characteristics

4.1 AIWWTP Effluent Flow

The Annacis Island Wastewater Treatment Plant (AIWWTP) provides secondary treatment to wastewater for over one million residents in 14 municipalities, treating about 175 billion liters of wastewater every year.

Currently, the plant is undergoing a Stage V expansion project to increase its secondary treatment capacity by over 25% to an average dry weather flow of 637 MLD (7.4 m^3/s). Based on the BC Environmental Impact Study Guidelines (Section 5.21 of MELP (2000), receiving water quality for a Stage 1 EIS should be estimated at the 2 times average dry weather flow (2xADWF). While the Stage 2 EIS guidelines do not specific an effluent flow rate, comments received from the British Columbia Ministry of Environment and Climate Change Strategy on the Stage 1 EIS (Hamelin, 2016) specified that “water quality predictions and modelling considering 2 times Average Dry Weather Flow as identified in the Guideline and the MWR.” For AIWWTP, the 2xADWF is 14.75 m^3/s and is referred to in this document as the “compliance flow.”

The peak wet weather flow (PWWF) for Stage V is 18.9 m^3/s; the ultimate plant buildout is Stage VIII, which will have a PWWF of 25.3 m^3/s. The timing of the flow increases is currently being evaluated, but will at minimum, need to meet the capacity requirements (**Figure 4-1**).

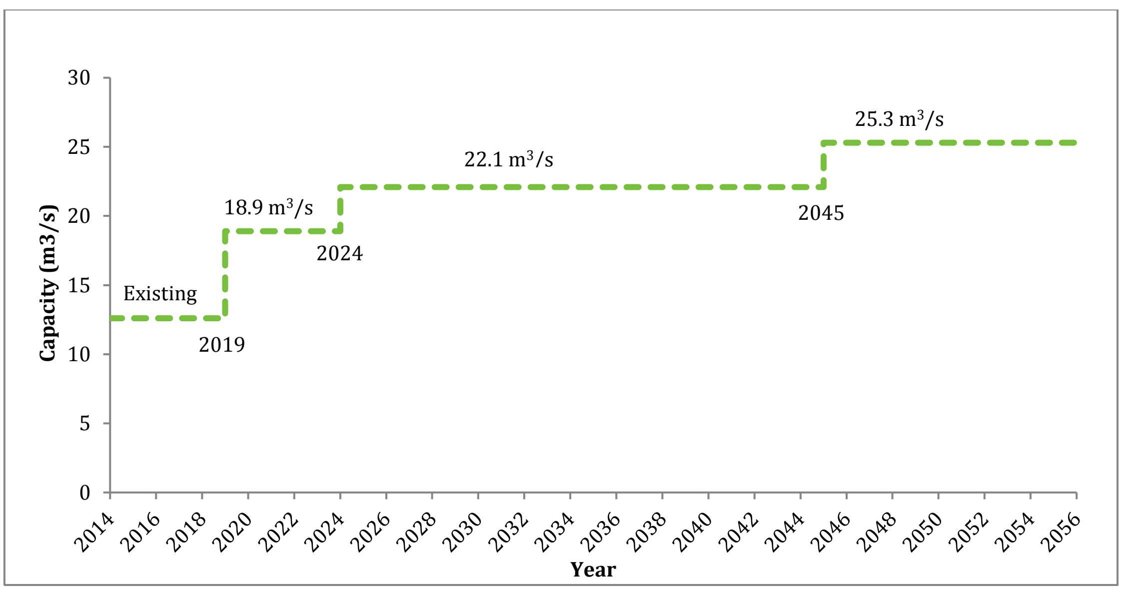

Figure 4-1. Possible Timing of Capacity Requirements for the Annacis Island WWTP
(based on Aggressive Growth Projections)

Figure 4-2 presents a time history of the daily maximum instantaneous effluent flow at the AIWWTP from 2012 through 2016. The data range from 5.5 m^3/s to 13.7 m^3/s, with a maximum instantaneous effluent flow in the past two years that exceeded the 12.5 m^3/s reported in Stage 1, which only used data through 2014. Sometimes during periods of high flow into the plant, the influent flow is manually throttled and diverted to Braid Street to prevent the plant from reaching its design capacity of 12.6 m^3/s. Thus, the upgrades to the plant would allow all the incoming flow to be treated with added capacity for other system wide improvements.

Section 6.4.4 discusses how the current range of flows was scaled up to create a predicted distribution of flows at Stage V, and how this distribution was segmented as input into the initial dilution modelling.

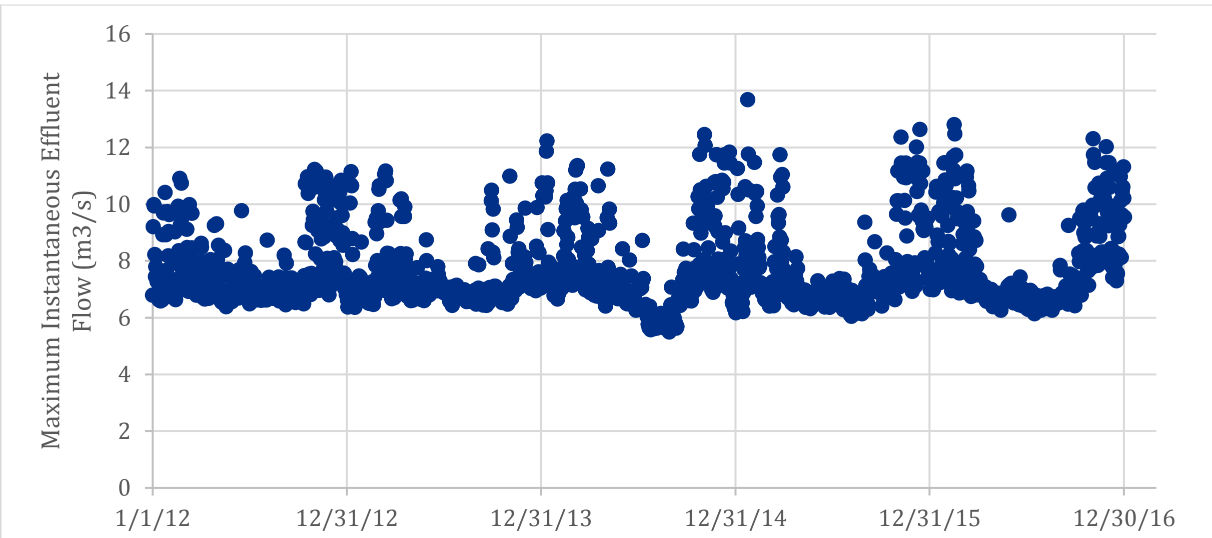

Figure 4-2. Daily Maximum Instantaneous Effluent Flow at the AIWWTP (2012-2016)

4.2 Effluent Temperature

Figure 4-3 presents a time history of the daily maximum instantaneous effluent temperature at AIWWTP from 2012 through 2016 taken from the plant's operational data base. The data range from 10°C to 23°C. The minimum temperature in the past two years have trended warmer than observed in Stage 1.

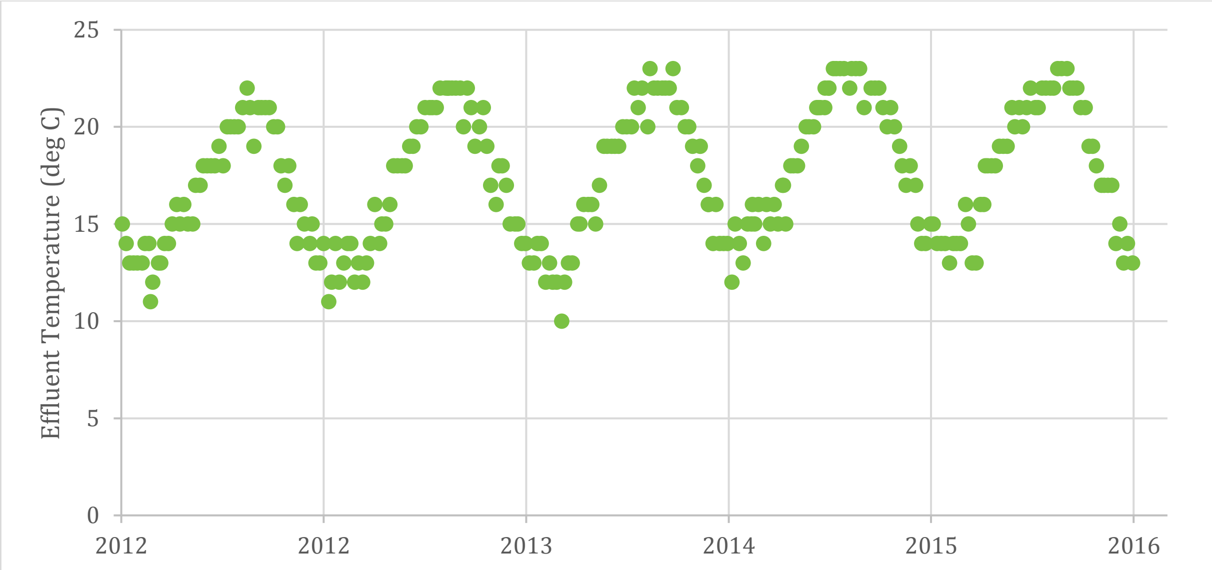

Figure 4-3. Daily Effluent Temperature at the AIWWTP (2012-2016)

4.3 Effluent pH

Figure 4-4 presents a time history of the daily maximum instantaneous effluent pH at AIWWTP from 2012 through 2016 taken from the AIWWTP operational data. The pH data range from 6.4 to 7.8.

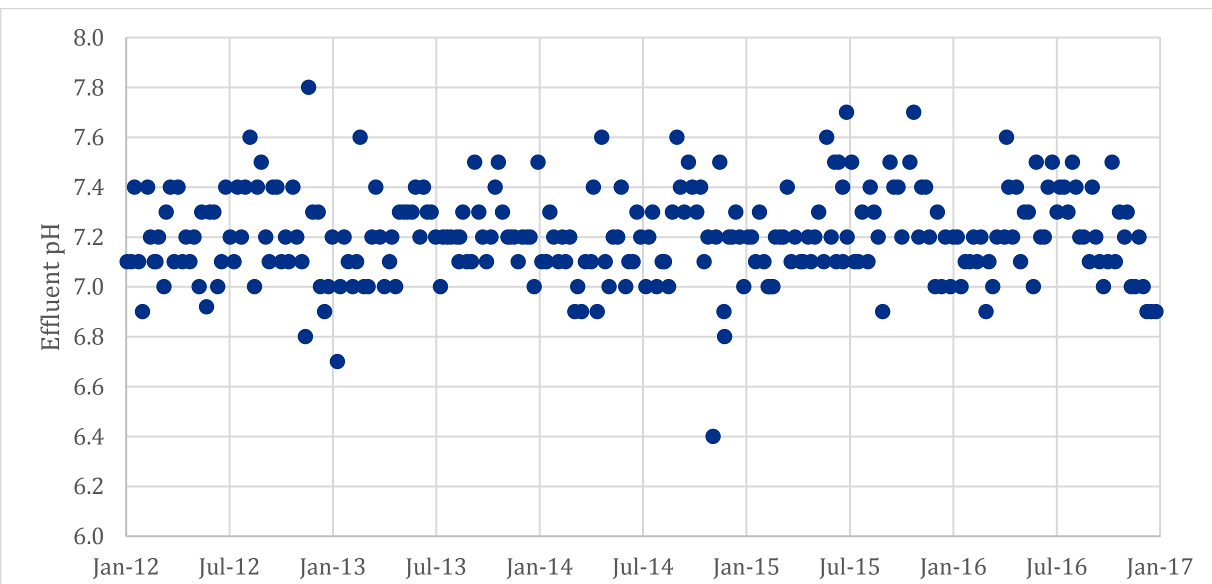

Figure 4-4. Daily Effluent pH at the AIWWTP (2012-2016)

4.4 Effluent Quality

Effluent quality data are available from the following sources: operational plant data, data from monthly comprehensive effluent monitoring, data gathered in conjunction with the existing outfall IDZ monitoring program, and water quality data reported in the *Potential Effluent Discharge Objectives for the Annacis Island Wastewater Treatment Plant* (EDO) report (Tri-Star Environmental Consulting, 2015).

Effluent quality data are available for many parameters including conventional parameters (e.g., carbonaceous BOD, TSS, residual chlorine, unionized ammonia, pH, phosphorus and fecal coliform levels) and potentially toxic parameters (e.g., metals and various organic substances).

The existing effluent data is used as the basis for characterizing future effluent quality. As the proposed Stage V upgrade to AIWWTP is to improve hydraulic capacity, it is reasonable to expect that future effluent quality can be predicted by scaling up the existing effluent mass load by the planned flow increase (i.e., effluent concentrations will remain the same).

The available effluent water quality data from 2012 through 2016 were compiled (some pesticide and metals data from 2017 are included) (**Attachment A**) and evaluated. In general, data for conventional and nutrient parameters were taken from the annual summaries of effluent data by month, while data for potential toxic parameters were taken from the IDZ monitoring program and the EDO report. Data for total residual chlorine, CBOD, TSS, and bacteriological parameters, are taken from plant operational data. The operational reports also include data for unionized ammonia, but these are not included for this analysis because the samples are held at 15°C to allow for comparison to WSER guidelines, and thus, are not representative of unionized ammonia in the effluent.

The following changes were made to the effluent data base:

- 17 α-ethinyl-estradiol – Two samples from 2014 that had non-detected values that were an order of magnitude higher than samples analyzed in 2012-2014 were removed as outliers because 19 other samples were analyzed at lower detection limits ranging from 2.44 to 17.1 µg/L. With these two outliers removed the average of the detection limits dropped from 9.7 to 6.0 µg/L.
- Total Beryllium – 28 analyses for total beryllium in effluent were conducted between 2012 and 2017. Of these 16 had a detection limit of 5 µg/L, while 10 had detection limits of 0.5 µg/L and the remaining two samples had detection limits of 0.1 µg/L. Because all values were not detected, the samples with the highest detection limits were removed from the analyses because sufficient samples remained to demonstrate that the likely concentration of total beryllium was lower than indicated by the higher detection limit.
- Total Mercury – 211 analyses for total mercury in effluent were conducted between 2012 and 2017. Of these 208 comprising all samples prior to 2017 were not detected with detection limits of either 0.02 or 0.5 µg/L. In 2017, 5 samples were analyzed at much lower detection limits and all 4 samples had detected values ranging from 0.00598 to 0.00869 µg/L. The four detected samples were used as the basis of predictions for total mercury.

When data were sufficient develop summary statistics, the following values were determined: count, minimum, mean, maximum, standard deviation, and 95th percentile concentrations, using the following guidelines.

- Minimum, maximum, and median were calculated using absolute values; that is, when the summary statistic corresponded to a non-detect (ND) value in the dataset, the MDL was reported;
- Mean was not calculated for parameters with greater than 50% non-detect values. A median was reported where a mean was not calculated;
- The 95th percentile was not calculated for parameters with less than 10 samples;
- The 95th percentile was not calculated for parameters with greater than 95% non-detect values; and
- Geometric mean was calculated for bacteriological constituents.

The data contain several data quality flags; the following flags were used as the equivalent as a ND value in the statistical calculations:

- < - less than method detection limit
- NDR – peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration
- R – peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration
- H – concentration is estimated
- MAX – concentration is an estimated maximum value
- K - peak detected but did not meet quantification criteria, result reported represents the estimated maximum possible concentration
- Q – a description of this qualifier could not be found; it could mean data are questionable for other reasons

In addition, the mean effluent mass flux and the standard deviation of effluent mass flux are calculated in **Attachment B**.

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Section 5

Diffuser Design

5.1 Overview

This section develops design considerations for the outfall/diffuser system, and recommends a preferred diffuser design for the AIWWTP discharge.

An outfall system typically comprises three main components:

1. The outfall headworks facilities discharge the plant effluent, by gravity or by pumping, against the various tidal conditions in the receiving waters. The headworks provide the necessary hydraulic head to ensure the effluent reaches the desired discharge site.
2. The conveyance facilities transport the effluent from the outfall headworks to the discharge site.
3. The outfall terminus is the point at the end of the outfall system where the effluent enters the receiving water. The terminus can range from a simple open pipe to a multiport diffuser, with the latter being common when a project's goals are to increase mixing or probability of submergence.

The diffuser design evolved from a previous diffuser design concept (Black and Veatch, 2015) and was advanced and refined through numerous iterations of the hydraulic analysis described in this section and initial dilution modelling as described in **Section 6** and **Section 7**. Selection of final design parameters was aided by experiments conducted by the Massachusetts Institute of Technology on a physical model of the AIWWTP diffuser; the results are presented in **Attachment F** and summarized in **Section 5.5**.

5.2 Previous Diffuser Design Concept

Black and Veatch (2015) modeled the dilution of several different outfall/diffuser system design cases (existing outfall, 1 new outfall, 1 new outfall and maintain existing outfall, 2 new outfalls), and recommended that 2 independent outfall/diffuser systems with independent IDZs would best achieve regulatory requirements.

The need for two diffusers was based on analyses using both a far-field model (RMATRK) and an initial dilution, jet-plume model (VISJET). RMATRK is an advection-dispersion model that accounts for potential plume interactions at the diffuser locations as well as dealing with the potential for returned effluent on tidally reversing currents. However, RMATRK does not account for any buoyant or momentum mixing that is important with the initial dilution calculations. VISJET was used to model the jet plume mixing. However, VISJET neither accounted for tidally reversing effluent entrainment nor the presence of the second diffuser. Also, the VISJET model does not provide for a dilution solution beyond the plume reaching the surface, which was often before the edge of the IDZ. The reported dilutions at the edge of the IDZ in the report are quite disparate as RMATRK results indicated an IDZ dilution of 22:1 to 44:1, while VISJET reports a dilution at the surface of 246:1. The difference between these two results is not adequately defined to aid in the concept design decisions.

During initial Stage 1 analyses for this study, the recommendation to use two new diffusers was discounted, and further design evaluations focused on a single diffuser. Key factors considered in discounting the two diffusers concept include:

- Initial dilution modelling performed by Black and Veatch (2015) assumed the water column during winter (low flow) conditions was uniform in its salt content at 10 psu and the river was unbounded. Several lines of evidence exist to indicate that most of the time the Fraser River is fresh throughout the water column at Annacis Island, and that saline water is only intermittently present. When present, the salinity is typically less than 10 psu but can reach 25 psu or more during very low river flows and asymmetrical high tides. The inclusion of a fully saline receiving water leads to over prediction of initial dilution.

There was no consideration of reduction in dilution from the presence of an up-current diffuser. Thus, the initial conceptual design did not adequately account for plume overlap, which would increase the required dilution at the downstream diffuser because of entraining upstream diluted effluent.

5.3 Diffuser Design Criteria

In a typical diffuser design, an attempt is made to maximize pipe velocities while maintaining head losses within limits determined by available hydraulic head to support gravity flow or pump selection in coordination with attaining the maximum initial dilution possible. As described in **Section 1.2.1**, Metro Vancouver defined target design criteria for outfall/diffuser system as:

- To provide an outfall system with a total capacity of 25.3 m^3/s at a river level of 103.18 m GD without impacting the hydraulic gradeline of the treatment plant.
- To achieve a minimum dilution ratio of 20:1.

For this project, the diffuser needs to convey both the Stage V (18.9 m^3/s) and projected Stage VIII (25.3 m^3/s) flows. This goal can be achieved by developing a design for the ultimate peak flow, and then determining the number of ports that need to be blocked off to allow the diffuser to also achieve the maximum dilution at the lower Stage V flows.

Additional criteria that must be considered in the diffuser design are the presence of bed waves in the Fraser River, protecting the diffuser ports from debris (primarily sunken logs), and anchor and ship strikes, and providing for a bulkhead or gate on the diffuser manifold.

- ***Bed Waves*** – The Fraser River is geomorphologically active. During periods of high discharge, bed waves, comprised of sand, travel down the river bed and vary in height based on local water depth. These waves can be 5-m high in the deep navigation channel, but are thought to be about 1-m high at the edge of the channel where the diffuser is proposed to be located (NHC, personal communication). For this analysis, it is assumed that the height of the diffuser risers between the river bed and the bottom of the diffuser port is 1 m to minimize the potential for the ports being covered by bed waves.
- ***Protection for the Diffuser Ports*** – The proposed diffuser will be located in a region of the river with heavy boat and ship traffic. Using risers protects the diffuser manifold from ship damage by allowing it to be fully buried. The disadvantage of risers is that they are subject to damage by ships, anchors and possibly other debris (e.g., sunken logs). Design of a

conical sleeve or cap to place over each riser pipe should significantly reduce the potential for damage and is included in the final design.

- ***Manifold Bulkheads*** – Given the high sediment load carried by the Fraser River, it is likely that over time some sediment will enter the diffuser. The diffuser manifold should be fitted with bulkheads at its ends to facilitate access as is included in the final design.

5.4 Diffuser Location and Layout

5.4.1 Location within Study Area

The discharge of effluent through a diffuser system creates an interaction of the plume with ambient currents and density stratification to provide initial dilution. Proper placement of the diffuser (location and orientation) creates proper plume formation and maximum dilution.

For the AIWWTP four factors determine the potential location for the diffuser: (1) the project study area boundaries and its bathymetry (defined in **Section 1.3**), (2) achieving the maximum depth below Chart Datum (discussed in **Section 1.3.2** and **Section 2.1.4**), (3) dredging activities at and near the study area, and (4) the presence of bed waves that migrate down the river during the freshet season. Ideally, the siting of the diffuser would account for other potential projects in the Fraser River that could affect the diffuser location (e.g., widening or deepening the navigation channel following replacement/removal of the George Massey tunnel), but these projects are not currently sufficiently defined to be included.

Bringing these factors together, the optimal location for a diffuser would be in the deepest water available, outside of the actively dredged areas, where the effects of passage of sand waves can be minimized. This leads to placement of the diffuser at the eastern end of the study area.

5.4.2 Bathymetry and Dredging Constraints

Figure 1-2 shows the 2016 bathymetry, the edge of the navigation channel (dashed green line). The dredging depth constraint at the project site is the Dredge Grade maintained by Port of Vancouver at 10.9 m below Chart Datum. Based on the most recent bathymetric survey done by CCG in January 2016, a 100-m portion of the study area along the navigation channel nearest the existing outfall is currently below the Dredging Grade (-10.9 m Chart Datum or elevation 87.51 m GD + 100), while the next 200 m portion further downstream is up to 0.5 m above the Dredge Grade. As described in **Section 1.3.2**, sediment deposition in the 300+ m river reach downstream of the existing outfall is limited and Port of Vancouver does not need to do routine maintenance dredging in this area. Therefore, the area just outside the navigation channel within 300 m of the existing outfall was determined to be the best location for the diffuser in terms of water depth (and resulting dilution) and limited requirements for future maintenance dredging due to the lower height of the sand waves.

5.4.3 Diffuser Orientation

Two diffuser orientations were considered, perpendicular and parallel to the shoreline. A diffuser manifold oriented perpendicular to the shoreline in shallow riverine water typically has two configurations (Adams, unpublished manuscript): co-flowing, where the ports at a 90-degree angle to the manifold and point in the direction of the ambient current, and staged, where the ports discharge either parallel to the manifold or at a small angle to the manifold and are pointed to the center of the river to create a net offshore discharge. The second diffuser orientation is known as a tee diffuser, where the manifold is oriented with the ambient current and the ports are at a 90-degree angle to the manifold and thus discharge across the current.

While a co-flowing diffuser has the advantage of discharging at a right angle to the predominant current direction, which aids in increasing dilution, this diffuser type is suited for wide rivers with unidirectional currents. Adams (unpublished manuscript) compared the performance of staged and tee diffusers for a physical setting and proposed diffuser sizing similar to that for the AIWWTP and found that the tee diffuser performs better in low currents. As currents increase significantly the staged diffuser provides much greater dilution, making is a suitable choice for settings with strong bidirectional currents, as long as the river width is sufficient to not have the plume impinge on the offshore boundary and cause recirculation.

A perpendicular manifold is difficult to fit into the project study area, particularly given the depth/dredging constraints and the upwardly sloping bottom towards shore. These constrain a perpendicular manifold to being on the order of the length of the existing diffuser. Review of the time history of bathymetry by the Canadian Coast Guard indicates that the maximum length for the diffuser manifold would be about 60 m, avoiding shallow water and the navigation channel dredging practices. Preliminary initial dilution runs using CORMIX testing a perpendicular diffuser using 3.5 m spacing, using the available head, and both a coflowing diffuser (90°ports to the manifold in the dominant direction of river flow) and a staged diffuser (similar to coflowing but with the ports on both sides oriented offshore) provided a dilution of no greater than 20:1 for 15% of the time, with dilutions of less than 10:1. This dilution is less than that for the perpendicular orientation. Given these factors, a diffuser manifold perpendicular to the shore was considered impractical.

Accordingly, the selected diffuser orientation is parallel to the shoreline along with the diffuse manifold located a few metres outside the edge of the navigation channel to take advantage of the deeper water. The distance between the edge of the navigation channel and the shoreline is approximately 175 m, which is sufficient to allow for the IDZ to be located shoreward of the diffuser without impinging on the shoreline. **Figure 5-1** is a schematic of the alignment selected for the conveyance tunnel and diffuser manifold.

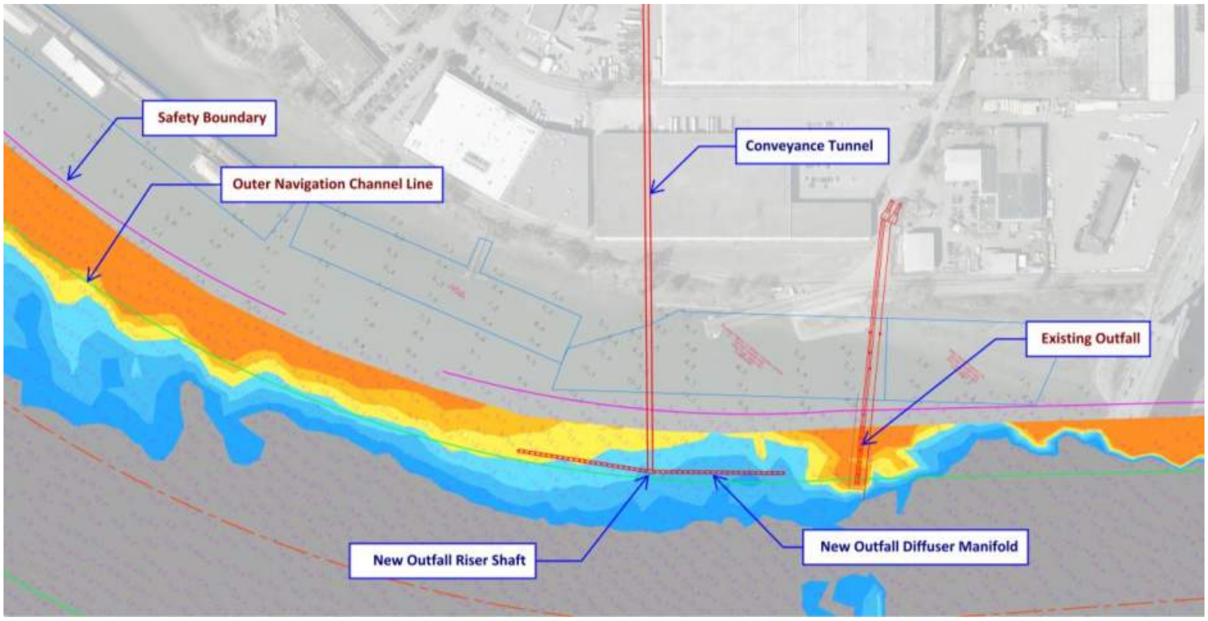

Figure 5-1. Planned Diffuser Location

5.4.4 Diffuser Length

Diffuser length can be a significant parameter contributing to initial dilution of treated effluent. Length, however, is a less sensitive term in dilution analysis with the diffuser concept for the AIWWTP – perpendicular to shore with unidirectional ports. Length, in the case of locating the Annacis diffuser within the project study area, is constrained by available water depth and the field of bed waves in the western end of the area. Given these constraints and the fact that construction of a new diffuser cannot impinge on the location of the existing diffuser, the maximum length of a diffuser is about 300 m.

The diffuser length must be sufficient to allow for good mixing dynamics, but not too long to increase head loss. Preliminary diffuser lengths can be estimated using a simplified equation for dilution.

$$L = (S * Q)/(u_a * D)$$

where L is length (m), Q is effluent flow (m^3/s), u_a is ambient velocity (m/s) and D is water depth (m), and S is the desired dilution.

The results of these calculations for a target dilution of 20:1, a water depth of 10 m, the Stage V and VIII peak flows, and typical project site velocities are shown in **Table 5-1**.

Table 5-1. Estimated Diffuser Length using Mass Flux Considerations

Ambient Velocity (m/s)	Diffuser Length for Stage V Flow (18.9 m^3/s)	Diffuser Length for Stage VIII Flow (25.3 m^3/s)
0.1	378	506
0.15	252	337
0.5	76	101
1	38	51

This simplified equation does not include entrained flow – only the river flow associated with the velocity passing by the diffuser – and thus yields conservatively high results. For this project, it is desirable to have a shorter diffuser length to minimize head loss in the diffuser manifold.

In the Stage 1 analysis, two lengths were tested: 240 m and 300 m; the latter being the longest diffuser that could be placed given project constraints. Stage 1 included a 240-m long diffuser as the design basis but recommended that two lengths be tested in a physical model. The results of the Stage 2 physical modelling are described in **Section 5.5**.

5.4.5 Port Orientation

Diffusers create dilution of the discharged effluent by entraining ambient river water into the plume. Dilution results from entrainment due to momentum and/or buoyancy. In the Annacis Island case, most of the time the treated effluent will discharge into freshwater, resulting in momentum being the only source of entrainment flux. Momentum is created by the discharge velocity at the diffuser ports. Thus, a goal of the diffuser design is to select small ports to achieve high discharge velocity while staying within available hydraulic head to discharge by gravity (or accepting that pumping of the discharge will be required).

With the orientation of the Annacis diffuser parallel to the shoreline, the greatest dilution will result if the effluent discharges in only one direction; in the parlance of outfall design, this type/orientation of diffuser is known as a unidirectional or tee diffuser in a crossflow. This way, the diffuser is pulling water from behind and from the sides of the diffuser and entraining it into the discharging plume to create dilution. The logical way to orient the ports is toward the center of the channel. This achieves two benefits: the discharge can access the greater depths of the main channel to achieve additional dilution and the plume moves away from the diffuser so that the concentration of flow returning to the area of the diffuser on an incoming tide will have lower concentration than if the diffuser had ports pointing in two directions.

Typically, unidirectional diffusers have been associated with thermal discharges from power plants; these types of discharges have higher momentum and less buoyancy. Certainly, wastewater discharges have less flow than power plant discharges, and for similar discharge velocity, less momentum. But for a wastewater discharge to a river, there is very little buoyancy and ultimately the dilution relies on the momentum of individual jets.

5.4.6 Number and Spacing of Ports

In Stage 1, two port spacings were evaluated: 10 m spacing, which is approximately the water depth at the project site (diffuser design guidelines suggest spacing typically should not exceed water depth) and 5 m spacing, to test whether tighter spacing would increase dilution. The method available for predicting dilution under unstratified conditions in Stage 1 (the updated Shrivastova-Adams equation (**Section 6.2.2**) did not have port spacing as a variable; thus, dilution predicted for unstratified conditions would be the same regardless of port spacing (assuming exit velocity was maintained).

The Stage 1 design concept included 10 m port spacing. The physical modelling described in **Section 5.5** tested both port spacings.

5.4.7 Diffuser Cross Section

Figure 5-2 shows a cross-section schematic of the diffuser manifold at a discharge riser. The top of the armor rock protecting the diffuser manifold is set at the maximum river dredging level maintained by the Port of Vancouver since placing it any lower than the river bed would result in sedimentation quickly covering the exposed portions of the risers and ports.

The water depth for the top of the diffuser infrastructure, which would be the top of the protection provided for the riser would be the sum of:

- 1 m above the native riverbed to allow the bottom of the diffuser port to reside above the height of predicted bed waves at the edge of the navigation channel,
- The diameter of the diffuser port, and
- An additional ~0.2 m allowance above the diffuser port to the top of the diffuser protective structure (a concrete conical sleeve).

Hydraulic considerations (**Section 5.6**) resulted in a diffuser port of 0.75 m, which means that top of the diffuser port would be at 89.53 m (GD+100), about 3.43 m above the dredge grade of 86.1 m (GD+100). This corresponds to a depth below Chart Datum of 8.90 m. This configuration will require a variance of the MWR diffuser depth requirement.

The diffuser protective structure will be between about 2 m above the armor rock. This corresponds to a depth of 8.71 m below Chart Datum, respectively. The Port of Vancouver indicated that the depth of the diffuser in the area between the navigation channel and its safety boundary should be at least 6 m; therefore, there is no variance required for Port of Vancouver criteria.

The cross section shows a Tideflex-style valve over the port opening, which allows for a variable orifice to increase port discharge velocities at low effluent flow. A horizontal orientation of the valve allows for the port to be closer to the river bottom, maximizing the water depth available for dilution. The elliptically shaped valve can further improve dilution by allowing for ambient river water to reach the jet centerline faster than with an equivalent round jet. In addition, the horizontal valve provides more bottom clearance whereas a vertical valve could be partially buried if sediment deposition occurs.

There is the potential for the navigation channel to be dredged or widened in the future to accommodate larger draft vessels. The outfall infrastructure (risers, manifold, headers, protective covering) related to the AIWWTP upgrade are designed to remain outside of the current navigation channel. Assuming the channel is deepened less than about 2 m, the outfall diffuser could remain at its design location presuming modifications are made to the rock protection armor configuration. Conversely, widening of the navigation channel would have significant impacts on the diffuser design.

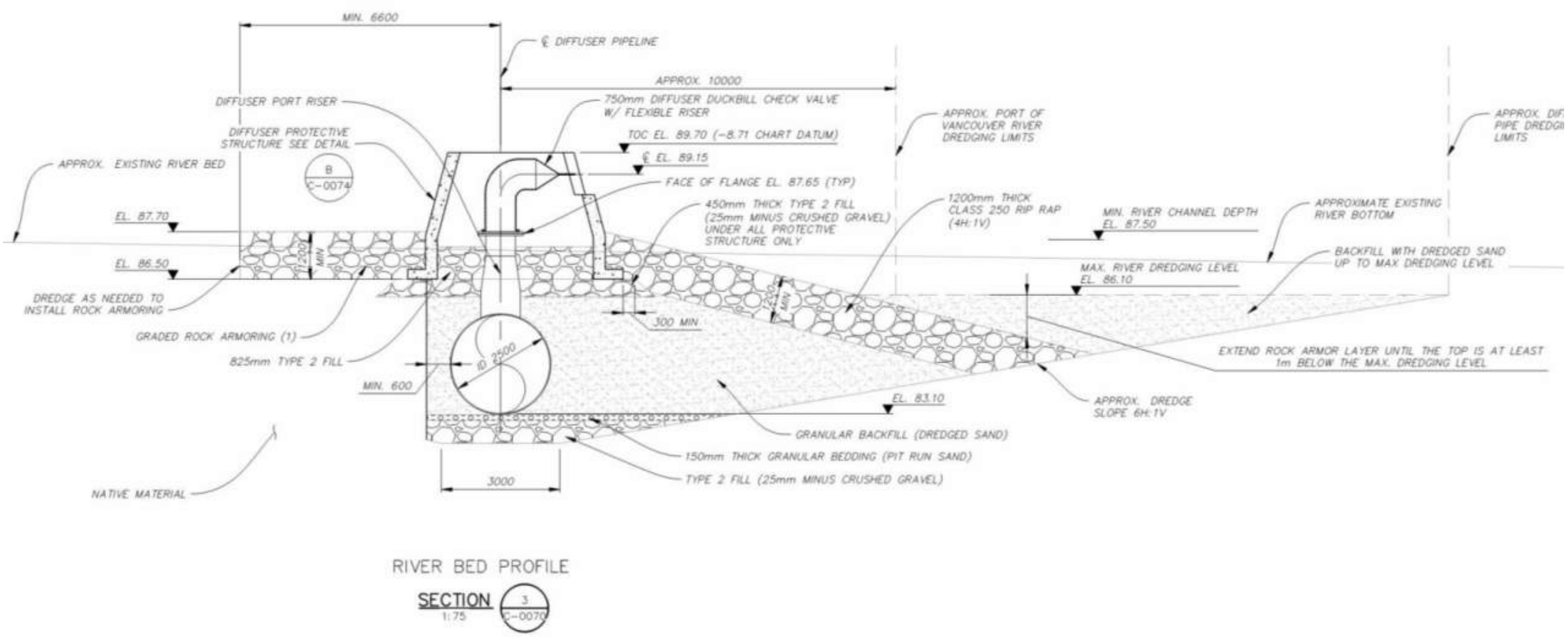

Figure 5-2. Schematic of Cross-Section of Diffuser Manifold, Riser, Port and Protective Cap

5.5 Physical Modelling

5.5.1 Goals of Physical Modelling

CDM Smith engaged Dr. Eric Adams of MIT to construct a physical model of the concept design of the AIWWTP diffuser that was recommended in the Stage 1 report on the diffuser design (CDM Smith, 2016). The goals of the physical modelling included:

- Performing experiments on different diffuser lengths and port spacings to refine the concept diffuser design from Stage 1,
- Estimating initial dilution at the edge of the IDZ for the selected diffuser configuration to refine the Sha-Adams equation used to estimate initial dilution under freshwater conditions in Stage 1,
- Examining the differences in centerline and flux-average dilution to refine the factor used in Stage 1, and
- Preforming experiments under a stratified scenario to examine the initial dilution under these conditions.

5.5.2 Experimental Setup of the Physical Model

The physical model of the AIWWTP diffuser was constructed in an existing tow tank in MIT's Hydraulics Laboratory. A detailed description of the model is found in **Attachment F**, and summarized below. **Figure 5-3** is a photograph of the physical model setup.

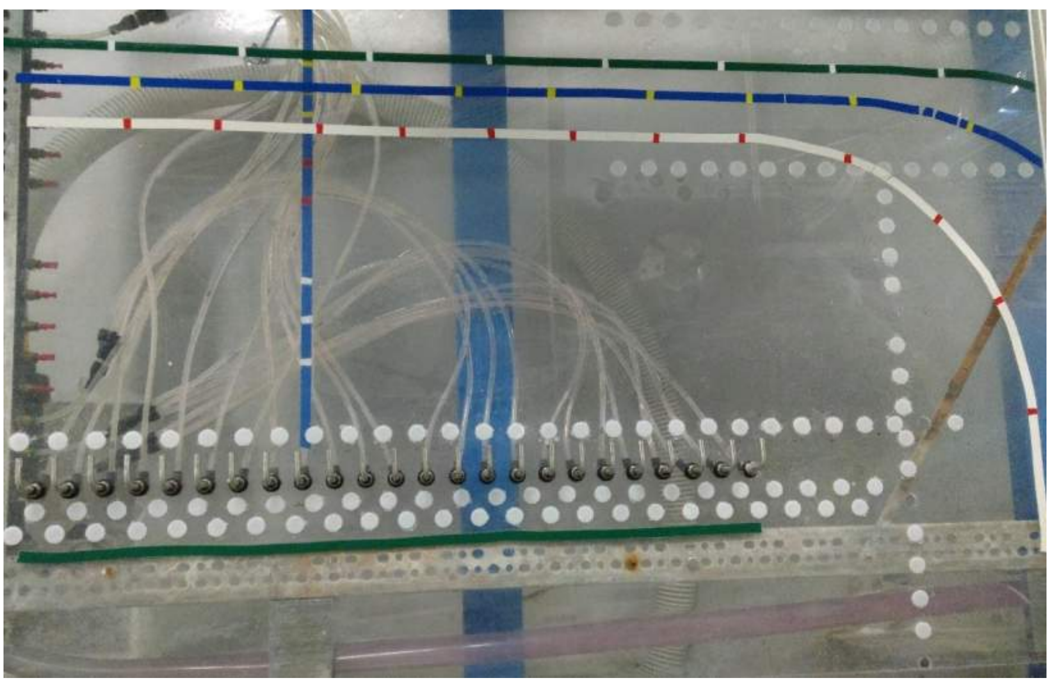

Figure 5-3. Setup of Physical Model of AIWWTP Diffuser in MIT's Tow Tank

The tow tank has dimensions of 4.8 m (length) x 1.2 m (width) and 0.6 m (height). The diffuser (oriented parallel to the longest side of the tank) consisted of circular nozzles that were mounted on a false floor, which was towed to simulate ambient current (the diffuser is towed to the left, simulating a current to the right). The nozzles are made of stainless-steel tubing with precisely measured inside diameter, bent 90 degrees with sufficient radius of curvature so that the water discharges smoothly and horizontally. Dense effluent (salt water) was supplied to a manifold by a head tank. The manifold (located on the left), in turn, supplied effluent through plastic tubing to individual nozzles. The manifold and the tubing were secured underneath the false floor. The effluent is supplied from the head tank to the manifold by the hose seen at the bottom of the picture, and is positively buoyant representing a temperature difference of about 6°C at an ambient water temperature of 15°C. The effluent flow rate to the manifold was measured using a rotameter. The IDZ boundary is marked on the model floor in white with red markers.

The experiments simulated a tee diffuser discharging treated wastewater effluent in a freshwater estuary with tidal flow at an ambient water depth of about 10 m. The model diffuser was scaled to honor Froude scaling (i.e., the value of densimetric Froude number for the model was equal to that for the prototype).

The following experiments were run, noting that because tubing comes in discrete sizes, a different set of nozzles and different holes are required for each of the three diffuser designs:

- Confirmation tests to verify density scaling was adequate, test the effect of the distance from the shoreline to the diffuser on dilution, and test the effect of the offshore boundary of the tow tank on dilution.
- Basic sensitivity tests to determine centerline and flux average dilution for the following diffuser configurations; all experiments, except those with stratification, simulated a freshwater ambient receiving water at a mean low water depth as this depth will yield lower dilution.
  - Base Case – 240-m long diffuser with 24 ports at 10 m spacing and Stage VIII flows (25.3 m^3/s)
  - Reduced Port Spacing – Base case conditions but with 48 ports at 5 m spacing
  - Longer Diffuser – Base case conditions but with a 300-m long diffuser with 30 ports at 10 m spacing
  - Stage V – base case diffuser run with 18 ports to simulate the number of open port when the AIWWTP is discharging up to Stage V flows (18.9 m^3/s)
  - Stratification – Base case run with ambient stratification where the water depth was mean high water because stratification is most likely to be present during flood tides.

Each set consisted of a diffuser design with a given discharge flow rate, ambient stratification, and water depth, and operating in four (or in one set five) ambient current speeds, making a total of 21 runs. Many runs also included up to 6 replicates.

5.5.3 Results of Physical Modelling

The results of the physical modelling are presented in **Table 5.2** in terms of S_{min} which is the minimum dilution at the boundary of the IDZ and S_{avg} which is the flux average dilution at the edge of the IDZ. The table also include key input parameters and three dimensionless parameters that are used to calculate dilution:

- m_r – a non-dimensional parameter characterizing the effect of ambient current (u_a)

  $$m_r = u_a^2 \, H \, L \, / \, (u_o \, Q_o)$$

  where H is the water depth (m), L is the diffuser length (m), u_o is the exit velocity from a diffuser port (m/s) and Q_o is the total effluent discharge (m^3/s).

- L/H – the ratio of the diffuser length to the water depth
- l/H – the ratio of the nominal port spacing to the water depth

Among the tests run in an unstratified ambient, the result in **Table 5-2** show that the best performance was achieved with the base case simulation: the shorter of the two diffusers tested, with the wider of the two port spacings tested.

Table 5-2. Measured Dilution using the Physical Model

Set	Run	L (m)	# of ports	Q_o (m^3/s)	u_a (m/s)	m_r	L/H	l/H	S_{min}	S_{avg}
1 Base Case	1	240	24	25.3	0.07	0.08	24	1	13.2	
	2	240	24	25.3	0.22	0.92	24	1	10.6	17.3
	3	240	24	25.3	0.52	4.94	24	1	12.4	23.8
	4	240	24	25.3	1.13	23.29	24	1	15.7	27.6
2 Reduced Spacing	5	240	48	25.3	0.06	0.07	24	0.5	11.2	
	6	240	48	25.3	0.21	0.81	24	0.5	9.0	
	7	240	48	25.3	0.48	4.27	24	0.5	10.2	19.6
	8	240	48	25.3	0.63	7.26	24	0.5	11.1	
	9	240	48	25.3	1.05	20.16	24	0.5	12.9	21.8
3 Longer Diffuser	10	300	30	25.3	0.07	0.10	30	1	14.1	
	11	300	30	25.3	0.22	1.16	30	1	9.9	
	12	300	30	25.3	0.52	6.15	30	1	10.1	17.7
	13	300	30	25.3	1.13	29.13	30	1	13.8	24.7
4 Stage V Flow and Port Configuration	14	240	18	18.9	0.07		24	1.33	18.9	
	15	240	18	18.9	0.22		24	1.33	11.3	
	16	240	18	18.9	0.52		24	1.33	16.5	
	17	240	18	18.9	1.13		24	1.33	13.5	
5 Stratification	18	240	24	25.3	0.07		24	1	11.4	
	19	240	24	25.3	0.22		24	1	5.7	
	20	240	24	25.3	0.52		24	1	7.7	
	21	240	24	25.3	1.13		24	1	8.3	

Based on the minimum dilution measurements for physical model tests as well as previously reported experiments with tee diffusers in a crossflow (Shrivastava and Adams, 2017), an equation was developed to describe the effect of various non-dimensional variables on the minimum dilution at the edge of the IDZ.

$$\frac{S_0}{S_{min}} = 0.8\left[1 + 0.08(L/H)^{3/4}(\ell/H)^{-0.28}\,\mathrm{sech}\{0.87\log_{10}(m_r)\}\right]$$

Where $S_0 = (HLu_0/(2Q_0))^{1/2}$ is the dilution of a tee diffuser in quiescent ambient (Adams, 1982).

The observations during the physical model experiments indicate that flux-averaged dilution exceeded centerline dilution by a factor of 1.8 for cases with strong currents (m_r >1). The ratio was found to be independent of ambient current or diffuser design.

A summary of result from the physical modelling are:

- Over the range tested, dilution generally decreases with increasing diffuser length. Thus a 240-m long diffuser is more effective than a 300-m long diffuser.
- Over the range tested, dilution decreases with increasing number of nozzles. Thus, a 240-m long diffuser with 24 nozzles is more effective than a 240-m long diffuser with 48 nozzles.
- Over the range tested and holding discharge velocity constant, dilution decreases with increasing effluent flow rate. Thus, Stage VIII effluent flows will have lower dilution (even with all 24 ports) open than Stage V flows with 18 ports open.
- Dilution decreases in the presence of ambient stratification.
- Minimum dilution occurs at intermediate current speeds and increases somewhat as current speed increases or decreases.
- Flow-average dilution exceeds minimum dilution by a factor of about 1.8.

5.6 Hydraulic Design

5.6.1 Hydraulic Design Analysis Summary

Hydraulic design analysis began with evaluation of hydraulic grade line and head loss in the conveyance system from the CTTs to the outfall diffuser manifold to determine the available head to drive flow through the manifold, risers and diffuser ports. Further analysis was performed iteratively in conjunction with the dilution modelling to determine optimum diffuser port sizes and resulting flow velocities to optimize dilution while working within available hydraulic head.

Hydraulic analysis was conducted using Visual Hydraulics (V 4.2) software to determine the hydraulic grade line and head losses. The software calculates head loss based on user input and the pipe system design. Memoranda with details on the modeled components and model inputs and results are available in **Attachment C** for Stage V and **Attachment D** for Stage VIII. Visual Hydraulics was also used to determine the manifold/diffuser flows, head loss, and velocities. Modeled assumptions included a Tideflex diffuser valve, which allows for a variable orifice size under different effluent flow conditions to increase diffuser port exit velocities. The available head for the Tideflex diffuser valves is 1.20 m. The Tideflex diffuser valve is sized to use all the available 1.20 m of head at the design flow of 1.050 m^3/s per diffuser port. During the early years of operation when the outfall system is new with smooth (not aged) concrete and when only a portion of the chlorine contact basin settlement allowance has occurred, there will be sufficient head to operate as configured without exceeding the maximum allowable water surface elevation at the chlorine contact tanks. For Stage VIII flows, the calculated available head was only 0.64 m, which was insufficient as the head requirement for the diffuser valves was 1.20 m; therefore, a net increase of head (pumping) of 0.56 m is required. The needed net pumping head is expected to increase as the outfall and diffuser system ages.

5.6.2 Hydraulic Design Criteria

The hydraulic design of a multiport diffuser needs to meet design criteria that affect the internal hydraulics of the diffuser pipe. These criteria ensure a uniform distribution of effluent discharge along the diffuser, set minimum scour velocities (this is not needed for the AIWWTP effluent because of its high quality), account for diffuser head losses, and set the number, spacing and diameter of discharge ports.

The main hydraulic criterion for successful diffuser operation is the achievement of an even effluent discharge from each port. Meeting this criterion ensures that the plume is discharged over the specified length of the diffuser and will achieve the initial dilutions computed by near-field models. Even discharge was evaluated using the two criteria below and checked with the detailed hydraulic calculations of the proposed design.

- ***Uniform Discharge and Port Area Criterion*** – If the total port area of a diffuser is greater than the area of the diffuser pipe, uneven flow distribution may occur as some ports may not flow full and others may not discharge any effluent. To avoid this, French (1972) suggests that the total port area never exceed the diffuser pipe area.
- ***Densimetric Froude Number*** – When the effluent discharges to saline water, this dimensionless parameter describes the combination of density-driven buoyancy and viscosity forces at the diffuser ports. The effective densimetric Froude number at the discharge port should be greater than 1 to ensure the port is flowing full and at sufficient pressure to prevent saltwater intrusion.

In a typical outfall system, the head required to drive a diffuser forms a large proportion of the overall system head. In such cases and particularly for the AIWWTP where there is only a small amount of available head for the outfall/diffuser system, minimizing overall head losses is an important consideration in outfall design to allow much of the available head to be expended at the diffuser ports.

To make full use of the diffuser length for initial dilution, it is necessary to distribute the discharge among many ports, rather than only a few. The number and spacing of ports must be configured to provide proper plume development to achieve maximum dilution.

5.6.3 Hydraulic Grade and Head Loss

The chlorine contact tank within AIWWTP is the starting water surface elevation. The original design maximum water surface elevation in the tank of 106.01 m was lowered by 0.31 m to El. 105.70 m, which accounts for historic and predicted settlement through 2067. The ending water surface elevation is based on the Fraser River 200-year flood level of 103.18 m (GD+100) plus 0.18 m to allow for hydrostatic head when a salt wedge is present at the site.

In a typical diffuser design, discharge exit velocities are maximized while maintaining head losses within limits determined by available hydraulic head to support gravity flow. The available head for the diffuser design is defined by the following key assumptions:

- The design water surface elevation in the Fraser River is the 200-year recurrence interval peak winter flood level of 103.18 m.

- The design water surface elevation was increased by 0.18 m to account for the hydrostatic head differential required to discharge when a salt wedge is present.
- An effluent pump station and piping will be located at the 16-m diameter outfall shaft for the effluent tunnel.
- The inside diameter of the tunnel is 4.2 m, and a main vertical riser from the tunnel to the diffuser manifold will have an internal diameter of 3.8 to 4.2 m.
- The 2.5-m diameter diffuser manifold is joined to the vertical riser at its center.
- All components are assumed to be in good condition for evaluating friction head loss during Stage V design period.

The hydraulic analysis accounts for head loss encountered through a conduit at the chlorine contact tank, through the effluent shaft and effluent tunnel to the outfall shaft and future effluent pump station, through the pump station, through the outfall tunnel and riser to the diffuser manifold, and through the diffuser manifold, risers, bends and ports. After accounting for conveyance head losses prior to the diffuser ports, the calculated head available for the diffuser ports is 1.20 m for Stage V flows. Initial dilution modelling indicated that optimizing outfall/diffuser design to take full advantage of the available gravity head for Stage V flows would be sufficient to achieve the target dilution. For Stage VIII flows, the calculated available head is only 0.64 m, which is not likely to be sufficient to achieve the target dilution. Therefore, a decision was made to optimize the outfall and diffuser design for the available gravity head for Stage V flows and include provisions in the design for a future effluent pump station provide additional head as required to address future plant capacity expansion.

5.7 Diffuser Construction and Operational Considerations

5.7.1 Construction Considerations

This construction work includes installation of a river riser structure within a cofferdam to provide a connection between the tunnel under the river and a diffuser pipe buried in the river bottom, installation of the diffuser pipe in a dredged and backfilled trench in the river bed, and final connection of the tunnel to the diffuser pipe through the riser near the completion of the construction.

River riser construction involves mobilization, installation of a cofferdam, excavation of a shaft within the cofferdam, installation of piles within the cofferdam at the base of the shaft, backfilling the shaft and installing the riser pipe, removal of the cofferdam and demobilization.

Diffuser construction involves mobilization, followed by installation of the diffuser manifold pipe in sections. It is assumed the contractor will elect to install the diffuser manifold in multiple sections. Each diffuser pipe section will be installed by dredging a trench, placing pipe bedding material, installing the pipe, and backfilling with native river sand. Following pipe installation, protective caps and the flexible risers with variable orifices or caps will be installed, armor rock will be placed over the entire diffuser, and construction demobilized.

Diffuser connection involves removal of the internal bulkheads in the 3.8-m diameter outfall riser pipe that isolate the tunnel from the diffuser manifold pipe when the on-land work is completed to the point that the tunnel is flooded.

5.7.2 Operational Considerations

The surface elevation of the completed outfall protective armor rock cover is level with the depth of the navigation channel maintained by the Vancouver Fraser Port Authority (VPFA). The location of the outfall was selected to be in an area where sand accumulation is limited by seasonal scouring and re-deposition of sand. Therefore, dredging to maintain navigation channel depth in this area has not been required at the planned diffuser location in the last 10 years, as compared to areas of the channel downstream of the diffuser location where maintenance dredging typically occurs every two years.

Immediately upon completion of the outfall construction, the river bed will be left at the over-dredged limit used by VFPA when maintenance dredging (about 2 m below the minimum dredge channel depth). The portion left below the navigation depth will quickly fill in with sand when left to the natural deposition environment. The natural sand waves in the area will re-establish themselves during the first freshet resulting in the armor rock being mostly covered by sand. If future navigation channel maintenance dredging is required in the diffuser area, the upper portion of the armor rock on the dredge channel side of the diffuser will be partially exposed for a short time until covered again by sand during the following freshet.

The upper portion of the concrete protective covers over the flexible risers that includes a variable orifice will be exposed at an elevation of -8.7 m Chart Datum. Diffuser inspection and maintenance requirements are anticipated to include:

- Routine diving and/or sonar inspection
- Repair of damaged risers, if necessary
- Coordination with Navigation Channel maintenance dredging
- Installation of additional risers for future plant flow expansion
- ROV inspection access in case of seismic event, etc.
- Riser replacement (every 30+/- years)

5.8 Design Summary

The goal of the diffuser concept design was to determine a diffuser length, port spacing, and port diameter that provided significant dilution so that the Stage V design flow could be discharged by gravity while maintaining other hydraulic design criteria (e.g., having ports that flow full with an even distribution of flows across the ports). During Stage 1, analyses indicate that a variable diameter port provided better dilution across the range of effluent flows, and this design was carried into Stage 2. Hydraulic considerations include that pumping will be required to discharge flows greater than 18.9 m^3/s.

Based on the criteria, constraints, and analysis presented in this section and the results of initial dilution modelling presented in **Sections 6** and **7**, a design for the diffuser system was selected with the following features:

- A 240-m long diffuser manifold located just outside the edge of the navigation channel just downstream of the existing outfall. The manifold would connect to the main vertical riser from the outfall tunnel at its center.

- The manifold has 24, 0.75 m diameter risers leading to 0.75 m diameter ports discharging horizontally via variable orifices with a fixed port equivalent diameter of 0.525 m toward the center of the river. For Stage V flows, 6 of the ports would be blocked off to aid in increasing dilution leaving 18 active ports. All 24 ports would be open at Stage VIII when peak wet weather flow was 25.3 m^3/s.
- The Stage V ports are fitted with variable orifices (e.g., Tideflex diffuser valves) to increase exit velocities at low effluent flows. These valves also reduce sediment entering the diffuser system. The remaining ports are capped until needed for increased Stage VIII flows.
- The diffuser ports are surrounded with a concrete conical sleeve to protect them from anchors, ship strikes and submerged debris. The sleeve accommodates access to the port terminus to permit maintenance of the variable orifices.
- The ends of the manifold are fitted with bulkheads to facilitate internal access and/or cleaning.

Figure 5-4 shows a schematic of the diffuser along the edge of the navigation channel.

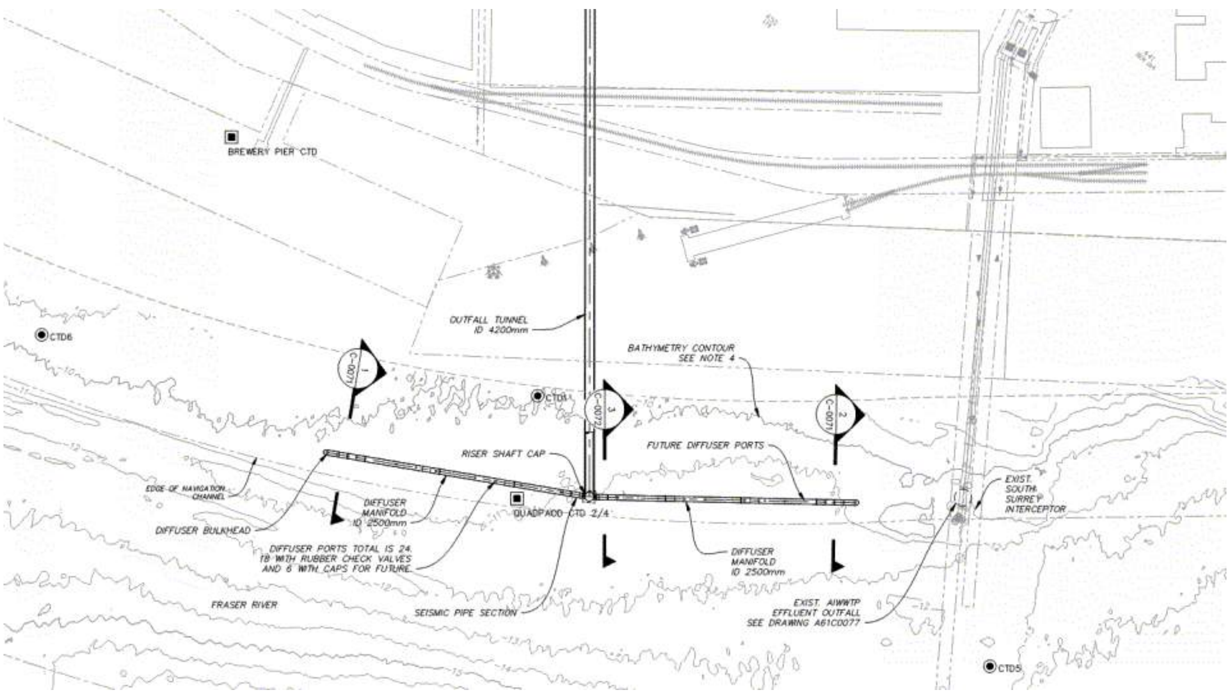

Figure 5-4. Plan View of Diffuser Design along the Edge of the Navigation Channel

Section 6

Modelling Approach for Water Quality Predictions

Modelling is used to determine the concentrations of discharged effluent at various locations in the Fraser River. The main objectives of the model tasks are to:

- Understand the factors affecting the fluid dynamics of the mixing of the effluent and ambient river waters; and parametrize them for use in the modelling,
- Model the instantaneous dilution process of contributing concentration of effluent under a wide range of ambient river conditions to determine dilution at the edge of the IDZ,
- Model the mixing of the effluent beyond the IDZ to understand the movement of the effluent beyond the IDZ, provide predictions at other far-field assessment nodes, and to define background buildup concentration from tidal forces when bilateral currents are present,
- Characterize effluent mass loads to be used with (1) entrained flux from the instantaneous dilution analysis to determine near-field concentrations and (2) far-field model dilutions to determine the far-field concentrations, and
- Provide modeled results of near- and far-field dilutions so they can be used to predict the concentrations for the contaminants of potential concern for comparison in the Stage 2 EIS to WQOs and WQGs and other regulatory endpoints.

This section first provides an overview of the near-field and far-field components of the predictions at the edge of the IDZ (**Section 6.1**), and then presents detailed methods and model inputs for the near-field analyses (**Sections 6.2** and **6.3**), followed by the methods used to determine the components of the far-field predictions: ambient background concentrations and concentrations beyond the IDZ due to the discharge of AIWWTP treated effluent (**Section 6.4**).

6.1 Method to Predict Concentrations at the Edge of the IDZ

The Municipal Wastewater Regulations allow for consideration of mixing with ambient waters in determining compliance with many of the WQGs. The regulations define an initial dilution zone (IDZ) and require that WQGs be met at the edge of the IDZ.

Determining the extent to which each chemical parameter in the treated effluent meets its WQG requires predicting the concentration of that parameter at the edge of the IDZ.

The concentration at the edge of the IDZ (C_{IDZ}) can be broken into separate components:

- The instantaneous contribution from the effluent plume that has just undergone initial dilution (C_n),
- Ambient (background) concentration (C_{amb}),
- Long-term background buildup as the concentration in the river due to the discharge of the treatment plant itself (C_{bb}).

Another component that needs to be consider is the contribution from other sources that would contribute to the ambient river concentrations between the location where the ambient background is measured and the discharge of effluent. For the AIWWTP project, this was investigated and there are no additional discharges between these locations that need to be considered.

A series of equation were developed to account for the different near- and far-field concentrations to develop a total concentration at the edge of the IDZ. Neglecting other sources, the far-field dilution (S_f) and the near-field dilution (S_n) are defined as:

$$S_f = (C_{eff} - C_{amb})/(C_{bb} - C_{amb}) \tag{1}$$

$$S_n = (C_{eff} - C_{bb})/(C_n - C_{bb}) \tag{2}$$

Where the total dilution (St) is defined as:

$$S_t = (C_{eff} - C_{amb})/(C_n - C_{amb}) \tag{3}$$

And is approximately the harmonic sum of the near-field and far-field dilution.

$$1/S_t \approx 1/S_f + 1/S_n \tag{4}$$

To determine the concentration at the edge of the IDZ, using the definition of the far-field, near-field and total dilutions, the equation yields:

$$C_{IDZ} = C_{amb} + \underbrace{\left[\frac{(C_{eff}-C_{amb})}{S_f}\right]}_{\text{Far-field}} + \underbrace{\left[\frac{(C_{eff}-C_{bb})}{S_n}\right]}_{\text{Near-field}} \tag{5}$$

Equation 1 can be solved for C_{bb} and substituted into equation 5 to yield:

$$C_{IDZ} = C_{amb} + \left[\frac{(C_{eff}-C_{amb})}{S_f}\right] + C_n - \left[\frac{C_{amb}}{S_n}\right] - \left[\frac{(C_{eff}-C_{amb})}{S_n * S_f}\right] \tag{6}$$

Where:

$$C_n = \frac{M_e}{E} \tag{7}$$

and: M_e = constituent mass flux (M/T)

E = entrained flux (the product of the initial dilution factor and the associated effluent flow rate (L^3/T)

It is worth mentioning that the initial dilution contribution (C_n) can alternatively be derived as the ratio of effluent concentration to some initial dilution factor (C_{eff}/S_n), which describes the percentage of dilution occurring as the effluent plume is entrained in the water column. However, as discussed below, the independence of each term on the right-hand side of **Equation 6** is important to the statistical methods applied here. Since both the effluent concentration and the initial dilution factor depend on the effluent flow rate, these two factors are not initially independent. Therefore, the mass flux, from which effluent concentration is derived, and the entrained flux were used to determine the initial dilution concentration. Since the constituent mass flux is independent of the flow rate, the mutual independence of the terms on the right-hand side of **Equation 6** is preserved.

Predicted dilutions may be combined with effluent flow rates to estimate entrained flux, which is a measure of the volume of water in which the constituent mass flux is diluted per unit time. The independence of each component used to calculate entrained flux (including the many used to derive the predicted dilution) is important because each may be assigned appropriate probabilities of occurrence. Provided these probabilities are independent, they can be combined in what is called a “joint probability” analysis. The probabilities of several independent but concurrent events can be multiplied together to determine the overall probability of that combination of events.

Since the frequencies of occurrence, or probability distributions, for each of the individual components can be determined, the mixing zone concentration can be predicted through a statistical analysis. The basic approach depends on the WQGs being used in compliance determination.

- For parameters with short-term maximum WQGs, the available data is used to model input parameters statistically, such as cumulative frequency distributions for ambient current. Representative values from the distribution are selected and interval of occurrence is assigned to each value. Individual model runs representing each combination of representative values are run (64 runs at 2xADWF and 256 runs at all flows for the AIWWTP discharge), and the joint probability of the predicted dilution is calculated. The distribution of instantaneous dilutions and their joint probabilities is used in combination with mass loads (Section 6.3.3) to determine the 95th percentile high concentrations as the near-field component (C_n) of the IDZ prediction. This was then added to the other components of Equation 6 (ambient background concentration as mean unless there were fewer than 10 samples, and then as median values and 95th percentile far-field concentration when bi-directional river conditions exist), and compared to determine if the short-term maximum WQG is met.
- For parameters with long-term average (30-day) WQGs, the available data is used to develop monthly average values for each model input parameter to permit calculation of dilution monthly. For months when salinity can be present, two simulations (stratified and unstratified) are made and then are combined based on the probability of salinity being present. Then, the monthly predicted dilution is multiplied by 2xADWF rate to determine entrained flux, which is then is divided into the average effluent loading to obtain the instantaneous average concentration. This is added to the monthly average ambient background concentration and monthly average far-field concentration, and compared to determine if the long-term average WQG is met.

6.2 Near-Field Modelling Approach

Section 6.1 provides the overview for making predictions at the edge of the IDZ, one half of which is the near-field component, which is the contributing concentration at the edge of the IDZ from the instantaneous dilution of the effluent discharge. This section provides:

- A brief overview of the process used in Stage 1 to select an approach for initial dilution modelling,
- The selection of a modelling approach for Stage 2, including results of the physical modelling, and

- The treatment of effluent quality data to determine mass loads that are combined with entrained flux from the dilution analysis to produce the near-field component of the IDZ predictions.

6.2.1 Stage 1 Initial Dilution Modelling

During Stage 1, an extensive review and trial of the application of initial dilution models to the AIWWTP's proposed tee diffuser in a crossflow was undertaken. All models were found to be lacking in their ability to predict dilution from the proposed diffuser type in a shallow tidal river. A comparison of the models is shown in **Table 6-1** for factors of importance to the mixing region of Annacis Island.

Table 6-1. Comparison of Initial Dilution Models for Annacis Island

Metric	CORMIX2	UM3 in Visual Plumes	VisJet
Water Body Type	Allows for bounded waterbodies	Infinite	Infinite
Where Initial Dilution Runs End	Both near-field and far-field regions	Ends when effluent plume reaches the water surface or its maximum rise, but includes ability to simulate far-field with Brooks (Gaussian diffusion) equation	Ends when effluent plume reaches the water surface or its maximum rise
Types of Diffuser Configurations Simulated	Can simulate either unidirectional, staged or alternating diffusers. 2 or 4 ports per riser depending on type.	Simulates unidirectional diffusers and can approximate alternating diffusers. Up to 2 ports per riser.	Has the flexibility to customize the diameter of risers and ports, and number of ports for each riser
How Individual Jets are Simulated	For an unstratified ambient, uses an equivalent slot diffuser; for stratified ambient uses CorJet module which treats each jet individually	Treated as individual jets until they merge	Treated as individual jets, merging accounted for
How Dilution is Accounted	Outputs flux-averaged or centerline dilution depending on module	Default is flux-averaged dilution; centerline dilution can be reported	Ability to determine dilution at a specified plane, but may not include all individual jets if the simulation has been stopped based on reaching water surface or maximum rise

The analyses undertaken in Stage 1 to reach a methodology to predict instantaneous dilution is summarized below; the Stage 1 document *Multiport Diffuser Design and Initial Dilution Modelling* (CDM Smith, 2016) provides a detailed description of the steps below.

1. Compared characteristics of initial dilution models (CORMIX2, UM3 and VisJet) and selected a model for use. Initially CORMIX2 was selected.
2. Upon applying CORMIX2 to Annacis' proposed diffuser design, inconsistencies were noted in the model results. Discussions with the model's developers ultimately identified some of the problem as a bug in the software.

3. Explored use of UM3 or VisJet for the Annacis design. More inconsistencies and counter-intuitive results were noted. While some variability in model results is expected, the degree of variability in application to the proposed Annacis diffuser led us to look for alternative approaches.
4. Investigated using results from physical model experiments of tee diffusers in a cross flow to develop an equation to predict dilution (key among the literature was the work by a professor at Seoul National University, Il Won Seo, who directed a large set of experiments for a unidirectional diffuser (Seo *et al*., 2001; the paper is included as **Attachment H**).

While Seo's experimental design is not a direct match to either the physical setting or proposed diffuser design, there was sufficient closeness or overlap in the variables important to dilution, particularly when expressed non-dimensionally, to rely on the experimental results to inform dilution for Stage 1 of this project.

Figure 6-1 is the comparison of the results from the simulations of the Annacis diffuser using UM3, CORMIX (before bug fix), and VisJet to Seo's experimental data, along with the empirical equation developed from available experimental data on unidirectional diffusers (see Figure 7 of Seo *et al*. (2001) in **Attachment H**), and an earlier equation developed by Adams *et al*. (1982) for which experiments were only calculated at low momentum ratios. UM3 results are presented as three series: the final dilution when the plume hits the surface before the IDZ, the dilution interpolated at a distance 100 metres downstream, and the final dilution reported of a trapped plume (saline conditions).

The x-axis is m_r – a non-dimensional parameter of the ambient current to the effluent discharge. While the y-axis is the ratio of theoretical dilution with no current (S_o) over the predicted dilution for the models and the minimum surface dilution for the experiment/equation. S_o is given in Adams et al. (1982) as:

$$S_o = \sqrt{\frac{H*L*u_o}{2*Q_o}} \qquad (8)$$

In **Figure 6-1**, a S_o/S_t ratio less than one indicates a higher dilution with current than the dilution at no current; and conversely S_o/S_t greater than one indicates lower dilution with current than with no current.

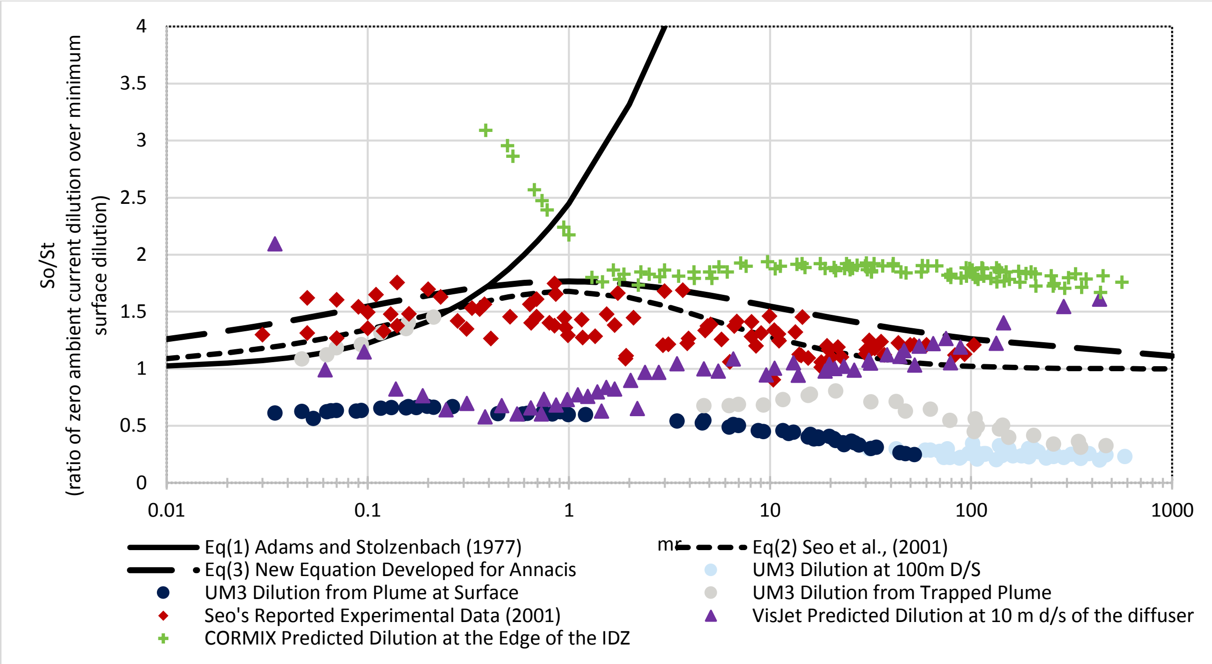

Figure 6-1. Comparison of Predicted Dilutions

The comparison of the two equations plotted in **Figure 6-1** demonstrate the importance of the momentum ratio on predicted near-field dilution (shown conceptually in **Figure 6-2**), whereas the momentum ratio gets large (due to higher ambient current) the ratio of S_o/S_t approaches unity rather than continue to rapidly increase.

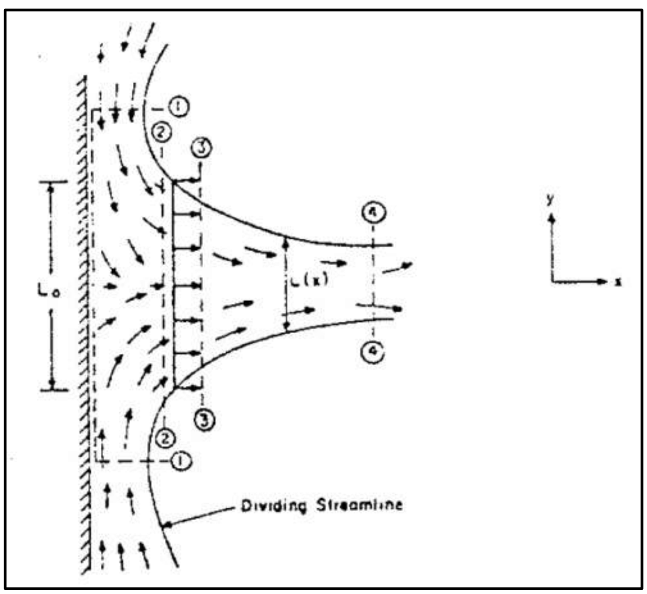

Figure 6-2. Depiction of a Tee Diffuser near a Shoreline
(from Adams *et al.,* 1982)

Dr. Eric Adams of MIT and his graduate student, Ms. Ishita Shrivastava, used the data from Seo, along with that from Adams and Stolzenbach (1977) and other experimental results for thermal unidirectional diffusers to develop an equation that can be used to predict dilution for the Annacis diffuser (Shrivastava and Adams, draft manuscript). The equation extends the work of Seo, whose equation (shown in **Figure 6-1**) was only a function of m_r, to have two additional terms: f2, which is function of L/H, and f3, which is a function of theta (θo), epsilon (ε), m_r, where theta is the angle of diffuser port from horizontal, and epsilon is approximately 0.099 and is the rate of spread of the jet half-width.

$$\frac{S_0}{S_t} = 1 + \max\{f_1(m_r) f_2(L/H), f_3(\theta_0, m_r)\}$$

Where: $f_1(m_r) = 0.45\text{sech}\{0.87 log_{10}(m_r)\}$

$$f_2(L/H) = \max\left\{1, 0.18(L/H)^{3/4}\right\}$$

$$f_3(\theta_0, m_r) = \begin{Bmatrix} \max\left[\left(\dfrac{1}{\sqrt{2\varepsilon \cot\theta_0}} - 1\right), 0\right] \\ 0 \quad \text{for } m_r \geq 1 \end{Bmatrix} \quad for \;\; m_r < 1$$

The Shrivastava and Adams equation was used in Stage 1 to predict the centerline instantaneous dilution when the ambient was unstratified. Then, this minimum dilution was converted to a dilution at the edge of the IDZ along the plume's centerline; and finally, a factor of 1.4 is used to convert the centerline dilution measured at the edge of the IDZ to a flux-averaged dilution. Based on the review of available modelling techniques for stratified conditions, UM3 was selected to predict instantaneous dilution when salt is present.

While the use of the Shrivastava-Adams equation and UM3 for Stage 1 was reasonable, questions about the ability of the equation to represent dilution for the proposed diffuser for AIWWTP remained. The equation did not, for instance, include a term for port spacing, often a critical diffuser design parameter. Therefore, a physical modelling study was undertaken as part of Stage 2 to refine the method for predicting instantaneous dilution.

6.2.2 Stage 2 Instantaneous Dilution Modelling Approach

The following analyses were undertaken to develop a methodology for use in Stage 2 to predict instantaneous dilution.

1. A physical model of the Annacis outfall's proposed diffuser was established in a large tow tank in the MIT Hydraulics Laboratory. The physical model setup, experiments conducted and results are summarized in **Section 5.5**. Adams and Shrivastava (manuscript in draft 2017; and report in **Attachment F**) established a revised equation to predict dilution under unstratified conditions.

$$\frac{\mathrm{S_0}}{\mathrm{S_{min}}} = 0.8\left[1 + 0.08(\mathrm{L/H})^{3/4}(\ell/\mathrm{H})^{-0.28}\,\mathrm{sech}\{0.87\log_{10}(\mathrm{m_r})\}\right]$$

2. The results of the physical model were also used to establish a revised ratio of centerline to flux-average dilution of 1.8.
3. The revised Shrivastava -Adams equation and conversion factor were used to predict dilution in unstratified ambient conditions.
4. For stratified ambient conditions, we re-reviewed the initial dilution model choices. Conversations with the model developers of UM3 and CORMIX indicated that the UM3 model did not easily simulate a tee diffuser in a crossflow, while the CORMIX developers indicated that the software bug that had been identified in Stage 1 was fixed. After some testing and comparison to the physical modelling, CORMIX2 is selected to predict instantaneous dilution under stratified ambient conditions.

6.2.2.1 Description of CORMIX

The USEPA program, Cornell Mixing Zone Expert System (CORMIX), is a software system used for the analysis, prediction, and design of discharges into diverse water bodies. Use of the program helps to determine what dilution can be expected from given outfall configurations, discharge concentrations, and receiving water characteristics. CORMIX2[3] is the multi-port diffuser module.

Bounding the water body is important in estimating the dilution from a tee diffuser. As discussed in Adams *et al*. (1982) the separation distance between the shoreline and the diffuser is observed to reduce the effective dilution by limiting the ambient diluting water reaching the discharge ports from behind the diffuser. As seen in **Figure 6-2**, the tee diffuser system acts as a pump in pulling ambient water from behind the diffuser (as indicated by the arrows) into the discharging effluent and creating the dilution plume. The research indicated that separation distance needed to be greater than 35% of the diffuser length to achieve 70% of the dilution predicted for infinite water.

CORMIX2 calculates concentrations in the near-field region and in the far-field region. The near-field region includes a small area of jet mixing where no influence is felt from the ambient conditions; initial characteristics of the effluent alone dictate flow. For complex hydrodynamic cases, CORMIX simplifies the design specifications into an “equivalent slot diffuser” and thus, embraces the merging of plumes and neglects the details of individual jets. In the remainder of the near-field region, the initial characteristics of the effluent, momentum flux, buoyancy flux and outfall geometry, dominate flow patterns, but ambient conditions have some effect. The near field gives way to the far field, which is the region of the receiving water where buoyant spreading motions and passive diffusion control the trajectory and dilution of the effluent discharge plume. (Jirka et al., 1996).

6.2.2.2 Selection of a Centerline to Flux-Average Dilution Factor

The literature on initial dilution modelling of tee diffusers (Isaacson *et al*. (1983), Baumgartner *et al*. (1992); Roberts and Snyder (1993); Doneker and Jirka (2001); Roberts *et al*. (2001); Tian, *et al*. (2004, and Lai (2011)) was reviewed and individual experimental or theoretical data points were screened to create a subsample of experimental results to best match the proposed conditions for the AIWWTP outfall pipe; parameters focused on multiport diffusers, with similar

[3] http://www.cormix.info/CORMIX2.php

length scale characteristics, and utilizing either uniform or nonlinear stratification. Applying those characteristics to the dataset reduced the range of ratios further to a range of 1.3 to 2.45.

Based on the physical modelling experiments performed by MIT as described in **Attachment F**, it is concluded that the flow-average dilution exceeds minimum dilution by a factor of about 1.8. A value of 1.8 was chosen to convert centerline to flux-averaged dilution as it is consistent with the proposed diffuser design.

6.2.3 Calculating Mass Loads from Effluent Sampling Data

As mentioned above, near-field concentrations were calculated on a mass loading basis to preserve the independence of all parameters used to calculate C_{IDZ}. Mass loads were statistically developed and divided by entrained fluxes, developed from the near-field model, to yield near-field concentrations. The methodology and statistical rational used to develop the mass loads and from them the near-field concentrations is discussed in this section.

Section 4.4 describes the available effluent quality data from the following sources: operation plant data, data from monthly comprehensive effluent monitoring, data gathered in conjunction with the existing outfall IDZ monitoring program, and water quality data reported in the *Potential Effluent Discharge Objectives for the Annacis Island Wastewater Treatment Plant* (EDO) report (Tri-Star Environmental Consulting, 2015). It also describes the statistical calculations performed to characterize the data for each parameter of interest. Golder Associates, who are preparing the Stage 2 EIS, then defined over 170 of the 615 parameters measured in the effluent (or parameters combining parameters measured) as contaminants of potential concern (COPCs) to be evaluated against water quality guidelines/objectives and/or for fish tissue.

Effluent daily mass loads were calculated as the product of the sampling concentrations and the estimated Stage V average daily effluent flow rate on the day of sampling. Stage V flows were determined using the actual flow on the day and translating them to Stage V flows using the relationship presented in **Section 6.3.3**. The daily mass loads for each parameter were then fit to one of three continuous statistical distributions:

- Normal
- Unbounded Johnson
- Bounded Johnson

Johnson distributions were considered to account for observed skewness (a measure of a distribution's asymmetry) and kurtosis (a measure of the weight of a distribution's tails relative to the whole) in daily load datasets. Both the bounded and unbounded Johnson distributions are transformations of the normal distribution, and can account for nearly any skewness and kurtosis.

Some parameters were deemed unsuitable for Johnson distribution fitting due to either low sample counts or a high percent of non-detected values and were consequently assumed to be normally distributed. Because algorithmically fitting loads to a Johnson distribution would account for some skewness and kurtosis in the data, it is important to have a high level of confidence in those data characteristics. If, for example, a parameter is 100% non-detect, there is typically no variation in the data since the only value measured is that of the detection limit (some parameters have multiple detection limits). However, when the concentrations are converted to loads based on the average daily effluent flow rate on the date of sampling, variation in the loads arises due to the variation in those daily flow rates. Because such flow induced variation in loads cannot be confirmed as real, due to the uncertainty of the concentrations, we cannot be confident in any skewness or kurtosis it may exhibit. If a parameter was greater than 50% non-detect values, its loads were fit to a normal distribution since we could only be confident in less than 50% of the variation in the loads. Additionally, if a parameter had less than 10 samples total, the loads were assumed to be normally distributed due to the limitations of Johnson distribution fitting algorithms with small datasets.

Percentile mass loads were calculated for each parameter using the percent point function (ppf) of the selected distribution with the best-fit parameters produced by the fitting algorithms.

$$M_e = \xi + \left[\left(1 + e^{-(z-\gamma)/\delta}\right)^{-1} * \lambda\right] \quad \text{Bounded Johnson Distribution ppf}$$

$$M_e = \xi + \left[\sinh\left(\frac{z-\gamma}{\delta}\right) * \lambda\right] \quad \text{Unbounded Johnson Distribution ppf}$$

$$M_e = \mu + z * \sigma \quad \text{Normal Distribution ppf}$$

Where: ξ = Johnson location parameter

λ = Johnson scale parameter

δ = Johnson shape parameter

γ = Johnson shape parameter

μ = Arithmetic mean

σ = Standard deviation

z = Standard normal variable (z-score)

100 mass loads were calculated for each parameter each with an occurrence probability of 0.01. The mass loads for parameters using a Johnson distribution were inspected to ensure the loads were reasonable and in agreement with engineering judgment.

6.3 Instantaneous Dilution Inputs

The instantaneous dilution is taken from the results of the initial dilution predictions as the value at the time when the plume's centerline intersects one of the boundaries of the IDZ. For the proposed Annacis outfall, instantaneous dilution was predicted as follows:

- When the Fraser River is unstratified the updated Shrivastava-Adams equation in **Section 6.2.2** is used.
- When the Fraser River is stratified, the CORMIX model is used; a change in software from the Stage 1 analysis. After consultation with the model developers, it was determined that UM3 was not adequate to represent a tee diffuser in cross flow and that the previously identified bug in CORMIX was fixed in the latest update of the software.

Determination of instantaneous dilution using initial dilution (or near-field) models requires the following parameters:

- Diffuser characteristics (configuration, number of ports, port size, port spacing, depth of discharge), as described in **Section 5**,
- Ambient river characteristics (width, depth, density profile, current speed), and
- Effluent characteristics (flow, density).

The data requirements for the equation to predict initial dilution are similar to those needed for an initial dilution model.

Due to the complexity of the Fraser River estuary, the ambient river and effluent characteristics are described for five flow "classifications" of the river, representing flows:

- Greater than 6,000 m^3/s –a period of freshwater and unidirectional currents when background buildup does not occur; this is the period of the higher flows during the freshet,
- Between 2,001 and 6,000 m^3/s – a period of bidirectional current and fresh water,
- Between 1,501 and 2,000 m^3/s – a period of bidirectional current with mostly fresh water and a very low probability of salinity at the site during high tides with significant asymmetry,
- Between 801 and 1,500 m^3/s – a period of bidirectional current and with mostly fresh water with a moderate chance of salinity at the site during high tide, and
- Less than 800 m^3/s – a period of bidirectional current when low river flows could result in salinity being present at the project site during the entire tide cycle under favorable tidal conditions.

Table 6-2 provides a conceptual overview of how ambient river and effluent properties are characterized as input into the initial dilution equation.

Table 6-2. Conceptual Overview of Treatment of Initial Dilution Input Parameter

Initial Dilution Input Parameter	Fraser River Flow Classification				
	<800 m^3/s	801 to 1,500 m^3/s	1,501 to 2,000 m^3/s	2,001 to 6,000 m^3/s	>6,000 m^3/s
Effluent Flow	One CFD represents three flow classes			Individual CFD	Individual CFD
Effluent Temperature	Average value	Average value	Average value	Average value	Average value
Fraser River Current	One CFD represents four flow classes for bi-directional flow				Individual CFD
Fraser River Salinity and Depth	Three profiles: unstratified, stratified high tide, stratified low tide	Two profiles: unstratified and stratified high tide	Two profiles: unstratified and stratified high tide	Unstratified	Unstratified
Fraser River Temperature	Average value	Average value	Average value	Average value	Average value

The following sections present the data used to develop the input parameters and how they were assigned a probability of occurrence. The probabilities of occurrence for each individual parameter is then combined to assign an overall probability of occurrence for the calculated dilution.

6.3.1 Fraser River Flow Classifications

Fraser River flows recorded at Hope are used to assign the percent of time when the flows fall within the five flow classifications defined in **Section 6.3,** and are based on current directionality and presence of the salt wedge. **Table 6-3** summarizes the data by flow classification, where Q_a is the ambient river flow**.** Flow is greater than 6,000 m^3/s only 10.7% of the time, between 6,000 and 800 m^3/s most of the time (79.5%), and is less than 800 m^3/s for 9.8% of the time.

Table 6-3. Fraser River Flow Classification

Flow Classification	Percent of Time Fraser River Flow Dataset (1966-2016)
$Q_a > 6{,}000\ m^3/s$	10.7 %
$2{,}001\ m^3/s < Q_a < 6{,}000\ m^3/s$	37.1%
$1{,}501\ m^3/s < Q_a < 2{,}000\ m^3/s$	12.6%
$801\ m^3/s < Q_a < 1{,}500\ m^3/s$	29.8%
$Q_a < 800\ m^3/s$	9.8 %

6.3.2 Fraser River Current

Initial dilution predictions require as input the ambient current speed and current direction with respect to the diffuser alignment. Representative current speeds were used as input. Using the results of the 2013 year-long simulation of the H3D model, a CFD of Fraser River current speed was developed at a model node located near the center of the river and 1km downstream of the proposed diffuser site. Initially, the current speed data were divided based on the flow classifications, but four of the low flow classifications were combined into one dataset ($Q_a < 6{,}000$ m^3/s) based on the similarity of their probability distributions.

Figure 6-3 and **Figure 6-4** show the cumulative frequency distribution of current speed for river flows greater than and less than 6,000 m^3/s, respectively. To represent the probability density function of Fraser River current speed, four values of current speed were selected as points of inflection along the curve and the percent of time of occurrence was assigned midway between the points of inflection (**Table 6-4**).

To represent conditions for parameters with long-term average endpoints, the average current speed using the H3D model (for the average year 2013) is calculated for every month and is presented in **Section 6.3.7**.

Table 6-4. Representative Fraser River Current

Q_a >= 6,000 m^3/s			Q_a < 6,000 m^3/s		
Current Speed (m/s)	**Cumulative Probability**	**Percent of Time**	**Current Speed (m/s)**	**Cumulative Probability**	**Percent of Time**
0.36	0.1%	0.2%	0.07	4.9%	9.8%
1.08	21.3%	42.0%	0.37	30.5%	41.4%
1.56	62.5%	42.3%	0.90	71.6%	40.5%
1.93	92.3%	15.4%	1.30	95.9%	8.3%

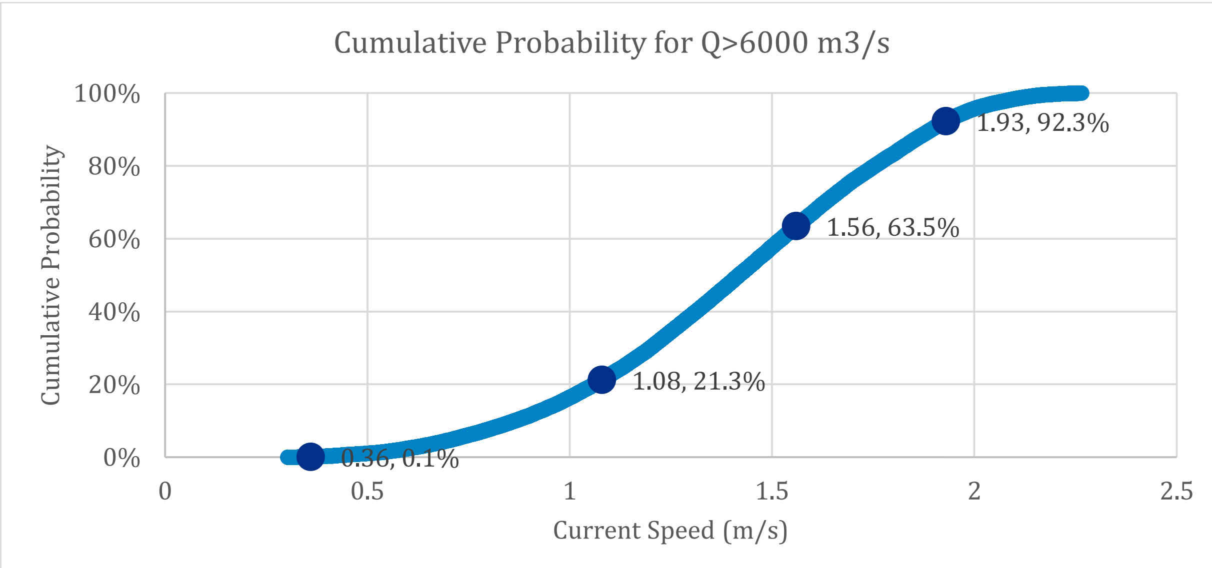

Figure 6-3. Cumulative Probability of Fraser River Current Speed for Q_a >6,000 m^3/s

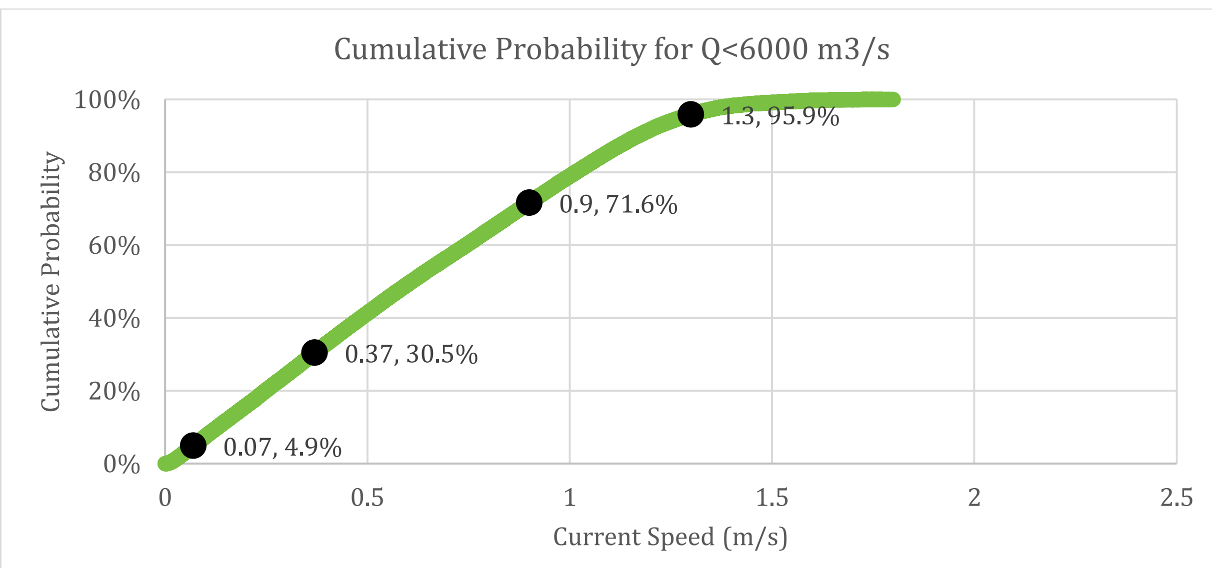

Figure 6-4. Cumulative Probability of Fraser River Current Speed for Q_a <6,000 m^3/s

6.3.3 AIWWTP Effluent Flow

Because the initial dilution process occurs on the order of minutes, initial dilution calculations are typically performed with hourly effluent flow rates (not daily flow rates). Hourly flow rates capture the greater variability of effluent flow conditions. For AIWWTP, peak instantaneous flows from 2012 through 2016 are used as the basis to develop the cumulative frequency curves as they represent recent effluent flow patterns.

The cumulative frequency curve for current flows then had to be extended for Stage V flows. This is done using the ratio of dry weather flow and peak wet weather flows for the current and Stage V periods.

The EDO report (*Potential Effluent Discharge Objectives for the Annacis Island Wastewater Treatment Plant* report (Tri-star Environmental Consulting, 2015)) states that the dry-weather flow would increase from 5.5 m^3/s to 7.37 m^3/s at Stage V. The ratio of these flows (1.34) was used as the starting point to scale the distribution of future hourly flows. The change in peak wet weather flow (13.7 to 18.9 m^3/s) is a factor of 1.38. Assuming the effluent flow pattern would not change, the current effluent flow record was converted to the Stage V flows by incrementally scaling individual data points by a ratio of 1.34 (to scale up the current minimum flow of 5.5 m^3/s to the future minimum flow of 7.37 m^3/s) to 1.38 (to scale up current recorded maximum flow from 13.7 m^3/s to the projected Stage V flow of 18.9 m^3/s).

Figure 6-5 displays the cumulative frequency curve for both the current and Stage V flows.

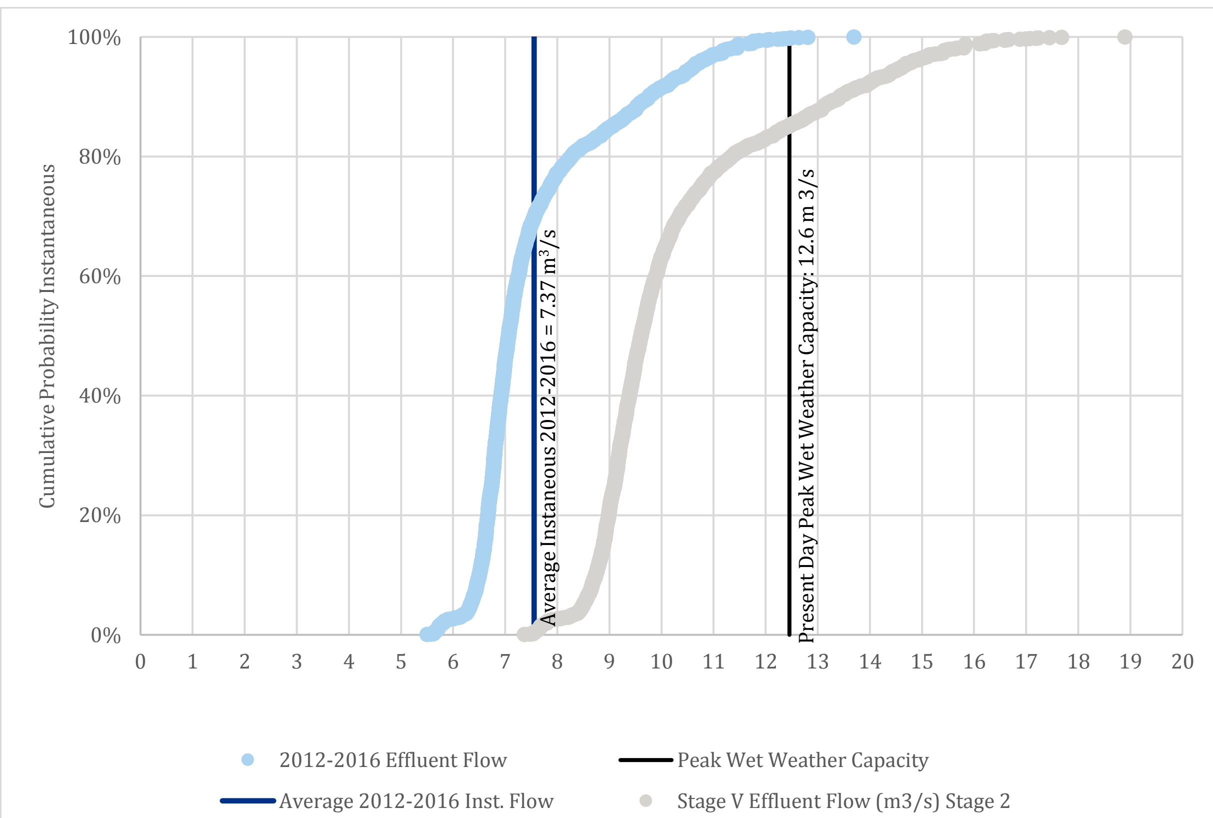

Figure 6-5. Cumulative Probability of Instantaneous Effluent Flow
(Current (2012-2016) Conditions and at Stage V)

To represent the probability of future effluent flows, four flow values were modeled for each flow period. The probabilities are assigned based on inspection of **Figure 6-6** to **Figure 6-8**, which represent Stage V flows, and are summarized in **Table 6-5**. To represent conditions for parameters with long-term average endpoints, the average effluent flow is calculated for every month, and is presented in **Section 6.3.7**.

Table 6-5. Representative AIWWTP Effluent Flows

Q_a >= 6,000 m³/s			6,000 m³/s > Q_a >= 2,000 m³/s			Q_a < 2,000 m³/s		
Future Flow (m3/s)	Cumulative Probability	Percent of Time	Future Flow (m3/s)	Cumulative Probability	Percent of Time	Future Flow (m3/s)	Cumulative Probability	Percent of Time
8.7	5%	10%	7.7	4%	8%	8.6	2%	4%
9.3	43%	66%	9.2	44%	72%	9.7	36%	64%
9.9	86%	19%	11.3	87%	14%	13.2	84%	31%
11.0	98%	5%	14.7	97%	6%	18.9	99.5%	1%

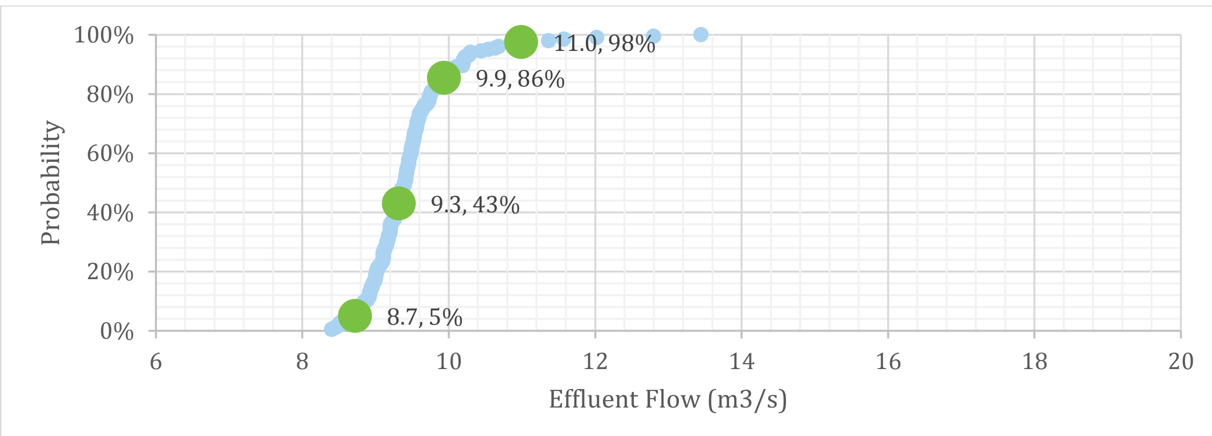

Figure 6-6. Cumulative Probability of Instantaneous Effluent Flow (Qa >6,000 m³/s)

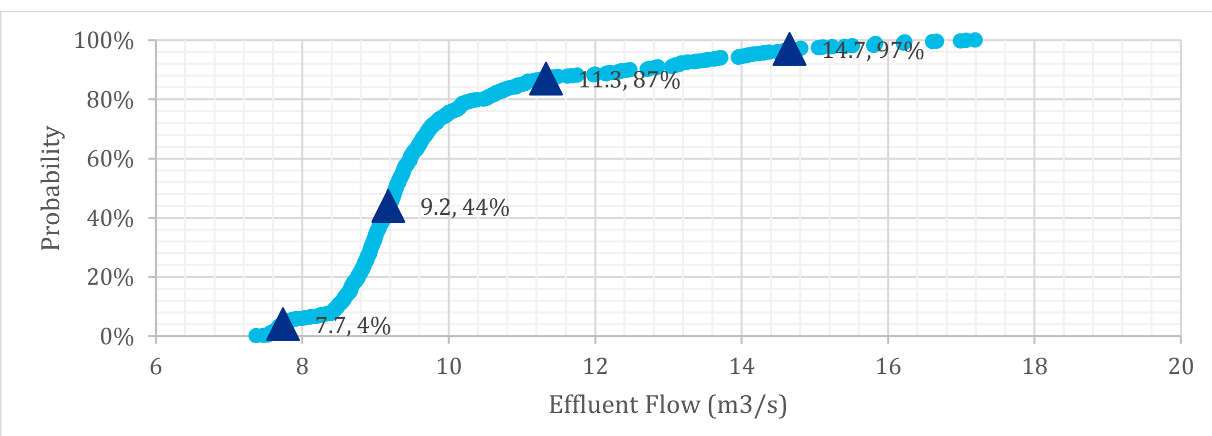

Figure 6-7. Cumulative Probability of Instantaneous Effluent Flow (Qa = 6,000 to 2,000 m³/s)

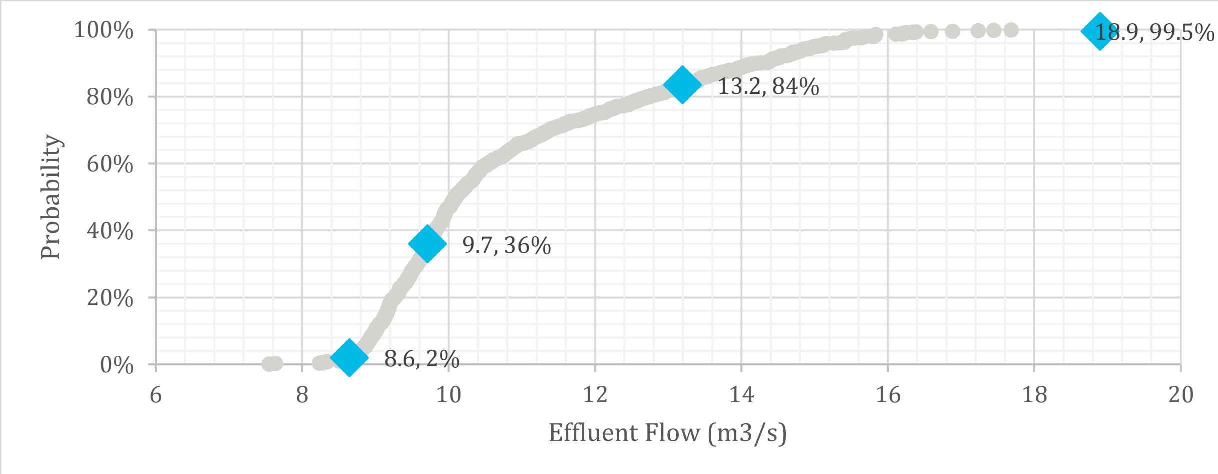

Figure 6-8. Cumulative Probability of Instantaneous Effluent Flow (Qa <2,000 m³/s)

6.3.4 Seasonal Differences in Temperature

Initial dilution predictions require inputs of effluent density and the vertical profile of ambient density. Because most of the discharge scenarios are freshwater effluent discharging to a freshwater ambient, temperature data is used to define density (the addition of salinity to the ambient density input term is presented in **Section 6.3.7**).

Figure 6-9 shows the cotemporaneous dataset between 2012 and 2016 for effluent and ambient temperatures measured at the Gravesend Reach buoy, which indicates that effluent temperature fluctuates less than ambient temperature. The annual average effluent temperature is 17.4°C. Average effluent temperature under the flow classifications ranges 12.8 to 19.3°C. Ambient temperature averages 7.7°C, and averages for the flow classifications ranged from 2.9 to 13°C.

Table 6-6 presents average effluent temperature, average ambient temperature for each flow classification, and their difference. To represent conditions for parameters with long-term endpoints, the average effluent temperature and the average ambient temperature are calculated for every month and are presented in **Section 6.3.7**.

Table 6-6. Seasonal Temperature and Temperature Differences by Flow Classification

Flow Classification	Effluent Temperature (°C)	Ambient Temperature (°C)	Temperature Difference (ΔT, °C)	Percent of Time
Qa > 6,000 m³/s	19.1	6.0	13.0	10.7 %
2,001 m³/s < Qa <6,000 m³/s	19.1	5.4	13.8	37.1%
1,501 m³/s < Qa <2,000 m³/s	18.2	7.9	10.3	12.6%
801 m³/s < Qa <1,500 m³/s	14.0	9.1	4.9	29.8%
Qa < 800 m³/s	12.8	9.9	2.9	9.8 %

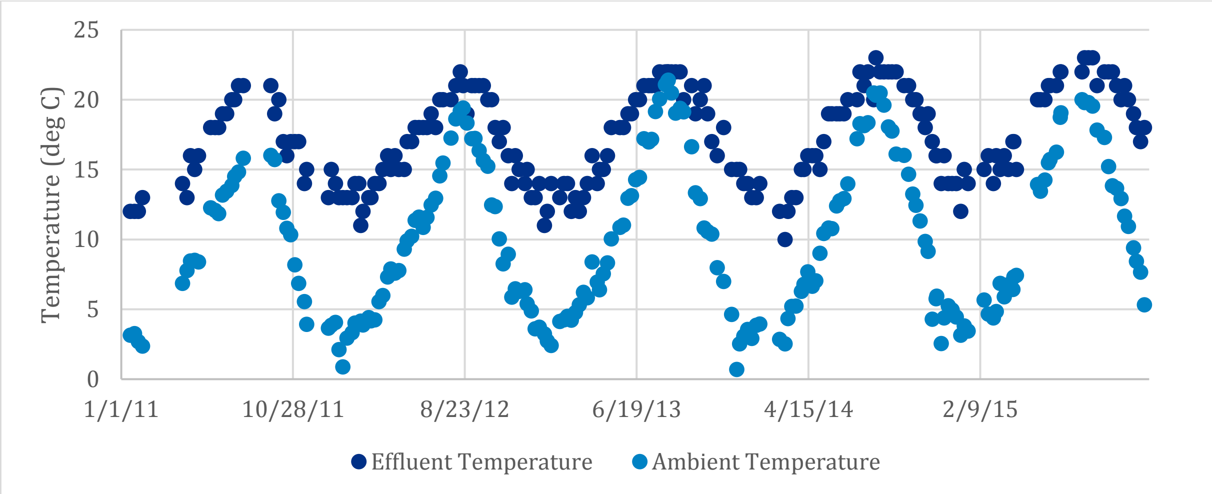

Figure 6-9. Cotemporaneous Temperature Data at AIWWTP and at Gravesend Reach

6.3.5 Water Depth

Initial dilution predictions require as input the ambient water depth and depth at which the discharging effluent occurs. As described in **Section 2.1.4**, the Municipal Wastewater Regulations require that the diffuser be in at least 10 m of water depth. As was discussed in **Section 5**, the project study area does not include a region of sufficient depth to accommodate the diffuser and meet the minimum depth requirements in the Municipal Wastewater Regulations. Therefore, a variance will be sought. For the initial dilution predictions, three depths were used: 10.9 m, which represents the low water depth at the elevation of the dredging grade when the flow in the Fraser River is less than 6,000 m^3/s; 11.65 m as the low water depth when the flow in the Fraser River is greater than 6,000 m^3/s; and 14.5 m, which represents a typical high-water level at that location. Each water depth was assigned a 50% probability of occurrence.

To represent parameters for long-term endpoints, the monthly average depth above the diffuser in the Fraser River was calculated assuming the discharge occurs 10 m below Chart Datum; the values are presented in **Section 6.3.7**.

6.3.6 Salinity

Most of the time the discharge of freshwater effluent from the AIWWTP occurs into the Fraser River when no salinity is present. Initial dilution models require vertical density profile, and under freshwater conditions, a uniform profile at the temperature described in **Section 6.3.4** was used.

As described in **Section 3.2.3**, salinity is present intermittently at the project site particularly at lower Fraser River flow, strong tidal asymmetry, and the occurrence of a bidirectional current. As demonstrated in the recent 2016-2017 Brewery Pier and QuadPod measurement data, IDZ monitoring data, and the results from the H3D model, salinity can be present, but is not always present, at the site when the ambient flow is less than 2,000 m^3/s. Flow classifications, as described in **Section 6.3.1**, are based on the current understanding of the presence, magnitude, and duration of salinity (**Table 6-7**).

Table 6-7. Salinity based on Flow Classification

Flow Classification	Percent of Time Based on Fraser River at Hope (1966-2016)	Percent of Time Salinity May be Present	Modeled Salinity Profile during High Tide	Modeled Salinity Profile during Low Tide
Qa > 6,000 m^3/s	10.7%	0%	Fresh	Fresh
2,001 m^3/s < Qa <6,000 m^3/s	37.1%	0%	Fresh	Fresh
1,501 m^3/s < Qa <2,000 m^3/s	12.6%	2.6%	TetraTech Model Profile at Site	Fresh
801 m^3/s < Qa <1,500 m^3/s	29.8%	19.6%	Average of 2016 IDZ Profiles High Tide and QuadPod Profile High Tide on 2/1	Fresh
Qa < 800 m^3/s	9.8%	38.9%	QuadPod Profile High Tide on 2/9	QuadPod Profile Low Tide on 2/9

The percent of time that flow in the Fraser River is within each flow classification is based on the daily Fraser River Flow at Hope record from 1966-2016. Overall, the percent of time that the joint occurrence of an ambient flow of less than 2,000 m3/s (52.2% of the time) and when salinity is greater than 1 ppt (multiplied by the percent of time salinity may be present in each individual flow classification, and summed) is approximately 10% of the time. The percent of time salinity may be present and the modeled salinity profiles are based on various sources:

- Greater than 2,000 m^3/s – We currently have no evidence that indicate that salinity can be present when flows are greater than 2,000 m^3/s. In the Brewery Pier dataset albeit from a metre located in relatively shallow water, flows in Fraser River rise above 2000 m^3/s without salinity being measured

- Between 1,501 and 2,000 m^3/s – During the monitoring period at the Brewery Pier, there is an instance in late October 2016, when the flow in the Fraser River is approximately 1,930 m^3/s. The Brewery Pier data was filtered for this range of flows, and about 2.6% of the time in this dataset, salinity was > 1 ppt. Neither the CTD profiling from the 2016-2017 monitoring period nor the CTD profiles from the IDZ boundary data collection was taken when river flows were in this range. It is assumed that this flow range prevents the salt wedge from penetrating upriver during low tide and even many high tides, but with sufficient tidal inequality, salinity could reach the site during high tide. Thus, the results of the TetraTech model for model year 2014 were used to develop a vertical profile (**Figure 6-10**) for a high tide condition.

- Between 801 and 1,500 m^3/s – This flow range fits within the QuadPod dataset, which was deployed when the flows in the Fraser River were 797-1,519 m^3/s. In this dataset, salinity is present with more frequency and persistence, but the time history shows that salt can still evacuate the site given the right tidal and flow conditions (**Figure 3-5**), and rarely does the salt wedge persist during low tide. The percent of time was calculated using a >1 ppt threshold, and in the QuadPod dataset, was present 19.6% of the time. Two CTD profiles were collected within this flow range: the 2016 IDZ profile taken at high tide (**Figure 3-10**) and a CTD profile taken at during high tide on February 1, 2017. The average of both profiles is used (**Figure 6-11**) to represent a high tide salinity condition.

- Less than 800 m³/s – The 2016-2017 monitoring did not capture a period when flows are less than 800 m³/s, but flows in this range occur 9.8% of the time in the recent record. The limited dataset available to represent salinity at the flow range is from the IDZ boundary monitoring between 2007-2016 with a minimum flow of 626 m³/s. This data are limited, the spatial measurement location changes depending on where the plume is detected, the vertical profile varies between at the water surface to the river bottom. This dataset is the only available record of salinity presence in this flow range and is calculated to be present 38.9% of the time. In addition, CTD profiles for this flow range are not available – thus, the salinity is represented using the worst-case CTD profile taken during the 2016-2017 monitoring period for high tide (**Figure 3-9**), and similarly a corresponding profile for low tide taken on the same day (February 9, 2017) shown in (**Figure 6-12**).

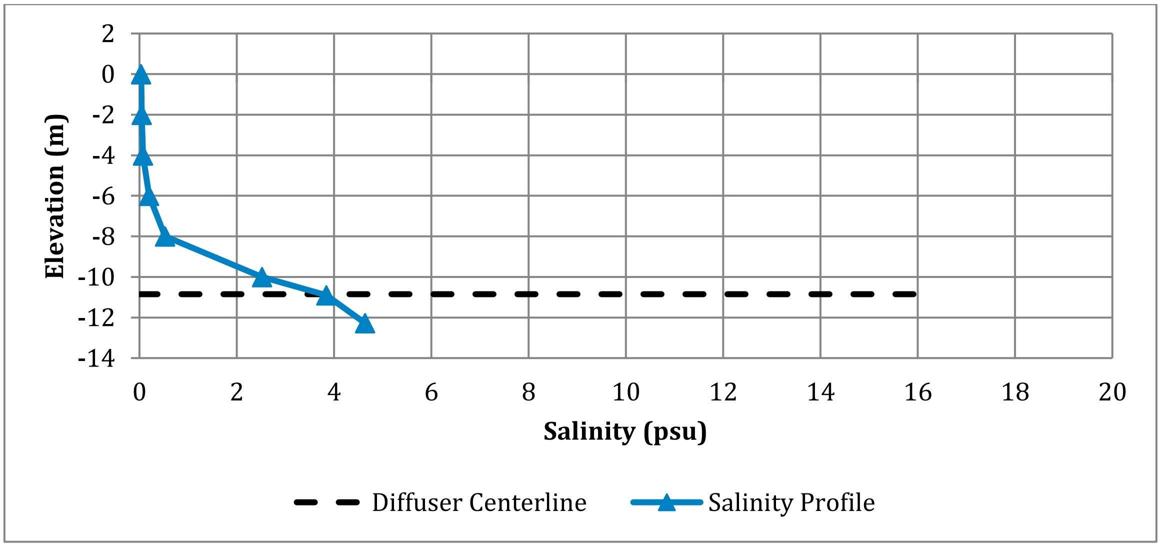

Figure 6-10. Profile of Salinity from H3D Model (Between 1,501 and 2,000 m³/s)

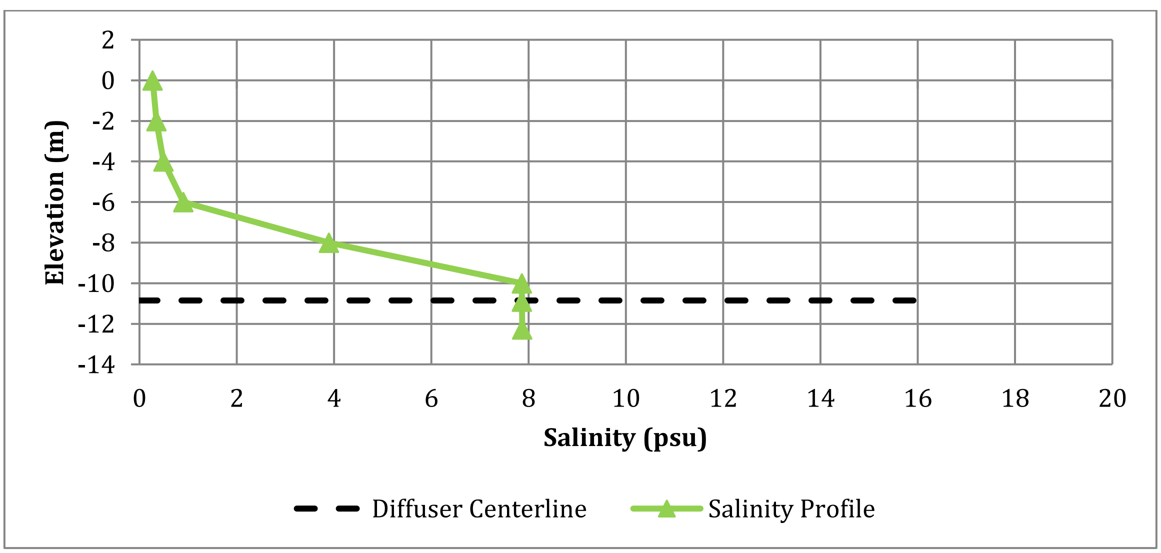

Figure 6-11. Profile of Salinity from the Average of the 2016 IDZ and 2017 CTD Profiles
(Between 801 and 1,500 m³/s)

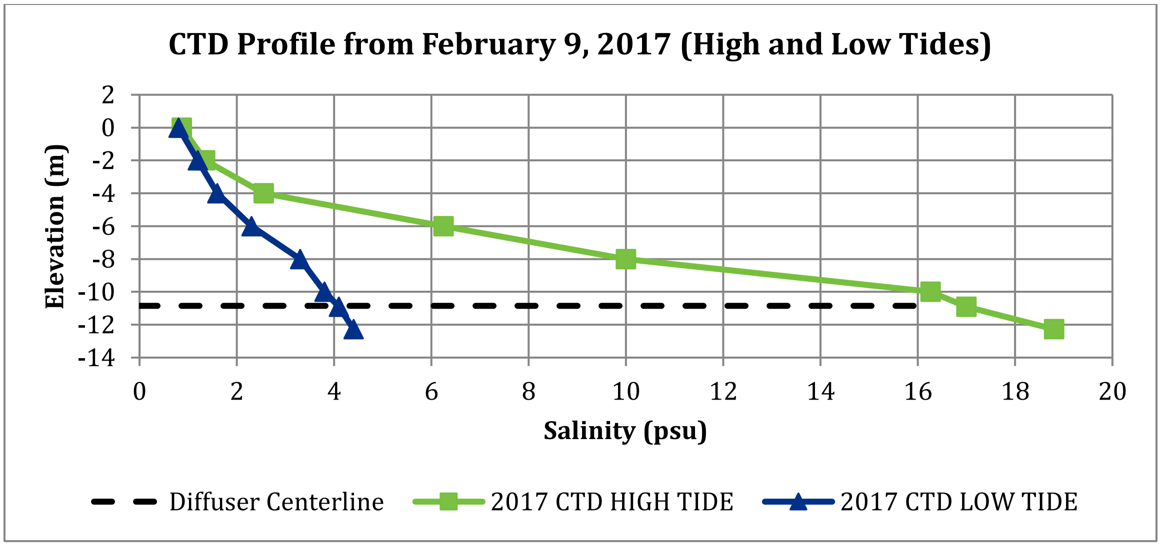

Figure 6-12. Profile of Salinity from the Average of the 2016 IDZ and 2017 CTD Profiles
(Less than 800 m^3/s)

To represent conditions for parameters with long-term average endpoints, the percent of time that salinity is potentially present is from the H3D year-long salinity model simulation (the average flow year of 2013). The average monthly Fraser River flow is calculated and the flow classification in which the average flow falls is the flow classification salinity profile used to represent the average conditions of that month.

6.3.7 Model Input Summary

This section summarizes the input parameters for the initial dilution predictions simulations. Table 6-8 presents the input parameters that are common to CORMIX runs.

Table 6-8. Input Parameters for Fixed Variables

Variable	Input Value
Channel width, m	590
Channel winding and non-uniformity	Slight Meander/Medium
River current, m/s	Varies
Wind velocity, m/s	2.4
Manning's friction factor	0.02
Distance from first port to right bank, m	170
Effluent water type	Fresh
Contraction ratio	1

Table 6-9 summarizes the 256 calculations of initial dilution that represent the range of model input parameters to create the cumulative frequency graph of predicted dilution that is used to determine the percentage of time that parameters with short-term endpoints meet WQGs. **Figure 6-13** provides a schematic view of each of the 256 runs and their input values and probabilities.

Table 6-9. Number of Effluent and Ambient Model Input Parameters

Flow Classification	Water Depths	Effluent Flows	Current Speed	Temperature Difference	Density Profile
Qa > 6,000 m^3/s	2	4	4	1	1
2,001 m^3/s < Qa <6,000 m^3/s	2	4	4	1	1
1,501 m^3/s < Qa <2,000 m^3/s	2	4	4	1	2
801 m^3/s < Qa <1,500 m^3/s	2	4	4	1	2
Qa < 800 m^3/s	2	4	4	1	3

Table 6-10 summarizes the model input parameters with the long-term average endpoints monthly model runs. Eighteen long-term 'runs' represent the average monthly conditions (12 runs with an unstratified density profile and 6 runs with a stratified density profile). The probability of occurrence of salinity monthly was determined by calculating the monthly percent of time when salinity was present using the H3D model, then calculations were executed with both an unstratified and stratified density profiles. A monthly probability weighted flux-averaged initial dilution included accounting for the presence of salinity and hence the application of the stratified density profile as well as the remaining dilution coming from times when freshwater is present.

Table 6-10. Monthly Effluent and Ambient Model Input Parameters

Month	Monthly Average Effluent Temp. (°C)	Future Monthly Average Effluent Flow (m^3/s)	Monthly Average Ambient Depth (m)	Monthly Average Ambient Velocity Magnitude (m/s)	Monthly Average Ambient Temp. (°C)	% of time Q_a > 1,000 m^3/s (Unstratified Density Profile Possible [Fresh])	% of time Q_a < 1,000 m^3/s (Potential for Stratified Density Profile [Saline])
January	13.4	11.1	12.5	0.60	3.1	75.5%	24.5%
February	13.5	10.9	12.5	0.59	3.7	87.4%	12.6%
March	13.8	11.2	12.5	0.58	5.0	97.3%	2.7%
April	16.2	9.9	12.5	0.65	7.1	99.9%	0.1%
May	18.3	9.4	12.8	1.29	10.3	100%	0%
June	20.1	9.4	13.1	1.39	13.1	100%	0%
July	21.2	9.1	12.9	0.99	16.7	100%	0%
August	22.0	8.8	12.6	0.67	19.2	100%	0%
September	21.5	9.4	12.5	0.60	16.5	100%	0%
October	19.5	10.5	12.5	0.60	11.7	100%	0%
November	16.8	12.0	12.6	0.60	6.9	96.2%	3.8%
December	14.3	11.8	12.6	0.61	3.9	85.3%	14.7%

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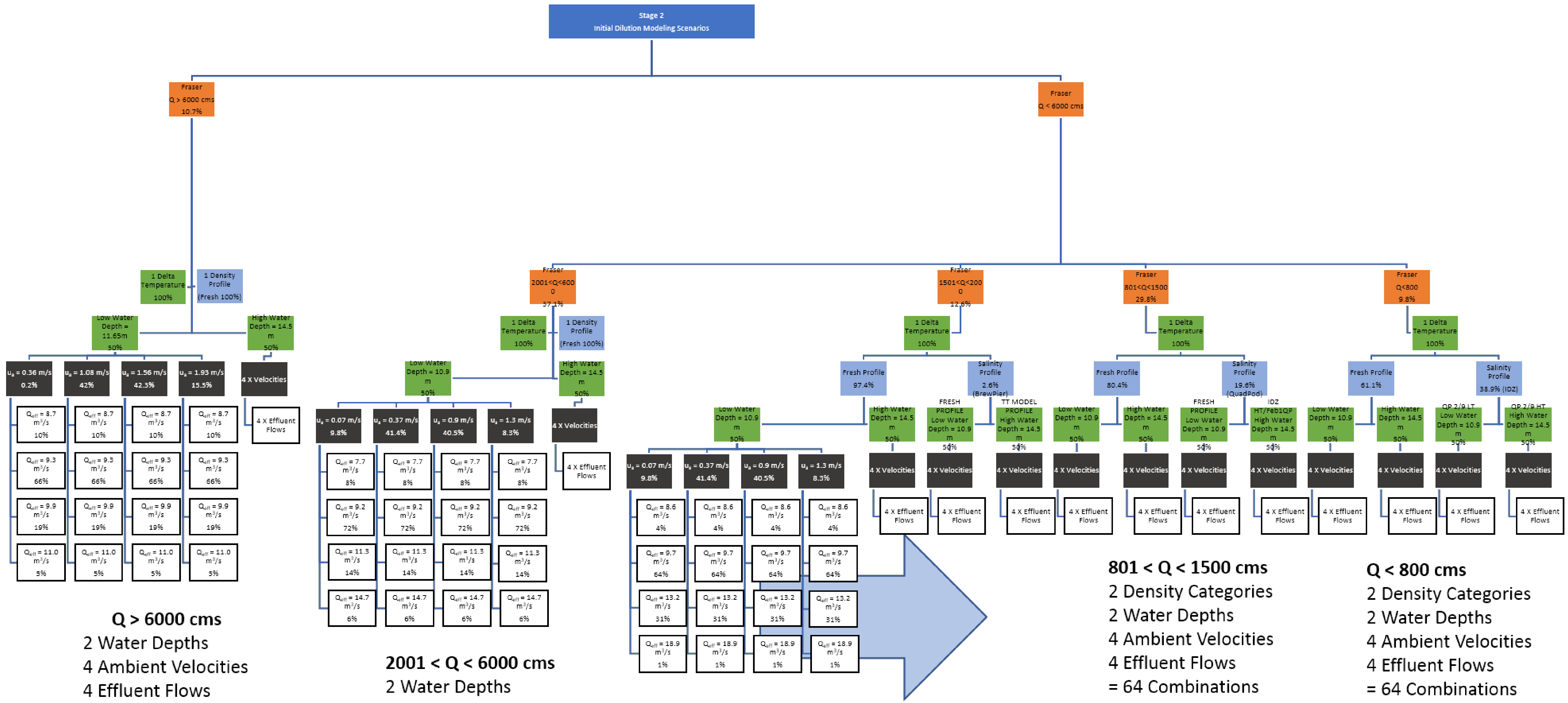

Q > 6000 cms
2 Water Depths
4 Ambient Velocities
4 Effluent Flows
= 32 Combinations

2001 < Q < 6000 cms
2 Water Depths
4 Ambient Velocities
4 Effluent Flows
= 32 Combinations

1501 < Q < 2000 cms
2 Density Categories
2 Water Depths
4 Ambient Velocities
4 Effluent Flows
= 64 Combinations

801 < Q < 1500 cms
2 Density Categories
2 Water Depths
4 Ambient Velocities
4 Effluent Flows
= 64 Combinations

Q < 800 cms
2 Density Categories
2 Water Depths
4 Ambient Velocities
4 Effluent Flows
= 64 Combinations

Figure 6-13. Schematic View of Initial Dilution Modelling Scenarios

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6.3.8 Additional Parameters for Ammonia Analysis

Because ammonia DQOs vary with temperature and pH, the near-field analysis used to predict IDZ concentrations for other parameters needed to be expanded to consider pH and alkalinity. Since several ammonia DQOs are assessed at the edge of the IDZ, the compliance assessment was performed with blended (ambient and effluent) temperature and pH values, which were calculated as a function of the predicted mixing of effluent and ambient waters.

To derive an edge-of-IDZ temperature, a weighted average of the ambient and effluent temperatures for each case was calculated using the dilution for each case as the weight for the ambient temperature.

To derive an edge-of-IDZ pH, the pH and alkalinity of both the ambient and effluent water had to be considered. Because the pH of effluent can be resistant to change due to carbonate buffering, a weighted average could not be used to calculate pH as it was temperature. The blend function in the water quality modelling software Water!Pro[4] was used to numerically calculate the equilibrium pH of the mixed effluent and ambient waters given inputs of ambient and effluent pH, temperature and alkalinity.

Ambient and effluent pH values with probabilities of occurrence were developed from available data. pH data from the Gravesend Buoy was used to derive ambient pH values while pH from effluent grab samples was used to derive effluent pH values. **Figure 6-14** shows the cumulative frequency distributions of ambient pH in the Fraser River for the five flow classifications and **Table 6-11** outlines the selected values and their probability of occurrence. Generally, pH values were selected as points of inflection along each curve and the percent of time of occurrence was assigned midway between the points of inflection. However, since unionized ammonia concentration is proportional to pH, the highest observed pH value in each flow classification was substituted for the highest point of inflection as a conservative practice.

Effluent pH values were chosen in the same manner as the ambient, but due to the relatively fewer recent measurements of grab pH data, CDFs were not generated for each flow classification. **Figure 6-14** shows the single CDF of effluent pH applied to all flow classifications and **Table 6-11** outlines the selected values and their probability of occurrence.

[4] http://schotteng.com/WaterPro%20Schott-1.htm

Table 6-11. Selected Effluent and Ambient pH Values

Ambient: Q<800 m^3/s			Ambient: 801<Q<1500 m^3/s			Ambient: 1501<Q<2000 m^3/s		
pH	Cumulative Probability	Percent of Time	pH	Cumulative Probability	Percent of Time	pH	Cumulative Probability	Percent of Time
7.41	6.5%	13%	7.32	2.5%	5.0%	7.44	8.0%	16.0%
7.61	46.5%	67%	7.56	40.0%	70.0%	7.73	55.5%	79.0%
7.85	88.0%	16%	7.83	86.0%	22.0%	8.10	100%	5.0%
8.16	100%	4%	8.20	100%	3.0%			

Ambient: 2001<Q<6000 m^3/s			Ambient: Q>6001 m^3/s			Effluent: All Flows		
pH	Cumulative Probability	Percent of Time	pH	Cumulative Probability	Percent of Time	pH	Cumulative Probability	Percent of Time
7.41	5.0%	10.0%	7.58	9.0%	18.0%	7.00	5.0%	10.0%
7.74	50.0%	80.0%	7.80	46.5%	57.0%	7.20	37.5%	55.0%
8.06	100%	10.0%	7.94	84.0%	18.0%	7.40	80.5%	31.0%
			8.07	100%	7.0%	7.80	100%	4.0%

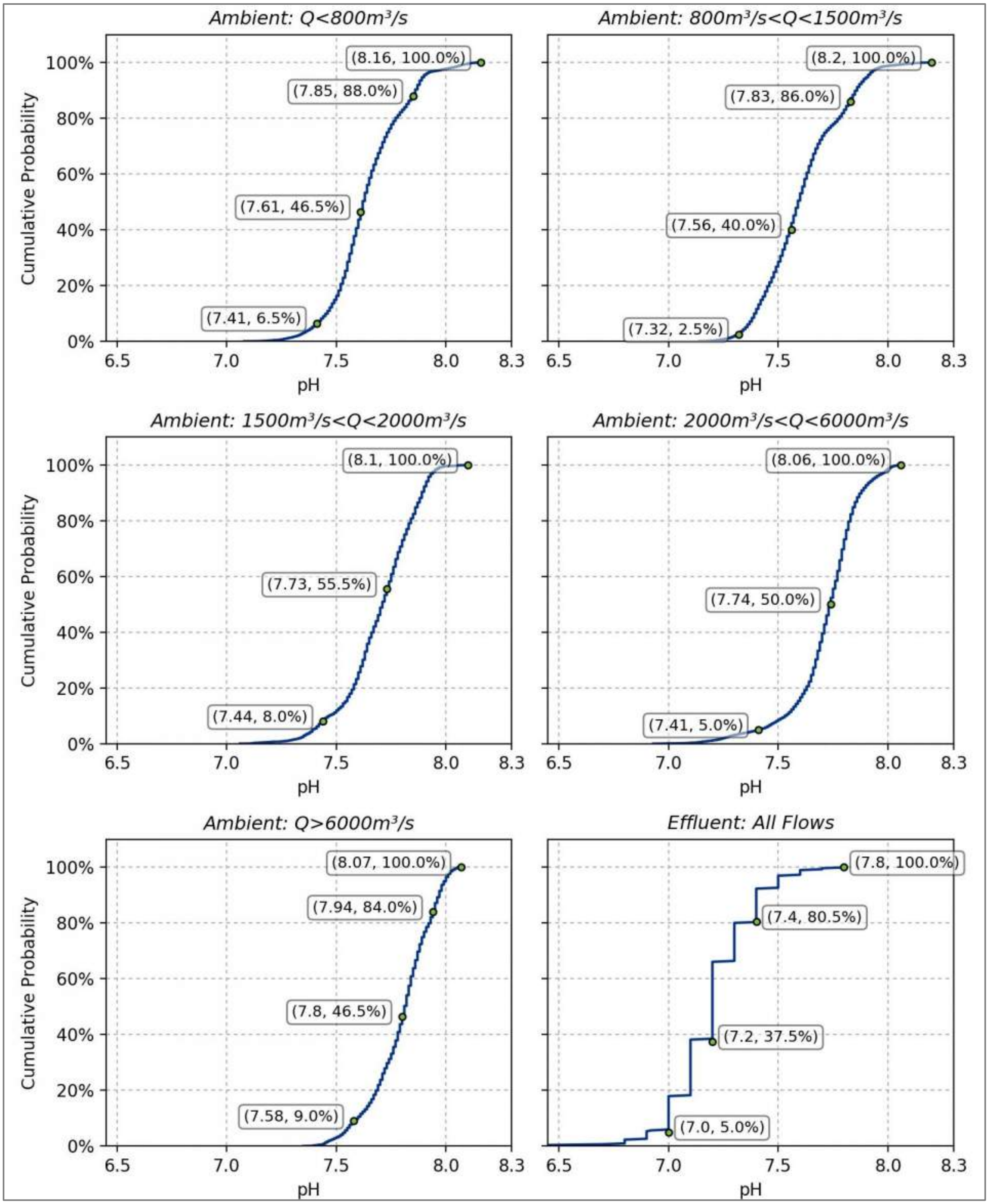

Figure 6-14. Cumulative Probabilities of Ambient and Effluent pH

Although pH is a component of alkalinity, it is a very small component; when effluent grab pH and alkalinity are compared on a scatter plot (**Figure 6-15**), little correlation is observed. Furthermore, coincident ambient pH and alkalinity data were unavailable, thus a correlation was indeterminable. Consequently, alkalinity values for the effluent and ambient water were selected independently of pH.

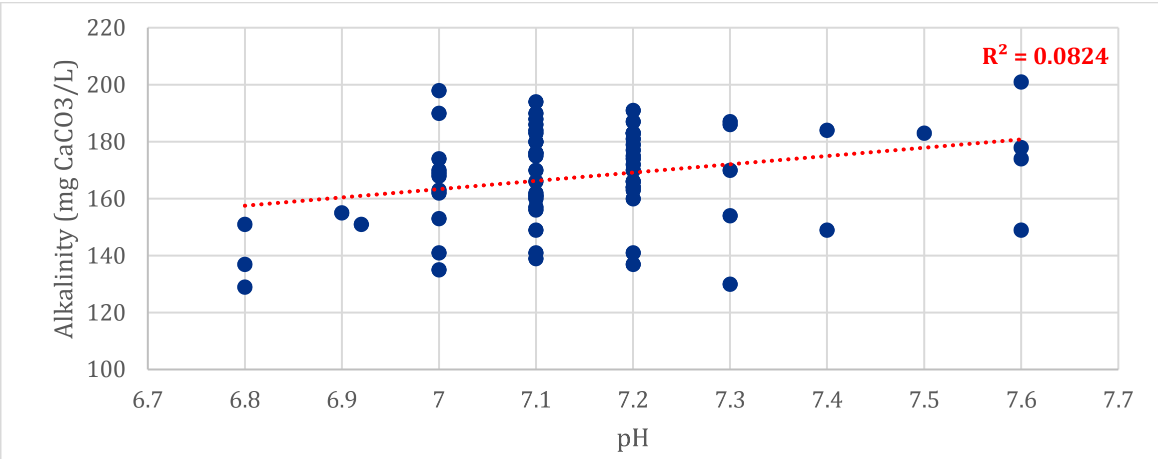

Figure 6-15. Scatter Plot of Coincident Effluent Grab pH vs Alkalinity

Representative alkalinities were selected as pH was, by selecting inflection point values on the CDF. Effluent alkalinity was found to vary little over the different flow regimes and thus regimes with similar alkalinity distributions were grouped generating two CDFs for, Q<2000 m^3/s and Q>2000 m^3/s. The CDFs are shown in **Figure 6-16,** the selected alkalinities for the effluent and their probability of occurrence are shown in **Table 6-12**.

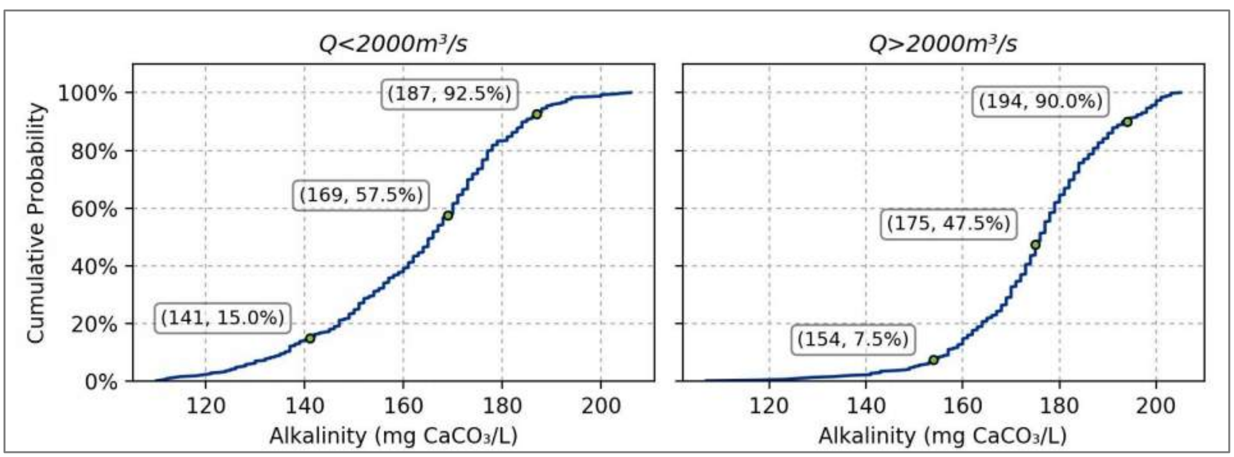

Figure 6-16. Cumulative Probabilities of Effluent Alkalinity

Table 6-12. Selected Effluent and Ambient Alkalinity Values

Effluent: Q<2000 m³/s			Effluent: Q>2000 m³/s			Ambient: All Flows		
Alkalinity (mg/L CaCO3)	Cumulative Probability	Percent of Time	Alkalinity (mg/L CaCO3)	Cumulative Probability	Percent of Time	Alkalinity (mg/L CaCO3)	Cumulative Probability	Percent of Time
141	15.0%	30.0%	154	7.5%	15.0%	34.7	12.5%	25.0%
169	57.5%	55.0%	175	47.5%	65.0%	42.8	57.5%	65.0%
187	92.5%	15.0%	194	90.0%	20.0%	49.5	95.0%	10.0%

Due to the paucity of ambient alkalinity data, only a single CDF was generated to represent all flow classifications. **Figure 6-17** shows the CDF and selected alkalinities for the ambient water. The values and their probability of occurrence are also shown in **Table 6-12**.

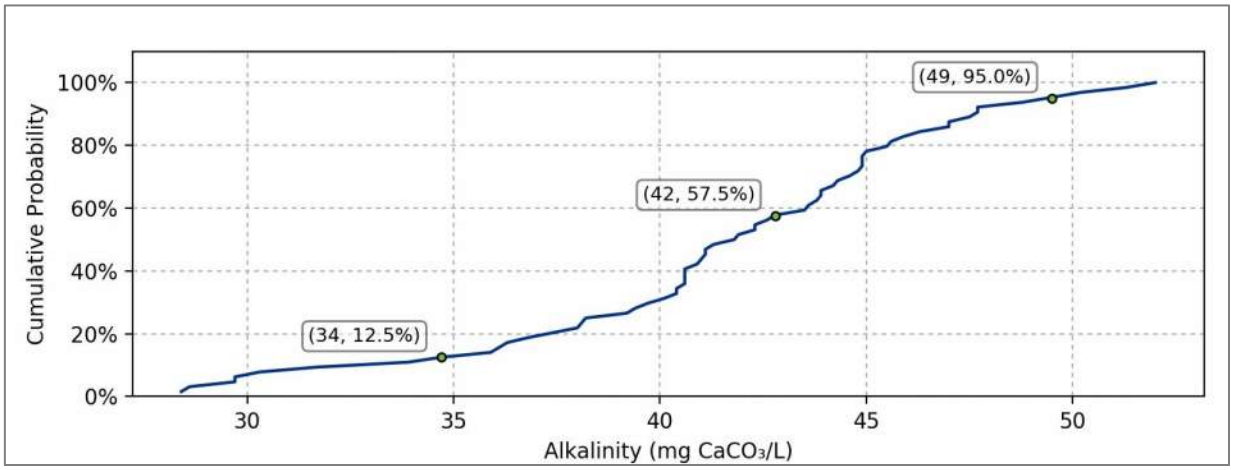

Figure 6-17. Cumulative Probabilities of Ambient Alkalinity

The ammonia analysis was completed using the 64 cases where effluent flow rate is 14.75 m^3/s (**Figure 6-13**), when combined with the additional possible pHs and alkalinities increases to a total of 835,200 cases as shown in **Figure 6-18**.

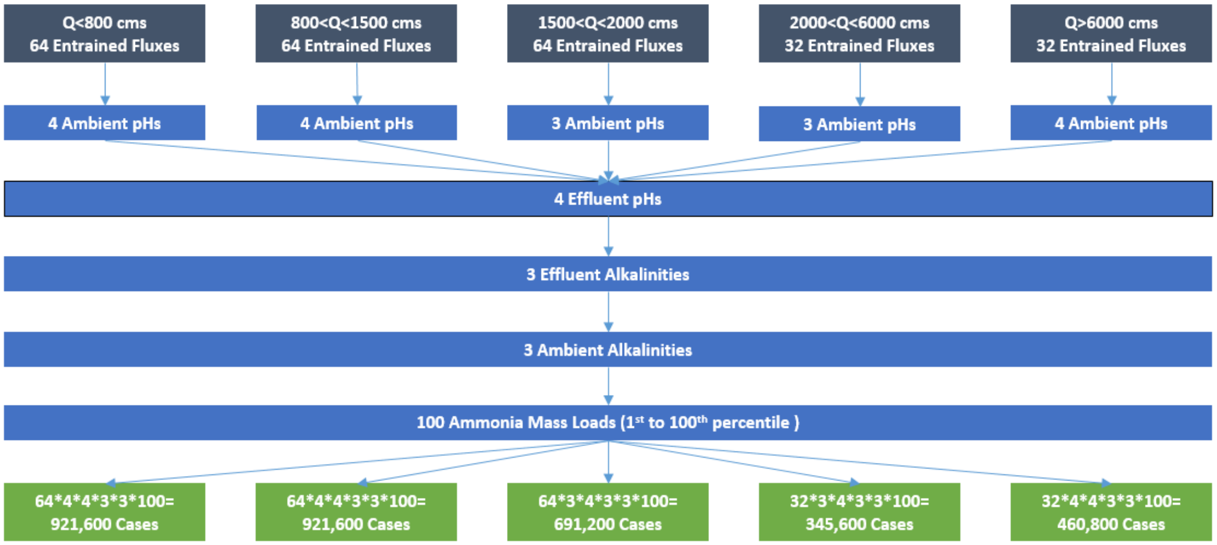

Figure 6-18. Expanded Cases for Ammonia Analysis

6.4 Far-Field Modelling Approach

The far-field modelling approach consists of two main elements: (1) defining the ambient concentrations for use in Equation 6 in Section 6.1, and (2) predicting effluent concentrations at points of interest beyond the IDZ boundary.

6.4.1 Ambient Background Concentrations

Ambient background concentrations are water quality data measured at a distance sufficiently upstream from the discharge to not be influenced by the discharge. Data representative of ambient background concentrations were compiled from available data and evaluated for relevance and data quality. The closest upstream station that describes ambient background conditions is the upstream reference area for Annacis' REM program (**Section 3.3**). Additional sources of ambient background data are the "upstream of Sapperton Bar" location of the Ambient Environmental Monitoring Program for the Fraser River (**Section 3.3.2**), and available federal-provincial monitoring data collected at Gravesend Reach (**Section 3.2**).

Because of its independence of any outfall characteristics, the ambient background concentration for a parameter would typically be characterized with a long-term average concentration at the boundary of the IDZ. In the Fraser River, however, sediment load varies significantly with season, and the increased sediment load results in increased concentrations for some parameters. For example, comparison of Fraser River flow to concentrations of both aluminum and iron shows a strong correlation between flow and metal concentration. Interestingly, the metal concentration rises with the beginning of the seasonal flow increase and peaks prior to the peak freshet flow. Therefore, the incorporation of ambient background concentration will need to account for this seasonal difference.

Figures 6-19 and **Figure 6-20** show the relationship between copper concentration and aluminum concentration, respectively, and flow at Hope. The strong correlation between copper and turbidity measured at Hope is evident in **Figure 6-21**.

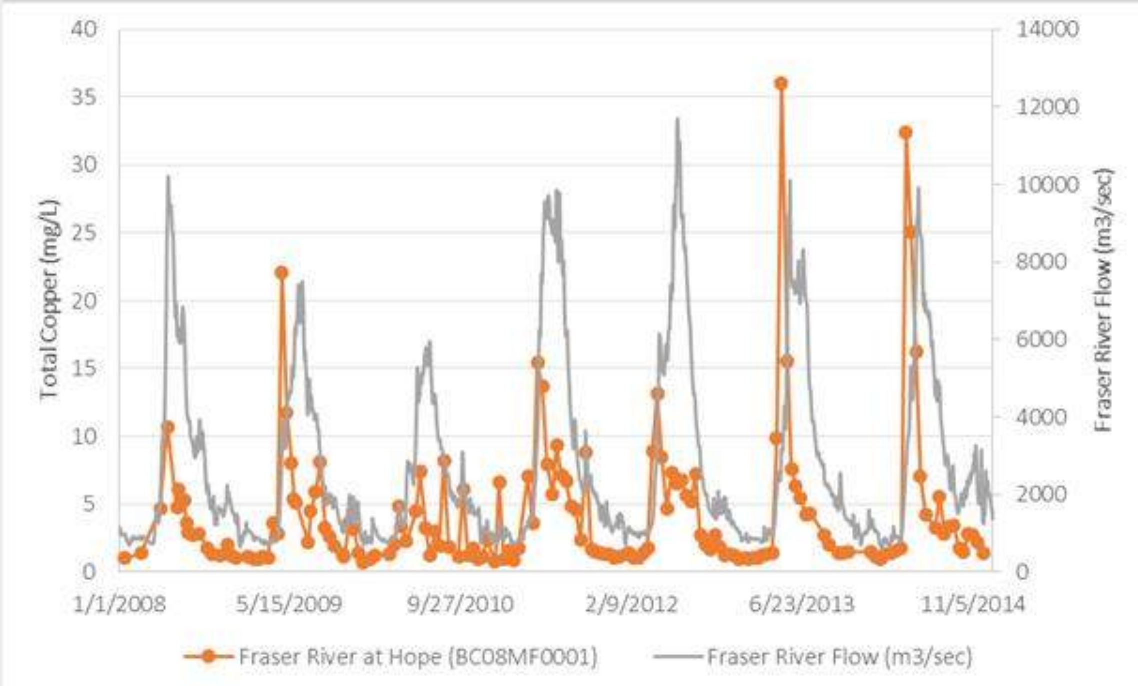

Figure 6-19. Time Series of Copper Concentration and Flow at Hope

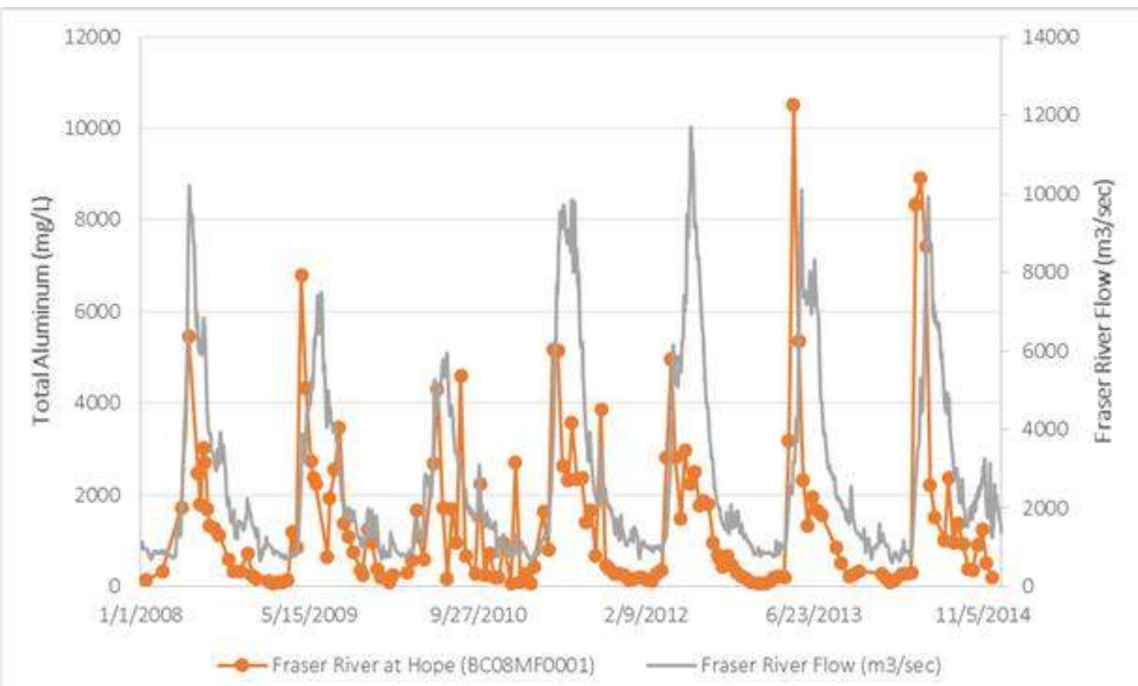

Figure 6-20. Time Series of Aluminum Concentration and Flow at Hope

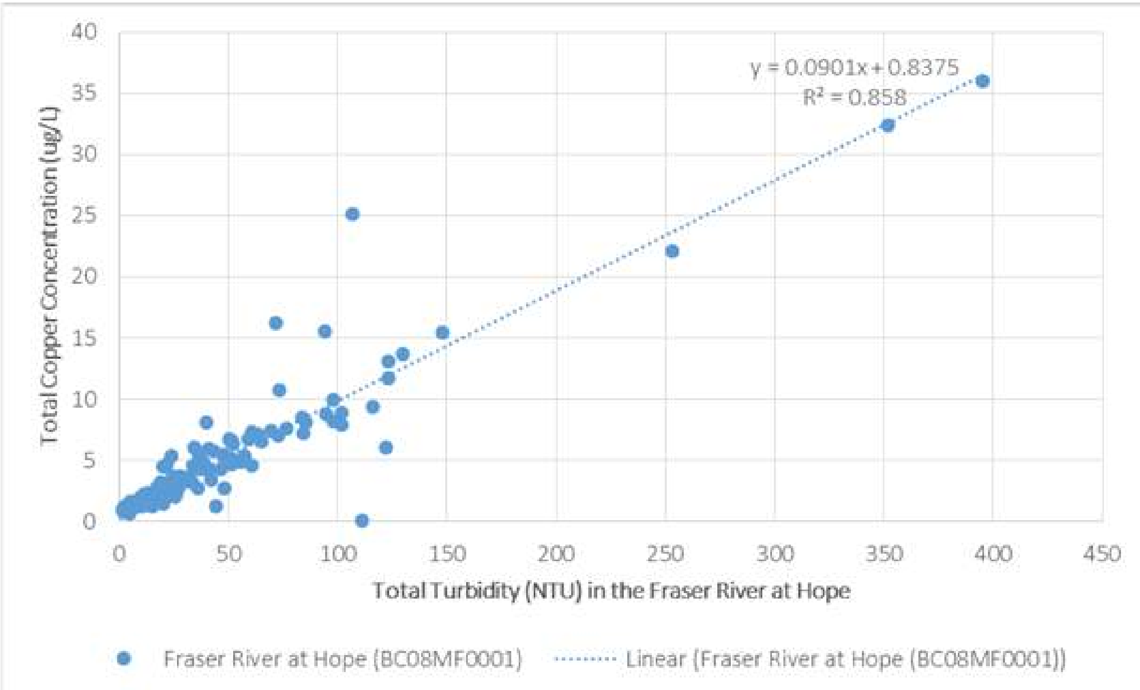

Figure 6-21. Correlation between Copper Concentration and Turbidity at Hope (2008-2014)

Golder Associates evaluated the ambient water quality data and performed the analysis to develop values of ambient background to be used in the predictions at the edge of the IDZ. The detailed approach is provided in the Stage 2 EIS Appendix B and describes the data and assumptions used to develop ambient background concentrations for the calculation of the predicted concentration at the edge of the IDZ. Individual ambient background concentration for each parameter are found in the Stage 2 EIS.

- The primary data set is the data from REM program's reference area stations. The REM data have been collected in February-March and September-October; data from 2012-2016 are used to coincide with the data period used for effluent characterization.
- As the REM program data are only collected when the Fraser River is at seasonal low flow, additional data is included to improve the year-round characterization of ambient background levels. Water quality data from Gravesend Reach fill this gap for nutrients, major ions and metals. Samples at Gravesend Reach collected from 2012-2016 will be used to augment the REM program data. (N.B.: Sapperton Bar data are not used because they also are collected at low flows, which are adequately characterized by the REM reference area).

6.4.2 H3D Hydrodynamic Model of the Lower Fraser River

CDM Smith Canada Ltd. contracted with TetraTech Canada Inc. to employ their existing hydrodynamic model H3D of the Lower Fraser River to assist with the following project goals:

- Predict a reasonable worse case salinity for use in hydraulic calculations to account for the need for additional head to discharge effluent when salt is present at the project site,

- Provide information on salinity at the project site to further aid in understanding its presence, magnitude and vertical profile, and
- Simulate the far-field mixing of AIWWTP effluent through a proposed diffuser to provide input into:
  - Background buildup that is part of the prediction of concentrations at the edge of the IDZ where background buildup represents typical tidal return flow concentrations for evaluating compliance with maximum (95th percentile) and 30-day average (calendar month average) water quality guidelines and objectives.
  - The Stage 2 EIS assessment of potential impacts from the discharge at identified far-field assessment nodes located outside the IDZ.

6.4.2.1 H3D Model Structure and Inputs

The details of the model's structure and setup for the AIWWTP application are described in **Attachment G**. Some key features of the H3D implementation are described below:

- Bathymetry – The model used bank-to-bank bathymetry from 2012.
- Model grid – A nominal grid of 50 m longitudinally (upstream-downstream) and 20 m laterally (across stream) was used. The model has nominal 1.5-m thick layers, resulting in 9-12 active layers in most locations in the model depending on the tide.
- Upstream boundary – River flow as recorded at Hope, augmented with Harrison River flows, were used as the upstream boundary condition.
- Downstream boundary – TetraTech's 1-km resolution Strait of Georgia-Juan de Fuca Strait model was used to establish the downstream boundary conditions using predictions for water level, temperature and salinity at Sands Head.
- Time step – A nominal 6-second timestep was used in the H3D model.
- Near-field Inputs – The initial dilution model UM3 was used at each timestep to represent the location of the end of the initial mixing for each of the 18 diffuser ports. The diffuser configuration is as shown in **Figure 5-4**. The mass, temperature and salinity associated with the discharge at the compliance flow (2xADWF of 14.75 m^3/s, which was held constant through the year-long simulation) from an individual port for the time step was then added to the appropriate grid cell in H3D.
- Parameter type – Both a conservative and first-order decay parameter were simulated. The first-order decay parameter used a US EPA algorithm to represent the decay of bacteria in ambient waters.

The near-field to far-field coupling described above has limitations. To date, no single hydrodynamic model has been able to simultaneously represent the turbulence of the initial mixing process as well as the general, large-scale circulation typifying the receiving environment. Consequently, various model approximations are required to provide a practical estimate of the performance of a new diffuser. In this case, the near-field model, UM3, does not function well when limited by the proximity to the bottom or water surface; that is its numerically-modelled plume diameter expands faster than it would in the real world. In the real world, and if the plume were not restrained by top and bottom boundaries, the plume diameter would grow at a rate governed by entrainment processes and by the plume diameter, which determines the area available for entrainment. Since the UM3 implementation in H3D does not adjust the amount of surface available for entrainment, allowing it to be overestimated, the plume acquires the ambient velocity quicker that it would in the real world. Thus, the UM3 plume does not travel as far before it releases its effluent to the H3D model as it would in reality, likely leading to higher modelled concentrations of effluent. For this reason, effluent momentum (**Figure 6-2**) may continue across the river farther than UM3 simulates, particularly when ambient currents are low. The boundary issues in UM3 are implemented in the H3D model coupling by only using UM3 to determine the location to insert mass into the three-dimensional model and thus constraining the modelled plume expansion, as discussed above. The overestimate of effluent concentration will be greatest when ambient velocities are small, such as at low flow, high tide slack conditions. The UM3-H3D coupling provides reasonable results at distance from the diffuser (as one would expect from a far-field model), but likely represents higher concentrations than are present at certain low velocity tidal conditions both within the IDZ (where far-field models are not representative) and the region immediately adjacent to it.

6.4.2.2 H3D Results: Maximum Salinity

The H3D model was run for a winter (January into April) of the lowest flow at Hope ever recorded on that date to simulate worst case salinity intrusion at the project site. The simulation was run without input from the AIWWTP as the goal was to characterize native river salinity.

The results of the simulation were examined several ways (e.g., maximum vertical change in salinity, highest bottom salinity, highest top salinity, etc.) to select a worst-case salinity profile from which the excess hydrostatic head differential would be calculated in the hydraulic analysis of the diffuser (**Section 5.4**); integrated across the water column, the salinity averaged 15 ppt. As a worst case it is reasonable to do this because during the winter it is possible for the highest plant flows to coincide with the most difficult ambient conditions to discharge effluent (i.e., the river is at its design elevation accompanied by a maximal salinity extent due to wind driven flooding). The model predicted a worst case salinity in the bottom water at the point of discharge of 24.7 ppt.

6.4.2.3 H3D Results: Background Buildup

The background buildup concentration is associated with the presence of previously diluted effluent within the Fraser River because of the tidal processes in the Fraser River. The background buildup concentration can be considered as a steady-state average process wherein re-entrainment of previously discharge effluent occurs after tidally reversing currents over many cycles. For the AIWWTP discharge, background buildup only needs to be considered when the currents at the site are bidirectional.

The *Annacis Island Wastewater Treatment Plant Pre-Discharge Monitoring Dilution/Dispersion Study* (LWMP Environmental Monitoring and Assessments Technical Committee, 1997) provides a description of the mixing processes at the existing outfall based on analysis of a dye study conducted in the mid-1990s; the mixing processes were found to vary with river velocity. When currents were moderate to high (e.g., flood/ebb periods of tidal cycle), the effluent rapidly dispersed due to jet velocity and (temperature-driven only) buoyancy. Then vertical diffusivity mixed the effluent field over the entire vertical section. When there was little current (e.g., slack tide periods), the effluent field rose rapidly to the surface, where it spread slowly incorporating additional dilution through gravitational spreading. Residual current (the net downstream flow when tides are removed) carried the effluent field away from the discharge point. At the lower current velocities, the study concludes "there is little or no opportunity for previously discharged, diluted effluent to be re-entrained in the forming effluent field. The effect of multiple dosing thus is not significant." The study does not provide a conclusion about the effect of multiple dosings during moderate and high currents.

Previous initial dilution studies of the AIWWTP discharge accounted for background buildup either through using CORMIX's tidal reversal conditions to account for transient recirculation and re-entrainment of the discharge plume remaining from the previous tidal cycle (Seaconsult, 1995) or using a far-field model (RMA) to obtain a 14-day average of the background buildup (Black and Veatch, 2015).

The present study includes consideration of background buildup for the following reasons.

- Dye study data confirm that the effluent field can be found throughout the water column, which will be located upriver of the outfall during flooding tides; thus, the return flow during ebbing tide has the potential to return a portion of the effluent field in the entrainment water used for dilution during ebbing tides.
- The diffuser design being evaluated discharges horizontally and not vertically, and this will result in altered mixing dynamics versus that observed in the dye study; horizontally discharging ports improve instantaneous dilution over vertical ports, and should minimize, if not avoid, the expression of the rising plume as boils on the river's surface. Further, the singular direction of the ports will push the plume to the middle of the river and the river flow being entrained into newly discharging effluent will come from behind the diffuser.

The presence of background buildup in the Fraser River will reduce the available potential dilution at the edge of the IDZ.

Using the results of the year-long simulation of the H3D model, a depth-averaged, year-long time history of dilution is calculated for a conservative contaminant assuming a constant effluent flow of 14.75 m^3/s. The dilution timeseries is based on an H3D model node located approximately in the center of the Fraser River and 1 km downstream of the proposed diffuser location. Based on initial model test runs, this distance seemed adequate in allowing for far-field processes to mix the plume without any direct impact of near-field processes from the coupling location of the near-field to far-field model, but was close enough to the proposed diffuser location that the plume could wash back over itself near the diffuser during periods of reversing tidal conditions.

A CFD of the depth-averaged dilution was developed, and the 5% exceedance value was selected to represent the risk of background buildup for maximum WQGs (**Figure 6-22**). The 5% exceedance background buildup dilution is approximately 58:1. This background buildup dilution will be used for WQGs with short-term endpoints. Background buildup concentrations are only considered when bidirectional flow in the Fraser River flow exists (i.e., when $Q_a < 6,000$ m^3/s).

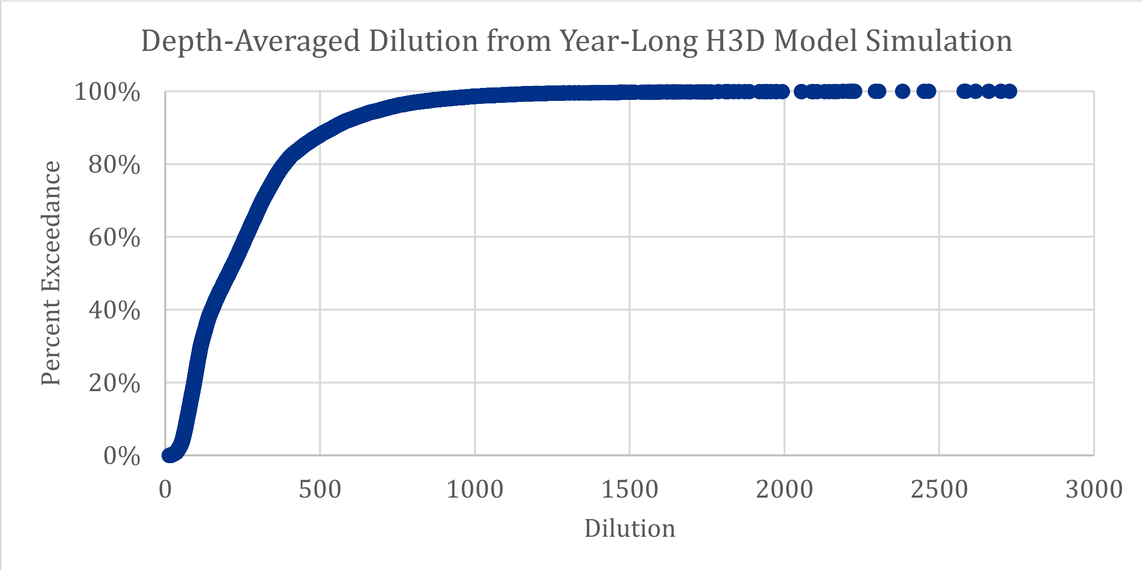

Figure 6-22. Cumulative Frequency Distribution of Background Buildup Dilution

For long-term average endpoints, a CFD was developed for each of the monthly instantaneous background buildup dilutions at the same H3D model node, and the 50% exceedance value was used to develop estimates of background buildup monthly and listed in **Table 6-13**. This background buildup dilution is used for WQGs with long-term average endpoints.

Table 6-13. Monthly Background Buildup Dilution for Use in Long-Term Assessments

Month	Monthly Average Background Buildup Dilution
January	160
February	137
March	158
April	317
May	772
June	932
July	726
August	354
September	277
October	244
November	191
December	175

6.4.2.4 H3D Results: Concentrations at Far-Field Assessment Nodes

The H3D model was used to predict concentrations of effluent COPCs at five far-field assessment nodes in the project study site (**Figure 6-23**). From the year-long H3D simulation, time histories were developed at these locations for every model layer at a 15-minute step. Using a unit concentration at the discharge point, to determine short-term effects, a water column average, 24-hour daily average timeseries was developed for each node. The 5th percentile dilution was

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calculated for a conservative and non-conservative pollutant. To determine long-term effects, a water column average, calendar monthly average timeseries was also developed for both types of pollutants at each of the nodes of interest. This information was provided to Golder Associates for use in the Stage 2 EIS analysis.

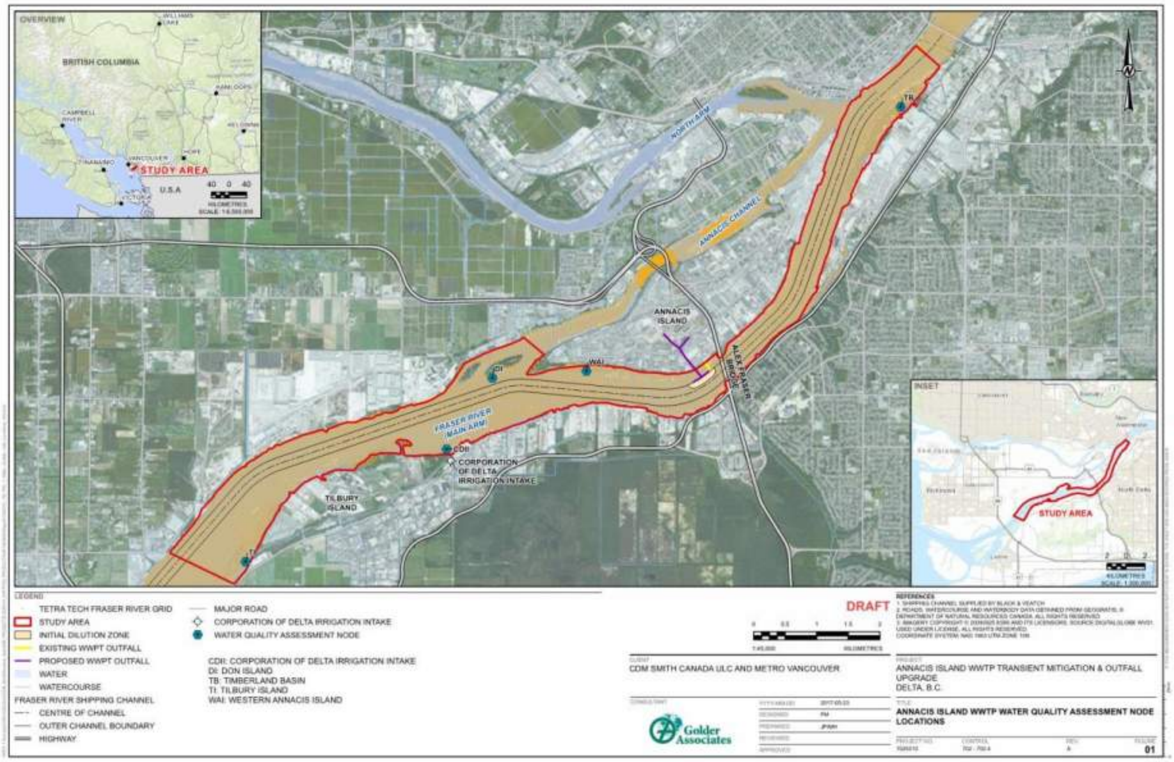

Figure 6-23. Far-field Assessment Nodes Receptor Locations in the Project Study Site

6.4.2.5 H3D Results: Behavior of the Effluent Plume in the Far Field

In addition to evaluating concentrations at far-field assessment nodes, concentrations and corresponding dilutions at cross-river transects near the discharge location were created to show the transport of the effluent in the Fraser River throughout a year. **Figure 6-24** is an example of the H3D model output in plan and section view during unidirectional flow conditions with no salinity present at the site. The panels show velocity vectors, a dark blue line marking the location of the proposed diffuser, and the plume represented as a function of dilution. On the plan view, an oval representing 100-m distance from the diffuser is shown, as well as the existing diffuser in red.

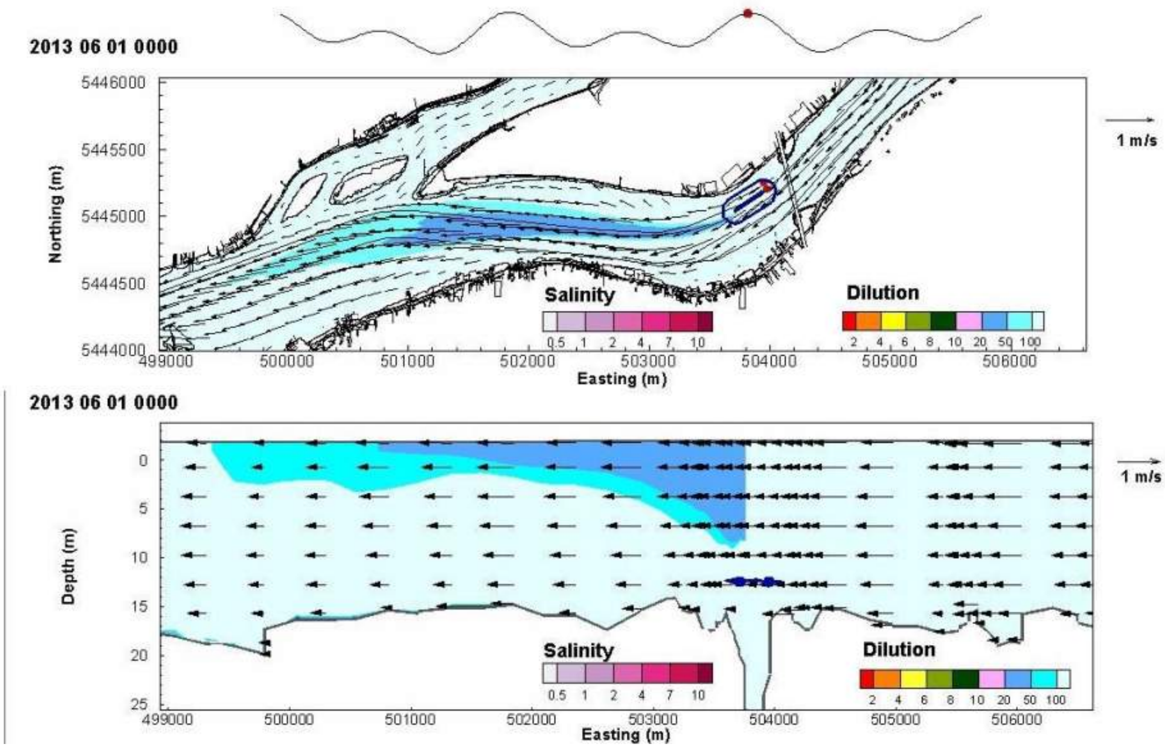

Figure 6-24. Example of H3D Model Output
Top: Plan View, Bottom: Cross Section

Figure 6-25 depicts the transect locations where data are displayed, and they are located relative to the ends of the diffuser 200 m upstream, 200 m downstream, 500 m downstream and 1,000 m downstream.

The model data was processed for different timeframes: water column average hourly, running 24-hour average, and running 30-day average. The data was processed by taking the water column average concentration over either an hour, 24-hours, or 30-days for each model node (purple dots in **Figure 6-25**, which were spaced nominally at 20 m), and then the maximum value along the transect was selected for data display. **Figures 6-26** through **6-28** shows the maximum value for the appropriate time averaging period (hourly, 24-hour and 30-day, respectively), along with the Fraser River flow at Hope for 2013, and the lines representing a 10:1 and 20:1 dilution of the effluent.

Each figure depicts the time history for all four transect locations. Salient observations on this analysis include:

- On a 24-hour and 30-day moving average basis, the maximum water column concentration along the transects always corresponded to a dilution greater than 25:1 and 35:1, respectively. These time frames match those used for the compliance assessment of water quality objectives and guidelines used in the Stage 2 EIS.
- Across all the simulated 2013 year, there were 16 instances when the maximum hourly concentration along one of the four transects had a corresponding dilution less than 10:1. Typically these are single hour spikes and suggest fleeting high concentrations, mostly likely associated with a strong tidal asymmetry. Nearly all occur at transect 597 located

200 m downstream of the downstream end of the diffuser. As discussed in **Section 6.4.2.1**, the coupling of the UM3-H3D model can yield less dilution than occurs in the intermediate region outside the IDZ, and this numerical process conservatism cannot be discounted here.

- As is expected, hourly concentrations drop significantly during freshet, when flow in the river is unidirectional and higher flows create greater mixing.

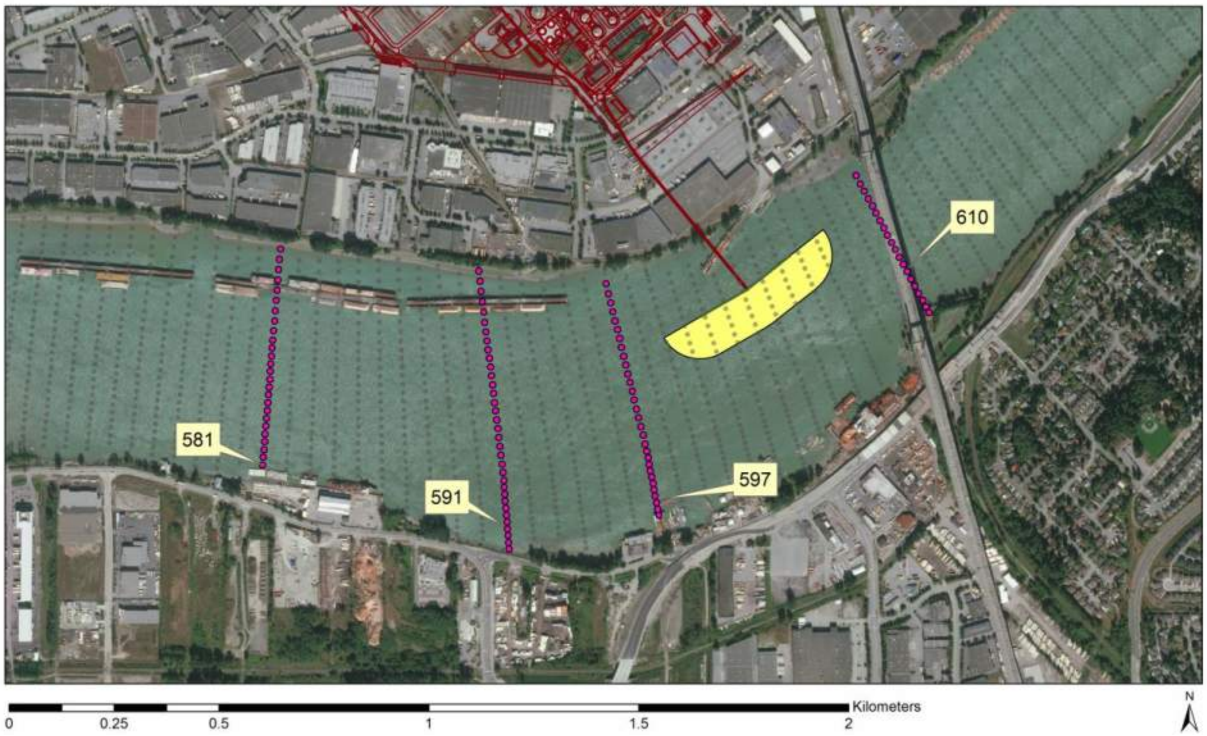

Figure 6-25. Transect Locations in H3D Model Grid

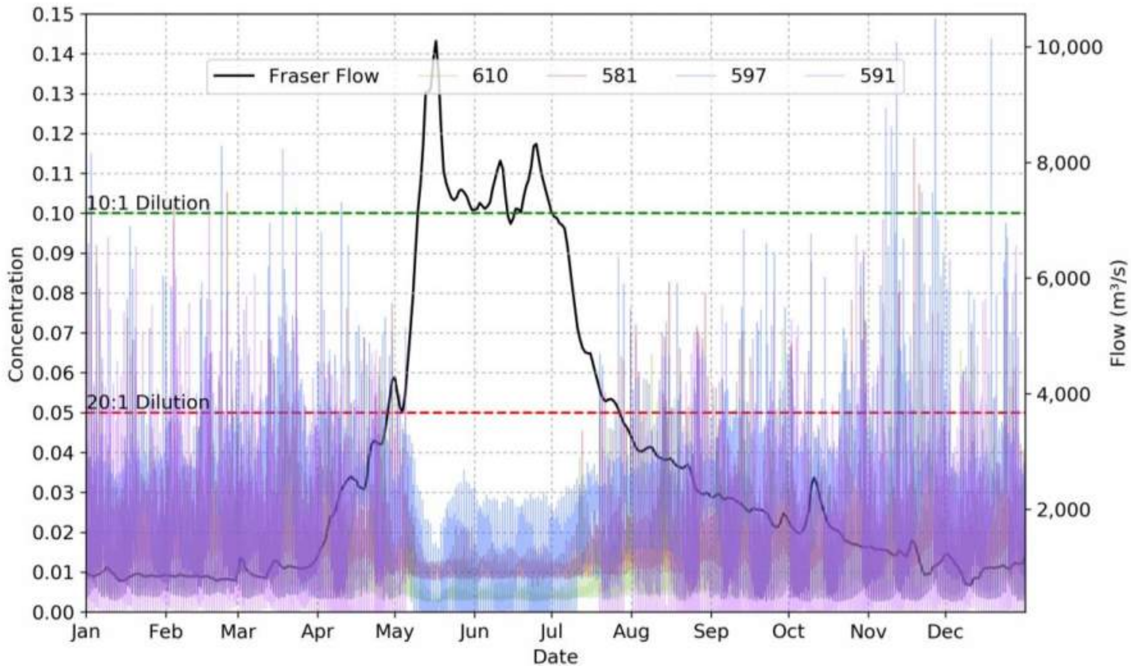

Figure 6-26. Maximum Water Column Average Concentration

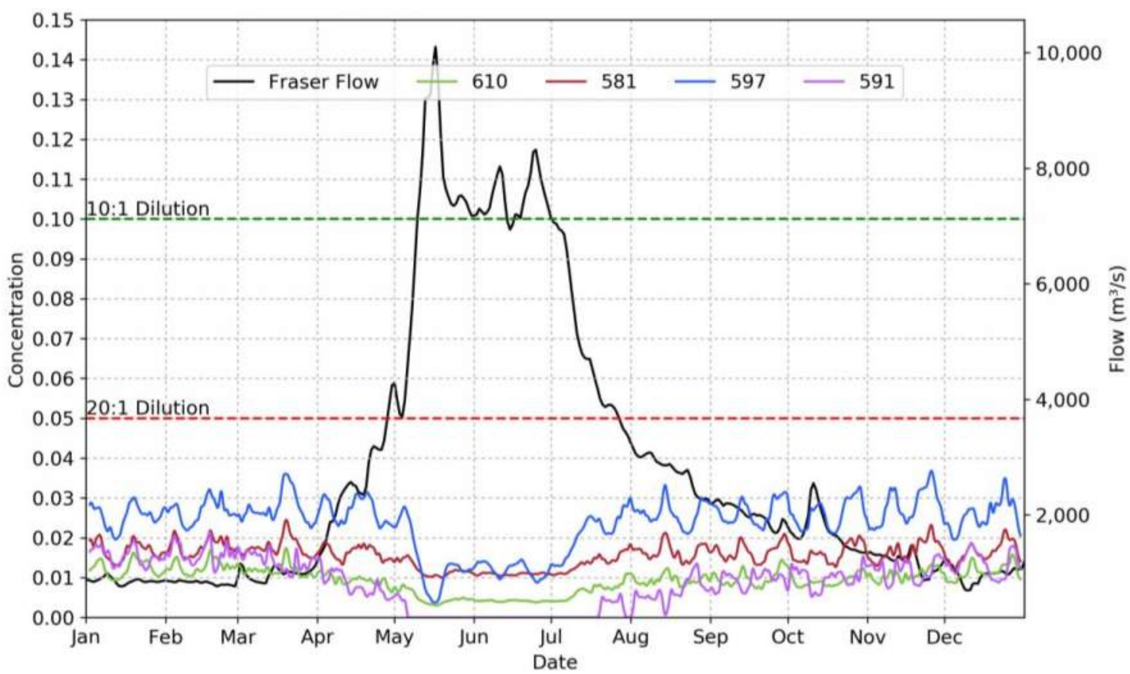

Figure 6-27. 24-hour Moving Average of Maximum Water Column Average Concentration

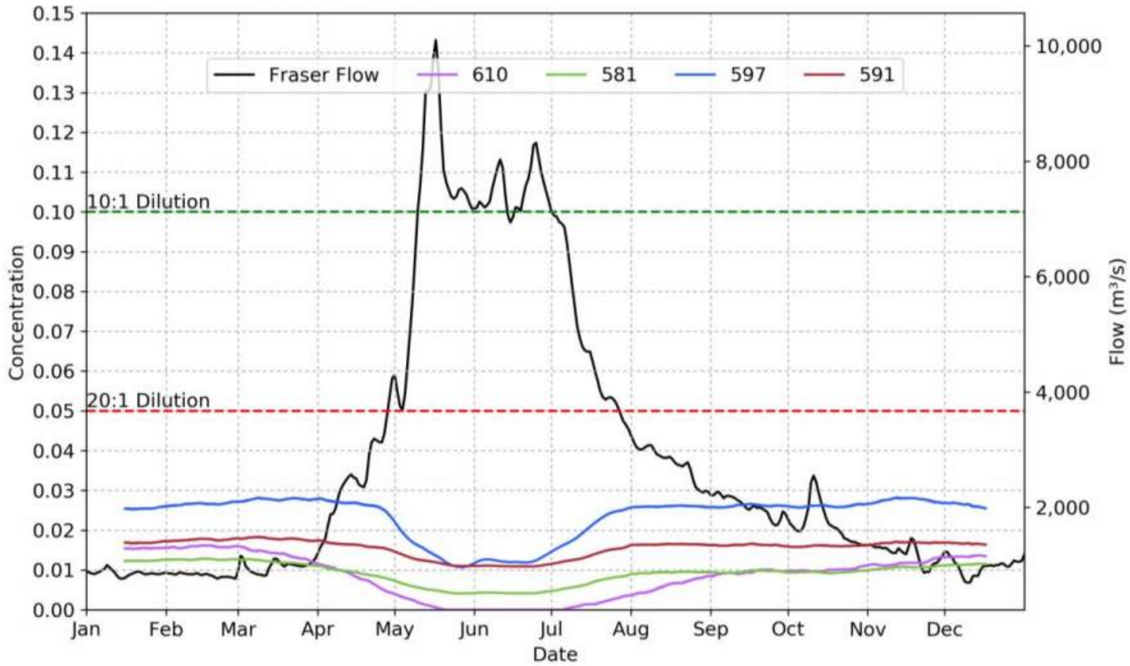

Figure 6-28. 30-day Moving Average of Maximum Water Column Average Concentration

Instances of hourly water column averaged dilutions less than 10:1 were identified across the model grid. **Figure 6-29** shows a map of the model grid and highlights all nodes with hourly dilution less than 10:1 and the percent occurrence in the 2013 simulation. The same analysis was performed on a 24-hour average basis. Hourly depth averaged model results were averaged over a 24-hour period; no instances of dilution less than 10:1 were found in the resulting dataset (**Figure 6-30**). The results shown in **Figure 6-30** suggest that dilutions less than 10:1 are fleeting not only at the transects discussed above, but also at all nodes in the model grid.

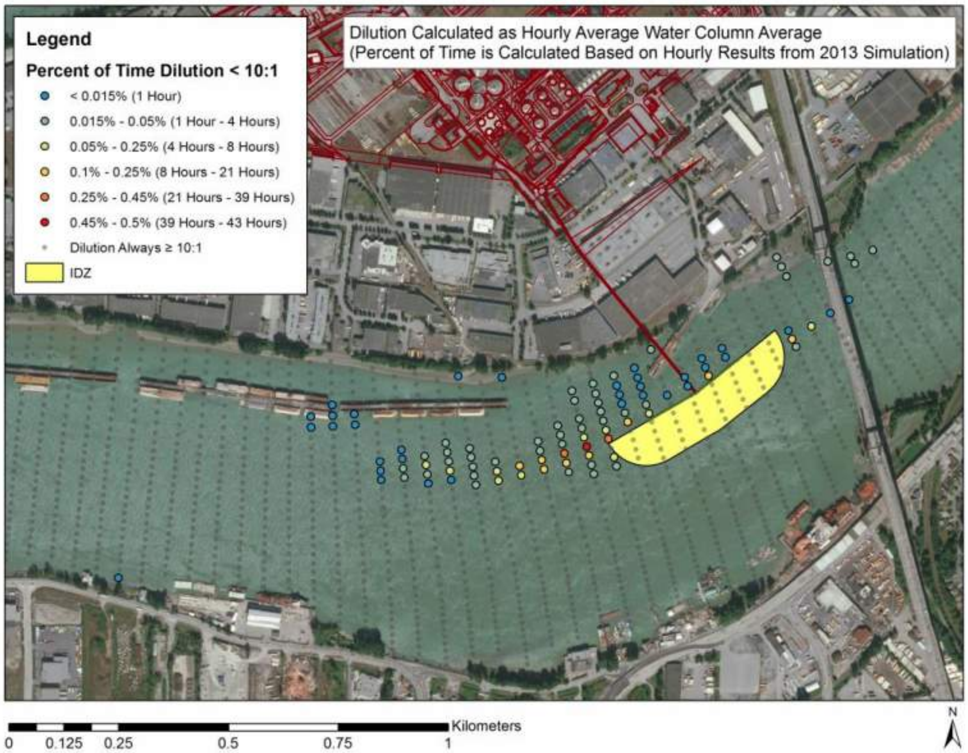

Figure 6-29. Nodes with Hourly Water Column Average Dilution Less Than 10:1

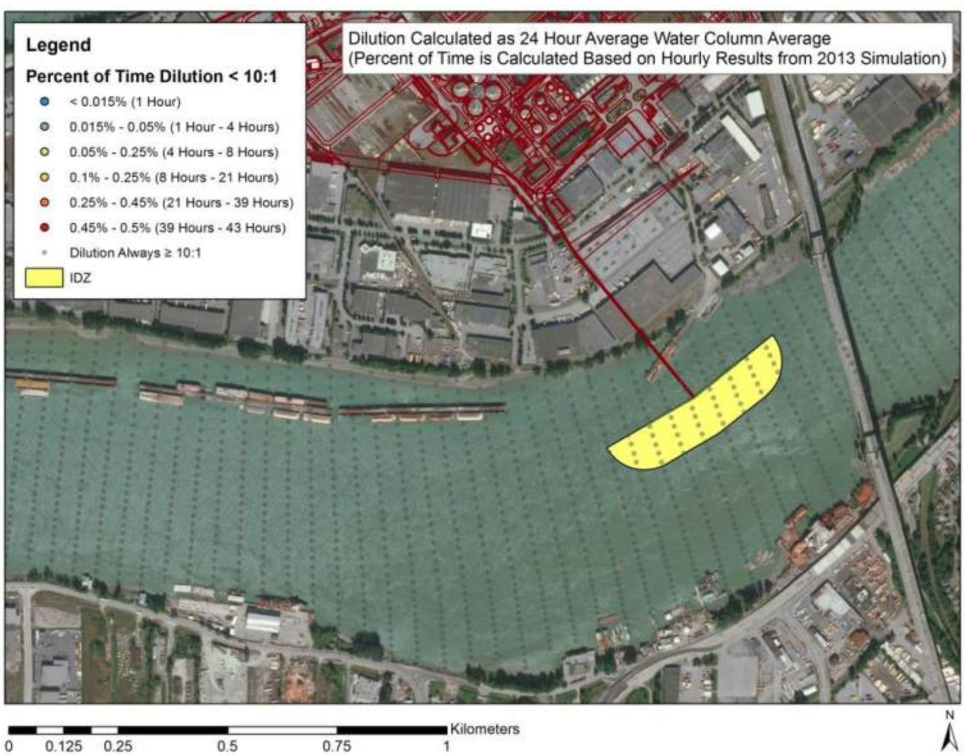

Figure 6-30. Nodes With 24-hour Average, Water Column Average Dilution Less Than 10:1

Section 7

Initial Dilution Prediction Results

This section presents the results of initial dilution results for the proposed diffuser design: a 240-m long diffuser with the variable diameter orifice at three effluent flow groups:

- The two times average dry weather flow (14.75 m^3/s), referred to as the compliance flow,
- Variable effluent flow ranges from 7.74 to 18.9 m^3/s for Stage V, and 25.3 m^3/s for Stage VIII, and
- Average monthly effluent flow rates at Stage V ranging from 9.1 to 12.0 m^3/s.

Results are presented in terms of cumulative frequencies of dilution and monthly average dilution for the recommended alternative. These results are then used with effluent and ambient background data to make predictions of concentrations at the edge of the IDZ.

7.1 Approach to Determining the Initial Dilution Ratio

The final concept diffuser design, as described in **Section 5**, is the physical configuration used to predict dilution using the Shrivastava-Adams equations for unstratified conditions and the initial dilution in CORMIX for stratified conditions. To assess the potential critical combinations of these input variables, a probabilistic approach was used.

Each combination of input parameters results in a probability of occurrence of initial dilution that is the product of the probabilities of each of the input parameters (percent of time Q_a occurs, percent of time current speed occurs, percent of time depth occurs, etc.). Predictions are used to define the initial dilution at the edge of the IDZ, which are assigned the joint probability of the model input parameters.

The results of dilution predictions for the compliance flow (14.75 m^3/s) and variable effluent flows (up to 18.9 m^3/s for Stage V) are listed in tables in **Attachment H.** Modeled assumptions included a Tideflex diffuser valve, which allows for a variable orifice size under different effluent flow conditions to increase diffuser port exit velocities. The 64 runs at the compliance flow are shown on page H-3, and the 256 runs with various effluent flow rates are presented on pages H-4 through H-8. The table provides the dilution for each combination of ambient Fraser River flow rate, ambient Fraser River current, depth at discharge, predicted future effluent flow rate, and density profile. Note that each combination of parameters is assumed to occur independently of the others, resulting in a probability of occurrence of each prediction that is the product of the probabilities of each of the input parameters. For example, there is a 9.8% chance of the Fraser River flow being less than 800 m^3/s, and there is an 9.8% chance that Fraser River velocities are 0.07 m/s, there is a 50% chance that the depth at discharge is 14.5 m, and there is a 4% chance that the future effluent flow is 8.65 m^3/s, and a 38.9% chance that salinity is present in the water column. Therefore, the probability of occurrence of the resulting dilution is 0.007% (0.098*0.098*0.5*0.04*0.389). In this manner, the probabilities of each of prediction was calculated. This method was applied to provide predicted dilution for assessing potential impacts for WQGs with short-term toxicity endpoints. A different approach was made when determining the probability of occurrence for parameters with long-term endpoints (see **Section 7.3)**.

7.2 Predicted Instantaneous Dilution at the Compliance Flow Rate (2xADWF)

7.2.1 Result of Initial Dilution Modelling

The flux-average dilutions at the edge of the IDZ for simulations at the compliance flow rate are listed on page H-3 of Attachment H, and are plotted against ambient current are shown in **Figure 7-1**. The figure shows that dilutions range from 12.8:1 to 42.4:1. The apparent matched pair data at the same ambient current are the simulations representing low and high water (with high water resulting in greater dilution).

As expected, the lowest dilutions occur at the lowest ambient velocity, and increase with increasing velocity. Also, as expected, dilutions are lower when the Fraser River is stratified, though this occurs infrequently and represent only 10% percent of the period simulated.

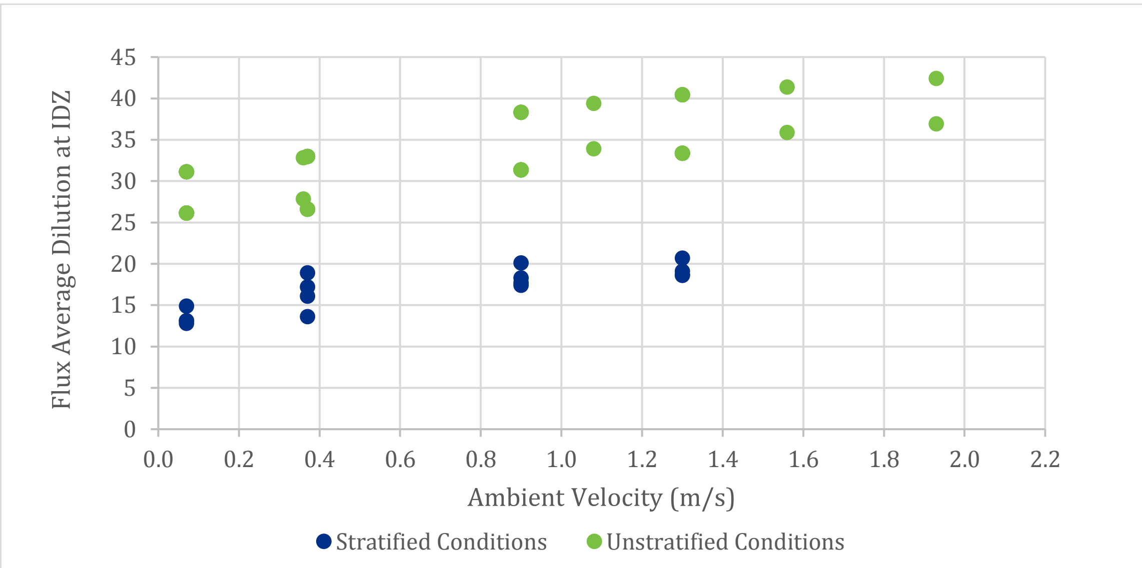

Figure 7-1. Comparison of Stratified vs. Unstratified Flux Average Dilutions at the Edge of the IDZ

7.2.2 Cumulative Frequency Dilution Results

Figure 7-2 shows the cumulative frequency distribution of flux-averaged initial dilutions resulting from the predictions at the compliance flow of two times the future average dry weather flow (14.75 m^3/s). **Attachment H** is a summary table of the primary model inputs, assigned probabilities, and initial dilution results. The cumulative frequency distribution, based on results from page H-3, indicates that predicted instantaneous flux-averaged dilution at the IDZ boundary ranges from 12.8:1 to 42.4:1. The 5th percentile dilution is calculated for each flow classification and is used to the instantaneous contribution to the evaluation of short-term water quality criteria. The 5th percentile dilution for the low flow class (less than 800 m^3/s) is 13.5:1. The predicted dilutions for the flow classes between 800 and 6,000 m^3/s are combined to represent moderate flows, and the high flow condition is represented as the greater than 6,000 m^3/s. The predicted dilution at the compliance flow is used for the predictions of individual constituents and the impact of the effluent at the edge of the IDZ.

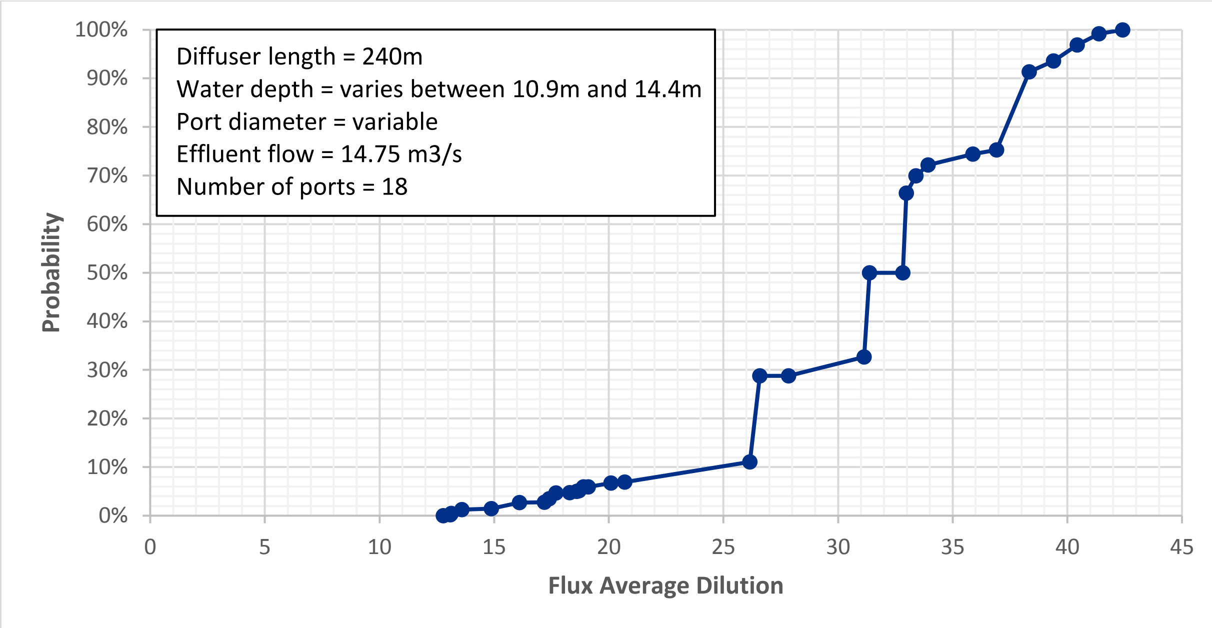

Figure 7-2. Cumulative Frequency Distribution of Predicted Instantaneous Dilution at the IDZ

Predicted dilution is always greater than 10:1, but is less than 20:1 about 6% of the time, which represents a fraction of the 64 cases simulated. The lowest values occur when low river current is combined with the presence of a salt wedge, which traps the plume in the bottom layer of the river. Most of the cases with dilution less than 20:1 occur at lower river current speeds, recognizing the impact of the square of the current speed in the momentum ratio. A few cases occur when the effluent flow and port velocity are high and this momentum from the diffuser (denominator of m_r) is about equal to the momentum in the river (numerator of m_r); in these instances, the updated Shrivastava-Adams equation notes the largest negative impact on dilution compared to dilution for the same input parameters at no current (the ratio of S_t/S_o).

7.2.3 Predicted Monthly Model Dilution at the Compliance Flow Rate

Table 7-1 summarizes the 18 monthly, flux-averaged initial dilutions at the IDZ for the compliance flow rate, using average monthly ambient conditions and the Shrivastava-Adams equation for unstratified conditions and CORMIX results for stratified conditions. The percentage of time salinity is present was applied to develop the monthly probability weighted flux average initial dilution.

The results in **Table 7-1** indicate that across the months, there is limited variability in dilution because dilution in unstratified flow cases varies little and that the major difference in the probability weighted flux-averaged dilution is because of the seasonal presence of salinity.

Figure 7-3 shows the predicted average monthly, flux-averaged initial dilutions at IDZ at the compliance flow rate for use in long-term criteria.

Table 7-1. Predicted Monthly Flux-Averaged Dilutions at the Compliance Flow Rate

Month	Flux- Averaged Initial Dilution for an Unstratified Density Profile (Fresh)	Flux-Averaged Initial Dilution for a Stratified Density Profile (Saline)	Percent of Time Salinity is not Present (Fresh)	Percent of Time Salinity is Present Based on H3D Model (Saline)	Predicted Monthly Flux-Averaged Initial Dilution @2xADWF
January	32.1	16.8	75.5%	24.5%	28.4
February	31.9	16.7	87.4%	12.6%	30.0
March	31.8	16.6	97.3%	2.7%	31.4
April	32.2	17.9	99.9%	0.1%	32.2
May	36.8	N/A	100%	0%	36.8
June	37.7	N/A	100%	0%	37.7
July	35.3	N/A	100%	0%	35.3
August	32.5	N/A	100%	0%	32.5
September	31.8	N/A	100%	0%	31.8
October	32.0	N/A	100%	0%	32.0
November	32.2	16.9	96.2%	3.8%	31.7
December	32.3	16.9	85.3%	14.7%	30.0

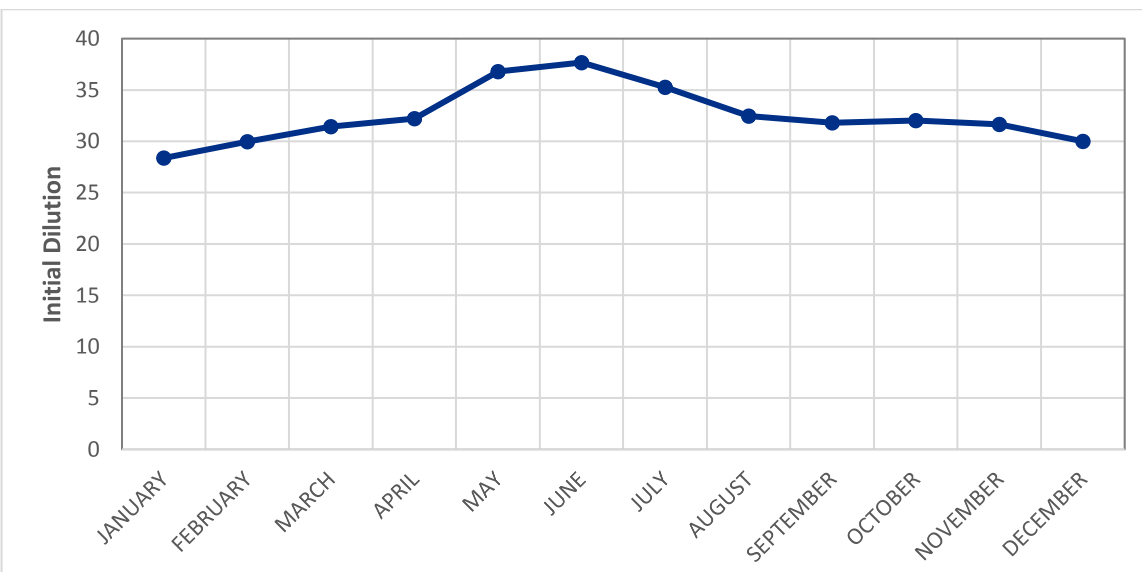

Figure 7-3. Monthly Flux-Averaged Initial Dilutions at the Compliance Flow Rate
For Use in Long-Term Criteria at the IDZ

7.3 Predicted Instantaneous Dilution for Final Diffuser Design for the Range of Stage V Flows

7.3.1 Cumulative Frequency Dilution Results

Figure 7-4 shows the cumulative frequency distribution of flux-averaged initial dilutions resulting from the predictions using a distribution effluent flows up to Stage V, 18.9 m^3/s. **Section 6.3.3** describes the various effluent flows for each flow classification. **Section 6.3.7** details the summary of the inputs for each model simulation. **Attachment H, on pages H-4 through H-8, presents** the primary model inputs, assigned probabilities, and initial dilution results. The cumulative frequency distribution indicates that predicted instantaneous flux-averaged dilution at the IDZ boundary ranges from 11.9:1 to 49.3:1.

Predicted dilution is always greater than 10:1, but is less than 20:1 about 6% of the time, which represents a fraction of the 256 cases simulated. Similar to the results from the predicted dilutions at the compliance flow, the lowest values occur when low river current is combined with the presence of a salt wedge, which traps the plume in the bottom layer of the river. Most of the cases with dilution less than 20:1 occur at lower river current speeds.

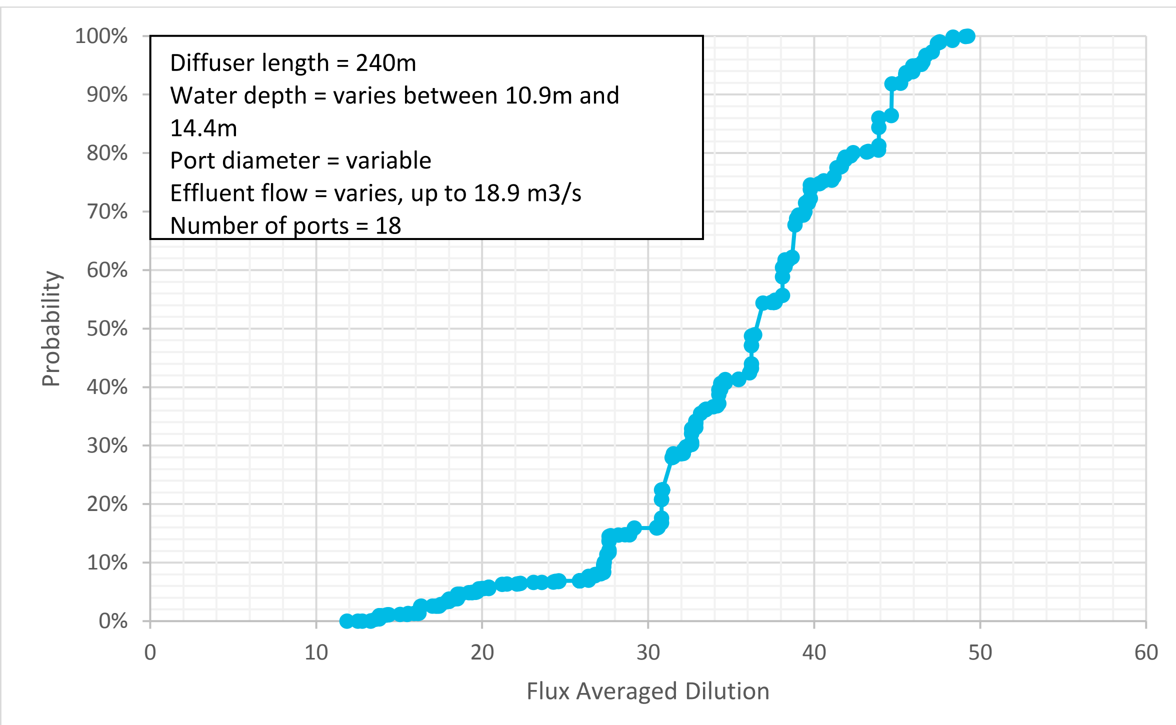

Figure 7-4. Cumulative Frequency Distribution of Dilution at IDZ for Variable Effluent Flows

7.3.2 Predicted Monthly Model Dilution at Monthly Average Effluent Flow Rates

Table 7-2 summarizes the monthly, flux-averaged initial dilutions for monthly average flows using the Shrivastava-Adams equation for unstratified conditions and CORMIX results for stratified conditions. The percentage of time salinity is present was applied to develop the monthly probability weighted flux average initial dilution.

The results in **Table 7-2** indicate that across the months, there is limited variability in dilution because of unstratified flow and that the major difference in the probability weighted flux-averaged dilution is because of the seasonal presence of salinity.

Figure 7-5 shows the predicted average monthly, flux-averaged initial dilution at IDZ for future average monthly effluent flow for long-term criteria.

Table 7-2. Monthly Flux-Averaged Dilutions for Future Monthly Average Effluent Flows

Month	Flux- Averaged Initial Dilution for an Unstratified Density Profile (Fresh)	Flux- Averaged Initial Dilution for a Stratified Density Profile (Saline)	Percent of Time Salinity is Present and Q_a <1000 m^3/s (Saline)	Percent of Time Salinity is not Present and Q_a <1000 m^3/s (Fresh)	Predicted Monthly Flux-Averaged Initial Dilution at Future Average Monthly Effluent Flow
January	35.6	17.2	24.5%	75.5%	31.1
February	35.6	17.0	12.6%	87.4%	33.2
March	35.2	17.0	2.7%	97.3%	34.7
April	37.5	16.5	0.1%	99.9%	37.5
May	42.8	N/A	0%	100%	42.8
June	43.8	N/A	0%	100%	43.8
July	42.1	N/A	0%	100%	42.1
August	39.5	N/A	0%	100%	39.5
September	37.7	N/A	0%	100%	37.7
October	36.3	N/A	0%	100%	36.3
November	34.9	30.8	3.8%	96.2%	34.2
December	35.1	29.6	14.7%	85.3%	32.4

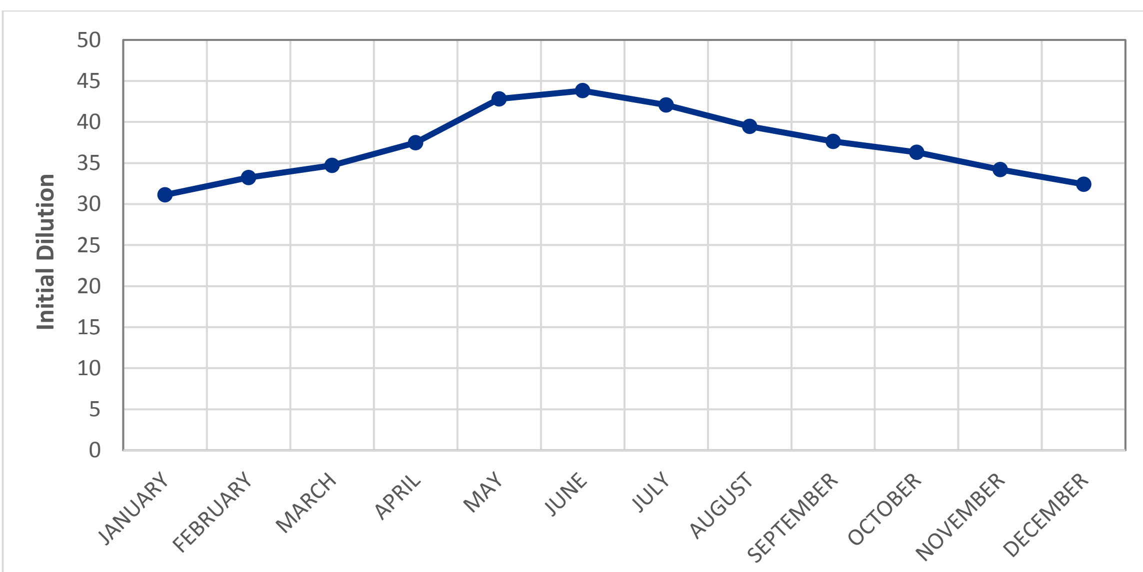

Figure 7-5. Monthly Flux-Averaged Initial Dilution at the Future Average Monthly Effluent Flow For Long-Term Criteria at the IDZ

7.4 Results for Stage VIII Flows

As described in **Section 5.4**, the proposed diffuser is to be constructed with 24 ports. Eighteen of the ports are open for the Stage V flows of 18.9 m^3/s and six additional ports are opened during the increase to Stage VIII flows of 25.3 m^3/s.

Initial dilution predictions were executed using the model input conditions (range of ambient current speeds, ambient depths, temperature difference, and density profiles) that described the Fraser River flow classification of 800 m^3/s < Q < 2,000 m^3/s. The effluent flow was held at 25.3 m^3/s as these model runs were not included to determine probabilistic-weighted initial dilution, but rather to ensure that the diffuser could function as designed for the Stage V to Stage VIII increase and still be operational without a negative impact to initial dilution.

Figure 7-6 shows the initial dilution for these calculations compared to the Stage V flows. The port diameter for this comparison is 0.525 m, but the difference is the number of ports that are open. The port discharge velocity is the approximately the same (4.86 m/s) for both Stage V and Stage VIII flows. The diffuser, when operating at Stage VIII flows shows decreased initial dilution due to the variable office being optimized to having the fixed orifice at Stage VIII flows. The variable orifice is functioning with increased port exit velocity with Stage V flows and hence the slightly improved initial dilution.

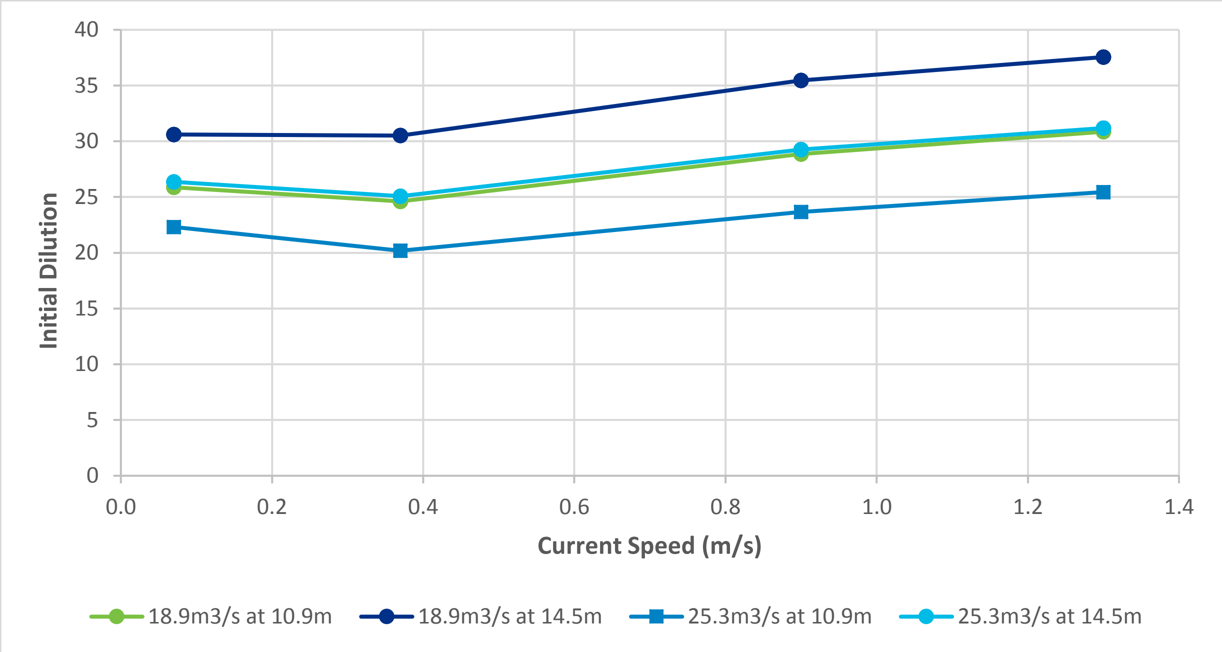

Figure 7-6. Stage V and Stage VIII Effluent Flow (Variable Orifice, Non-Stratified Conditions)

7.5 Summary of Predictions for Ammonia

As discussed in **Sections 2.1.3** and **2.2.1**, there are six regulations relevant to the discharge of ammonia dissolved in wastewater effluent. The ammonia predictions in relation to each of those regulations is discussed in this section. A summary of the compliance assessment is provided in **Table 7-3**.

Table 7-3. Ammonia Compliance Summary

	Regulation	Rule	Result
End-of-Pipe	WSER Unionized Ammonia	Unionized ammonia must be <1.25 mg-N/L at 15°C ± 1°C	100% Met
	CEPA Total Ammonia	Maximum Allowable Total Ammonia (mg-N/L) $= 306{,}132{,}466.34 * 2.7183^{(-2.0437 * \mathrm{pH_{eff}})}$	100% Met
	British Columbia Environmental Management Act	Maximum Allowable Total Ammonia is the concentration necessary to meet provincial long-term water quality objectives	100% Met
Receiving Environment	British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Maximum concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-1 in Attachment J	100% Met
	British Columbia Provincial Water Quality Objectives for Fraser River from Hope to Sturgeon Banks	Average 30-day nitrogen concentration of total ammonia (mg-N/L) at the edge of the IDZ is less than the values listed in Table J-2 in Attachment J	100% Met
	WSER & Canadian Water Quality Guidelines for the Protection of Aquatic Life	Unionized ammonia concentration at the edge of the IDZ is less than or equal to 0.016mg-N/L	99% Met*

*This regulation is contingent on effluent being acutely toxic due to the concentration of unionized ammonia (<1.25 mg-N/L at 15°C ± 1°C)

7.5.1 WSER End-of Pipe Unionized Ammonia Regulation

Figure 7-7 below shows the CDF for the predicted effluent unionized ammonia concentration calculated using the equation published in the regulation (**Table 2-2**). The predicted unionized ammonia concentration is consequently very low, with a maximum predicted value of about 0.35 mg-N/L. The CDF indicates the unionized ammonia concentration is always below the maximum allowable values of 1.25mg-N/L.

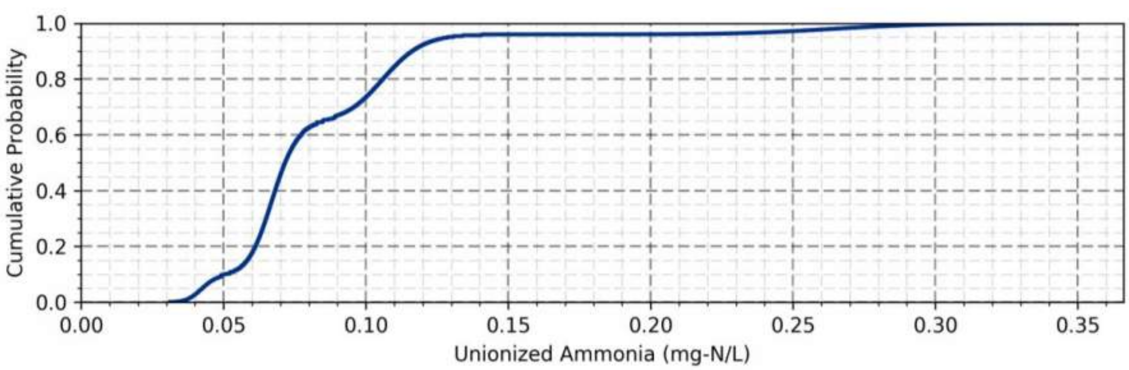

Figure 7-7. Predicted Effluent Unionized Ammonia Concentration

7.5.2 CEPA End-of Pipe Total Ammonia Regulation

Figure 7-8 below shows the CDFs for predicted effluent total ammonia concentration as well as maximum allowable effluent concentrations calculated for each of the 835,200 cases. The two CDFs are independent, that is the predicted ammonia concentration and criteria are not matched pairs. The lack of overlap between the CDFs indicates that the CEPA effluent total ammonia objective is met 100% of the time at the compliance flow. The maximum allowable total ammonia CDF resembles a step function because it is entirely based on effluent pH, of which there are only four in the simulations. Each abrupt leap in probability in the green line of **Figure 7-7** corresponds to the probability of occurrence of each effluent pH discussed in **Section 6.4.9**. The highest predicted effluent concentration occurs at the estimated 99th percentile mass load of 26,120 kg/day resulting in an effluent concentration of about 20.5 mg-N/L at the compliance flow rate of 14.75 m³/s.

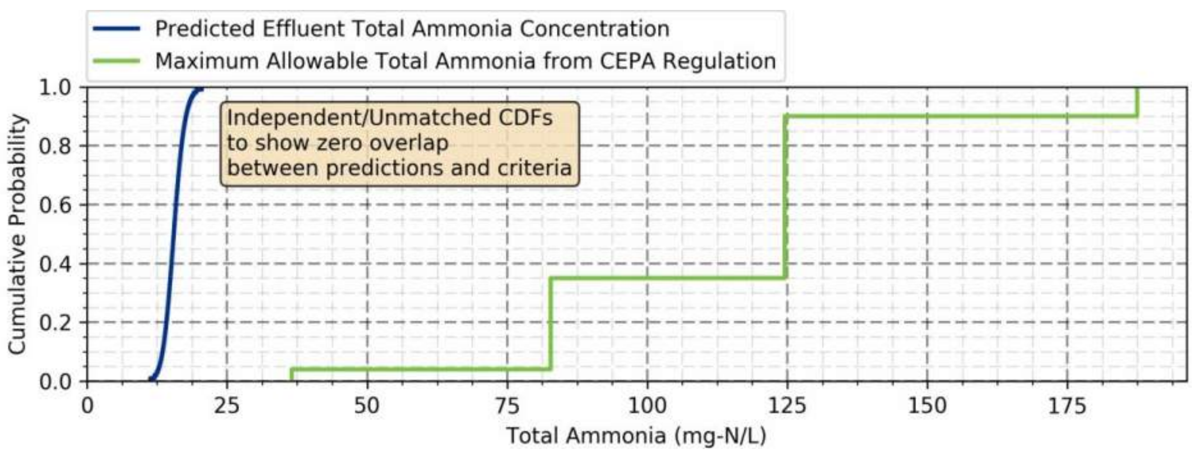

Figure 7-8. Predicted and Maximum Allowable End-of-Pipe Total Ammonia CDFs

7.5.3 Back Calculation

As discussed in **Section 2.1.3**, provincial wastewater regulation, pursuant to the British Columbia Environmental Management Act, require that:

> *"a discharger must determine the maximum allowable municipal effluent ammonia concentration at the 'end of pipe' by a back calculation, from the edge of the initial dilution zone that considers:*
>
> *(a) the ambient temperature and pH characteristics of the receiving water, and*
>
> *(b) water quality guidelines for chronic ammonia."*

Because the regulation references the provincial long-term WQGs, the back calculation was done on an average monthly basis. For each month, the long-term ammonia guideline was calculated using the blending pH and temperature at the edge of the IDZ. The effluent concentration necessary to achieve each month's long-term guideline was calculated by solving the initial dilution equation (**Section 6.2**) for effluent concentration. **Table 7-4** shows the predicted monthly average effluent ammonia concentrations, the long-term guideline at the edge of the IDZ, and the corresponding maximum allowable effluent concentration. The maximum allowable effluent ammonia is always well higher than the predicted effluent concentration. It should be noted that effluent concentrations are low compared to historical data due to nature of a mass loading based analysis. Because the compliance flow rate of 14.75 m^3/s is in the 96th percentile of Stage V effluent flows (**Figure 6-8**), future ammonia concentrations are diluted in the effluent more than they would be lower effluent flow rates.

Table 7-4. Predicted Monthly Effluent Ammonia Concentrations at 2xADWF

Month	Monthly Initial Dilution @ 2xADWF	Monthly Average Blended Temperature (C)	Monthly Average Blended pH	Provincial Long-term Total Ammonia Guideline at Edge-of-IDZ (mg-N/L) *	Future Predicted Effluent Total Ammonia Concentration @2xADWF (mg-N/L)	Back Calculated Maximum Allowable Effluent Concentration (mg-N/L)
January	28.4	3.45	7.45	1.99	15.50	46.65
February	30.0	4.02	7.51	1.97	16.15	47.15
March	31.4	5.27	7.57	1.94	15.98	49.55
April	32.2	7.37	7.62	1.90	16.43	54.20
May	36.8	10.51	7.62	1.85	16.37	63.23
June	37.7	13.28	7.69	1.81	15.94	63.84
July	35.3	16.82	7.63	1.56	14.90	51.03
August	32.5	19.28	7.67	1.31	14.35	37.61
September	31.8	16.65	7.62	1.58	14.83	43.79
October	32.0	11.94	7.60	1.82	15.12	50.16
November	31.7	7.20	7.43	1.90	15.44	50.24
December	30.0	4.24	7.42	1.97	15.64	49.04

** see Attachment J for Guidelines*

7.5.4 Provincial Receiving Environment Maximum Total Ammonia Objective

Figure 7-9 shows there is no overlap between the predicted total ammonia concentrations and maximum objectives at the edge of the IDZ, indicating 100% compliance at 2xADWF.

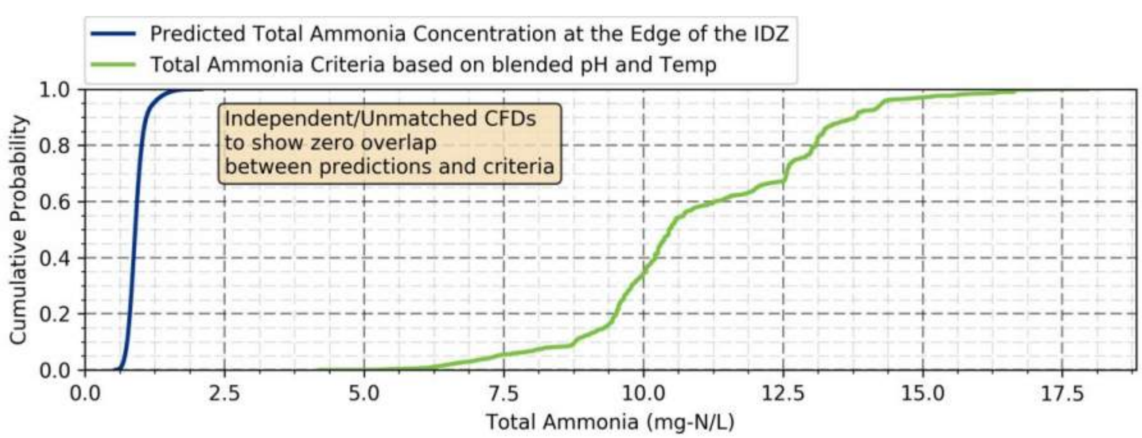

Figure 7-9. Predicted and Maximum Allowable Edge-of-IDZ Total Ammonia CDFs

The case closest to non-compliance has the minimum difference between the predicted concentrations and the maximum objectives of -2.60 mg-N/l. This case has a 99th percentile ammonia mass load with a dilution of about 13:1 and maximum effluent mand ambient pHs of 7.8 and 8.2, respectively. The objective for the case is 4.64 mg-N/l, which is interestingly not the minimum in the simulation. The minimum objective found in the analysis is 4.18 mg-N/l, which also occurs at the maximum effluent and ambient pHs, but the dilution is about 40. The difference stems from how the blended pH is calculated. Because the maximum ambient pH is greater than the that of the effluent, the blended pH maximizes when both the effluent and ambient are maximized and the dilution is also maximized, which enhances the effect of the higher ambient pH. However, when the dilution is maximized, concentrations at the IDZ are depressed and the gap between prediction and objective widens. This presents as a negative feedback mechanism where higher dilutions decrease total ammonia concentrations, but typically increase pH which in turn reduces the objective concentration.

7.5.5 Predicted 30-day Average Total Ammonia Objective at 2xADWF

Table 7-5 shows the predicted monthly average total ammonia at the edge of the IDZ determined at the compliance flow of 14.75 m^3/s compared to the 30-day average objectives defined in **Attachment J, Table J-2**. The predicted total ammonia concentration is always 60-70% less than the 30-day average objective, indicating that on average, the AIWWTP IDZ is always in compliance with the provincial regulation. Predicted concentrations minimize in June when the near-field dilution is largest with a monthly average value of 37.7:1. The minimum objective occurs in August, when receiving waters are the warmest and more basic. For the August prediction to be non-compliant, the average ambient pH value would need to be at least 8.2, which has not been observed in available historic data (2012-2016). If the maximum observed ambient August pH of 8.05 is used instead of the average blended, the 30-day average objective falls from 1.31 to 0.73 mg-N/L, which is still above the predicted concentration.

Table 7-5. Predicted Monthly Average Total Ammonia at IDZ Edge at the Compliance Flow Rate

Month	Monthly Initial Dilution @ 2xADWF	Monthly)Average Blended Temperature (C)	Monthly Average Blended pH	Future Total Ammonia Concentration at the Edge of the IDZ @ 2xADWF (mg-N/L)	Provincial Long-term Total Ammonia Guideline at Edge-of-IDZ (mg-N/L) *
January	28.4	3.45	7.45	0.681	1.99
February	30.0	4.02	7.51	0.694	1.97
March	31.4	5.27	7.57	0.648	1.94
April	32.2	7.37	7.62	0.604	1.90
May	36.8	10.51	7.62	0.509	1.85
June	37.7	13.28	7.69	0.483	1.81
July	35.3	16.82	7.63	0.486	1.56
August	32.5	19.28	7.67	0.524	1.31
September	31.8	16.65	7.62	0.560	1.58
October	32.0	11.94	7.60	0.574	1.82
November	31.7	7.20	7.43	0.607	1.90
December	30.0	4.24	7.42	0.649	1.967

7.4.6 WSER Receiving Water Unionized Ammonia

The WSER indicates that if "effluent deposited via its final discharge point is acutely lethal because of the concentration of unionized ammonia", the discharger may apply to receive temporary authorization to continue discharging given that unionized ammonia "at any point that is 100 m from the point of entry where effluent is deposited in that water via the final discharge point is less than or equal to 0.016 mg/L, expressed as nitrogen (N)". Two methods are referenced in the WSER (34)(1) for determining if the acute lethality is due to concentrations of unionized ammonia. The first is reference Method EPS 1/RM/13 using the procedure set out in Section 6 of that method, which details a multi concentration LC50 test that is out of the scope of this computational based analysis. The second is to calculate the effluent unionized ammonia concentration according to Section 14 of the WSER, which is summarized in the WSER end-of-pipe regulation in Table 1; if the effluent unionized ammonia concentration is greater than 1.25 mg-N/L, effluent acutely toxicity can be attributed to unionized ammonia concentration. Although, as previously shown in **Section 7.4.1**, predicted future effluent unionized ammonia concentration do not exceed 1.25 mg-N/L, compliance with the WSER receiving environment regulation for unionized ammonia is evaluated. Unionized ammonia concentrations at the edge of the IDZ are calculated using the equation published in WSER (34)(3), which can be found in **Table 2-2**, with the total ammonia concentration, blended pH and blended temperature for each case.

Figure 7-10 shows the CDF of predicted unionized ammonia at the edge of the IDZ. The predicted unionized ammonia concentration at the edge of the IDZ exceeds 0.016 mg-N/L in 65,853 out of the total 835,200 cases. Although this is over 7% of the total cases considered, when the probability of each case is included, unionized ammonia is predicted to exceed the objective about 0.92% of the time. Duration of an individual exceedance cannot be determined from the analysis. Out of the cases that do exceed the objective, more than 90% of the time they are less than 0.005 mg-N/L over.

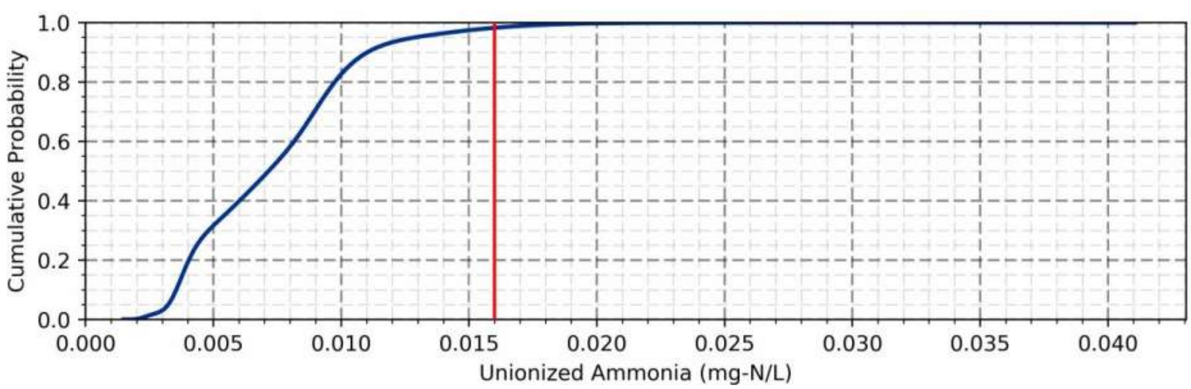

Figure 7-10. Predicted Unionized Ammonia at the Edge of the IDZ

7.6 Predictions at the Edge of the IDZ

This section provides predictions of effluent concentrations at the edge of the IDZ for:

- The interim guideline for temperature in estuaries where the comparison to the criterion is calculated directly using matched pair river and effluent temperature data from 2012-2016, and
- The remaining effluent parameters where the comparison to criteria follows the methodology described in **Section 7.1**.

7.6.1 Comparison of the Effect of Effluent Temperature on Ambient Water Temperature

The interim water quality temperature guideline to protect aquatic life limits the temperature changes to a +/- 1°C temperature variation at any time, location or depth in marine and estuarine waters. A conservative analysis was undertaken to evaluate this guideline using the minimum dilutions associated with effluent flow class. The simplification is justified if the guideline is met in all circumstances, otherwise an assessment of predicted daily dilution would be used.

The conservative comparison of effluent and river temperatures at the edge of the IDZ was performed as follows:

- Cotemporaneous temperature data between 2011-2015 from the AIWWTP daily operational dataset and ambient river temperature measured at the Gravesend Reach buoy are compared, and the difference in temperature calculated for each date.
- The data are then correlated by date to the Fraser River flow at Hope to determine the flow classification and the respective value of 5th percentile dilution associated with each flow class.
- The difference in temperature is then divided by the 5th percentile dilution.

The differences between effluent and ambient temperature range between -0.49°C to 14.3°C. Based on the 95th percentile predicted dilution for the low flow classification, the predicted impact in temperature is 1.06°C and slightly above the allowable change in the interim guideline.

7.6.2 Predictions of Concentrations at the Edge of the IDZ

The goal of this Stage 2 dilution analysis was to provide the best estimate of dilution at the compliance flow of 14.75 m^3/s for the selected multiport diffuser design: a 240-m long diffuser with 18 ports fitted with a variable orifice.. Estimates of initial dilution were determined for a wide range of river conditions, and these were used in prediction methodology are described in **Section 6.1** to determine the edge of IDZ concentrations for comparison to WQGs.

The prediction methodology Calculations for comparison to maximum (short-term) guidelines are based on the 95th percentile concentration of each parameter calculated taking the mass load of each measured effluent data sample adjusted to future flows and divided by the compliance flow of 14.75 m^3/s. Average (long-term) calculations for comparison to long-term guidelines are based on the average mass loads for each parameter divided by the compliance flow. Ambient data, summarized by Golder Associates in the Stage 2 EIS, are categorized by the three-river flow classification for short-term calculations and by high flow months (April, May, June, July, and

August) or low flow months (January, February, March, September, October, November, December) for long-term calculations.

Background buildup concentrations are only calculated for short-term conditions when bi-directional flow is present (when Q < 6,000 m^3/s) as described in **Section 6.4.2.3** and for long-term conditions, are calculated based on monthly predictions as described in **Table 7-1**.

For the compliance flow of 14.75 m^3/s, near-field concentrations are calculated based on the 5th percentile predicted dilution (or 95th percentile concentration) for the flow classifications, which ranges from 13.5:1 to 29.6:1, or the monthly average predicted dilution, which ranges from 28.4:1 to 37.7:1, as described in **Section 7.2.2**. Concentrations at the edge of the IDZ are based on the methodology described in **Section 6.1**.

Predictions are presented for only parameters that have water quality guidelines, objectives, or other screening criteria. If effluent data are not available, predictions are not determined. For instances when ambient data are not available, an ambient concentration of zero is assumed. For instances when mean concentrations for ambient data are not available, median concentrations, as a substitute of central tendency, are used. Some parameters that do not have ambient or effluent data, but may have water quality guidelines are also included to demonstrate a gap and potential need for future monitoring.

A summary of the predicted concentrations at the edge of the IDZ calculations for use in comparison to both short-term and long-term WQGs are presented in **Table 7-6,** along with the data on effluent and ambient concentrations. Golder Associates uses these predictions to assess compliance with the WQGs, WQOs and other screening criteria in the Stage 2 EIS.

7.7 Initial Dilution Modelling Conclusions

This report summarizes the planning and design considerations for a 24 variable port, 240 m long diffuser designed for future Stage V and Stage VIII flows. Continuous monitoring and synoptic measurements of conductivity and temperature near AIWWTP aided in developing a better understanding of the timing, magnitude, and frequency of salinity at the site. Physical modelling experiments were conducted to simulate ambient and effluent conditions corresponding to a scaled model of AIWWTP. Results from the physical modelling confirmed certain design assumptions such as port spacing, length, and effect of salinity on initial dilution. In addition, far-field impacts were estimated using a coupled UM3-H3D far-field model to estimate water quality impacts at far-field assessment node locations. The far-field model was also used to estimate the frequency and magnitude of a simulated salt wedge. Outcomes from the physical modelling and the far-field modelling were incorporated into the initial dilution modelling analysis to predict instantaneous initial dilution, parameter concentrations at the edge of the IDZ, and ammonia concentrations as they related to receiving water quality guidelines to support the findings of the Stage II EIS.

Table 7-6. Predicted Concentrations at the Edge of the IDZ

(240-m Diffuser with 18 Variable Orifice Ports for the Compliance Flow)

		MEASURED EFFLUENT INFORMATION		EFFLUENT ENTRAINED FLUX INFORMATION		AMBIENT INFORMATION					FINAL CONCENTRATIONS (EDGE OF THE IDZ)														
		SHORT-TERM	LONG-TERM	SHORT-TERM	LONG-TERM	SHORT-TERM			LONG-TERM		SHORT-TERM			LONG-TERM AVERAGE											
Parameter	Units	95%ile or MAX CONC	AVG OR MED CONC	95%ile Fitted Distribution CONC	AVG CONC	HIGH FLOW 95%ile or MAX CONC	MOD FLOW 95%ile or MAX CONC	LOW FLOW 95%ile or MAX CONC	APR-AUG AVG OR MED CONC	JAN - MAR SEP - DEC AVG OR MED CONC	HIGH FLOW CONC	MOD FLOW CONC	LOW FLOW CONC	JAN CONC	FEB CONC	MAR CONC	APR CONC	MAY CONC	JUNE CONC	JUL CONC	AUG CONC	SEP CONC	OCT CONC	NOV CONC	DEC CONC
Conventional Parameters																									
Salinity	ppt	0.4	0.34			0.57	1.0	0.56	0.40	0.19	0.58	0.95	0.54	0.20	0.20	0.20	0.40	0.40	0.40	0.40	0.40	0.20	0.20	0.20	0.20
Conductivity	µS/cm	717	599				105	325		70	37	154	360	91	91	90	20.4	17.0	16.5	17.8	20.1	88	88	89	90
Temperature	deg C	22.6	17.8			16.8	20.2	6.0	14.3	7.8															
Dissolved Organic Carbon	mg/L	14.6	11.6	8.1	5.8	4.3	4.7	2.8	3.3	2.4	4.6	4.7	3.1	2.6	2.6	2.6	3.4	3.3	3.3	3.3	3.4	2.5	2.5	2.5	2.6
Hardness as CaCO3	mg/L	59.3	44.8	43	23	47	60	123	49	53	48	57	114	52	52	52	48	48	48	48	48	52	52	52	52
Total Organic Carbon	mg/L	17.3	13.9	9.4	6.9		4.1	3.1		2.7	0.41	4.3	3.5	2.8	2.8	2.8	0.24	0.20	0.19	0.21	0.23	2.8	2.8	2.8	2.8
Total Suspended Solids	mg/L	14.0	9.3	9.1	4.9	172	89	21	58	20.8	169	82	20	20	20	20	56	56	56	56	56	20	20	20	20
Total Residual Chlorine	mg/L	<0.10	<0.02	4.39E-02	1.70E-02						1.90E-03	2.17E-03	2.81E-03	7.00E-04	6.86E-04	6.45E-04	5.79E-04	4.83E-04	4.68E-04	5.04E-04	5.69E-04	5.93E-04	5.98E-04	6.22E-04	6.60E-04
Major Ions																									
Fluoride (Total)	mg/L	<0.12	0.07	0.08	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Sulfate (Total)	mg/L	20.2	17.0	13.3	8.8	6.3	18	15	7.1	10	6.8	17	15	9.9	9.9	9.9	7.1	7.1	7.1	7.1	7.1	9.9	9.9	9.9	9.9
Calcium (Total)	mg/L	18	13	12.4	6.7	14	16	20	14	14	15	16	19	14	14	14	14	14	14	14	14	14	14	14	14
Magnesium (Total)	mg/L	4.1	3.2	2.7	1.6	2.7	4.6	19	3.3	4.2	2.8	4.4	18	4.1	4.1	4.1	3.3	3.3	3.3	3.3	3.3	4.1	4.1	4.1	4.1
Potassium (Total)	mg/L	15	13	6.9	5.9	1.4	2.0	5.8	1.3	1.2	1.7	2.2	5.9	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Sodium (Total)	mg/L	53	41	30	21	1.9	29	352	3.7	29	3.2	28	322	29	29	29	4.3	4.2	4.2	4.2	4.3	29	29	29	29
Nutrients																									
Total Ammonia as N	mg-N/L																								
Ammonia (unionized)	mg-N/L																								
Nitrogen - Nitrate as N	mg-N/L	<0.07	0.02	0.03	0.01	0.062	0.208	0.247	0.05	0.12	0.06	0.19	0.23	0.11	0.11	0.11	0.05	0.05	0.05	0.05	0.05	0.11	0.11	0.11	0.11
Nitrogen - Nitrite as N	mg-N/L	<0.12	0.05	0.07	0.02	0.02	0.01	0.01	0.01	0.003	0.03	0.01	0.01	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.003	0.003	0.003	0.003
Nitrate + Nitrite	mg-N/L	<0.2	0.07	0.09	0.04	0.15	0.23	0.25	0.16	0.16	0.15	0.21	0.24	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15
Total Kjeldahl Nitrogen		41	33.5	20	17						0.88	1.05	1.5	0.69	0.67	0.63	0.57	0.47	0.46	0.49	0.56	0.58	0.59	0.61	0.65
Total Nitrogen (calculated)	mg-N/L	<39.6	33.40	20	17	0.38	0.53	0.50	0.37	0.32	1.3	1.5	2.0	0.99	0.98	0.94	0.93	0.83	0.82	0.85	0.92	0.89	0.90	0.92	0.96
Total Phosphorus	mg-P/L	3.7	2.6	1.8	1.3	0.35	0.15	0.05	0.10	0.03	0.42	0.23	0.18	0.08	0.08	0.08	0.14	0.14	0.14	0.14	0.14	0.07	0.08	0.08	0.08
Dissolved Phosphorus	mg-P/L	3.4	2.3	1.3	1.1	0.03	0.03	0.02	0.01	0.02	0.09	0.10	0.13	0.06	0.06	0.06	0.05	0.05	0.04	0.05	0.05	0.06	0.06	0.06	0.06
Bacteria																									
E. Coli	MPN/100mL		64.00		29				26	62							26	26	26	26	26	61	61		
Enterococci	MPN/100mL		28.00		12				27	25							26	27	27	27	26	25	25		
Fecal Coliform	MPN/100mL		27.00		12				39	92							38	38	38	38	38	89	89		
Total Metals																									
Aluminum	µg/L	59.7	41.9	47	22	4136	1558	382	1438	337	4067	1438	351	324	324	325	1390	1398	1399	1396	1390	326	326	325	324
Antimony	µg/L	<0.50	<0.50	0.23	0.22	0.12	0.07	0.09	0.07	0.05	0.12	0.08	0.10	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
Arsenic	µg/L	1.0	0.7	0.70	0.37	1.5	0.96	0.6	0.77	0.49	1.5	0.92	0.6	0.49	0.49	0.49	0.76	0.76	0.76	0.76	0.76	0.49	0.49	0.49	0.49
Barium	µg/L	<20.0	6.30	8.3	3.3	60	39	19	30	17	59	36	18	17	17	17	29	29	29	29	29	17	17	17	17
Beryllium	µg/L	<0.5	<0.5	0.3	0.2	0.11	0.06	0.01	0.04	<0.01	0.13	0.07	0.03	0.02	0.02	0.02	0.05	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.02
Boron	µg/L	211	151	122	76	4.2	50	61	5.5	<10	9.5	52	64	13	13	13	7.9	7.5	7.4	7.6	7.8	12	12	12	13
Cadmium	µg/L	3.7	<0.20	0.32	0.10	0.10	0.07	0.03	0.04	0.02	0.11	0.08	0.04	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.02	0.02	0.02	0.02
Chromium	µg/L	2.1	1.7	1.6	0.8	7.5	3.7	0.75	2.7	0.68	7.4	3.5	0.8	0.69	0.69	0.69	2.6	2.6	2.6	2.6	2.6	0.69	0.69	0.69	0.69
Cobalt	µg/L	<0.7	0.50	0.41	0.28	3.8	1.9	0.29	1.4	0.35	3.8	1.8	0.3	0.35	0.35	0.35	1.3	1.3	1.3	1.3	1.3	0.35	0.35	0.35	0.35
Copper	µg/L	31.4	18.3	16	9.2	11	7.2	2.6	4.7	1.8	11	7.4	3.4	2.1	2.1	2.1	4.9	4.8	4.8	4.8	4.8	2.0	2.0	2.0	2.1
Iron	µg/L	666	484	479	250	6233	2400	565	2181	514	6146	2235	544	503	503	504	2115	2126	2128	2124	2116	505	505	504	504
Lead	µg/L	<1.0	0.50	0.52	0.31	2.5	1.4	0.31	0.94	0.32	2.5	1.3	0.3	0.32	0.32	0.32	0.92	0.92	0.92	0.92	0.92	0.32	0.32	0.32	0.32
Lithium	µg/L	<50.0	<50	33	16	3.7	2.2	2.6	1.8	1.1	5.0	3.7	4.5	1.7	1.7	1.7	2.3	2.2	2.2	2.3	2.3	1.6	1.6	1.7	1.7
Manganese	µg/L	79.5	61.7	55	32	191	94	30	71	23	190	89	31	23	23	23	70	70	70	70	70	23	23	23	23
Mercury	µg/L	0.00869	0.0075	0.00458	0.00353		0.01	<0.01		<0.01	0.00020	0.00945	0.00944	0.00973	0.00974	0.00975	0.00012	0.00010	0.00010	0.00010	0.00012	0.00977	0.00977	0.00976	0.00975
Molybdenum	µg/L	<2.1	1.30	1.33	0.66	0.65	0.79	0.95	0.61	0.65	0.69	0.80	0.95	0.65	0.65	0.65	0.61	0.61	0.61	0.61	0.61	0.65	0.65	0.65	0.65
Nickel	µg/L	<5.0	2.80	2.7	1.4	13	7.6	1.9	5.4	1.5	12	7.1	2	1.5	1.5	1.5	5.3	5.3	5.3	5.3	5.3	1.5	1.5	1.5	1.5
Selenium	µg/L	<1.0	0.50	0.40	0.27	0.10	0.12	0.39	0.09	0.10	0.12	0.13	0.39	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Silver	µg/L	<0.50	<0.50	0.38	0.24	0.03	0.02	0.01	0.01	<0.005	0.05	0.04	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Strontium	µg/L	39.9	39.2	17	17	88	91	166	81	81	87	85	152	78	78	78	79	79	79	79	79	78	78	78	78
Thallium	µg/L	<0.50	<0.20	0.23	0.13	0.04	0.02	0.01	0.02	0.01	0.05	0.03	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Uranium	µg/L	<0.50	<0.20	0.23	0.13	0.39	0.30	0.27	0.24	0.21	0.39	0.29	0.26	0.21	0.21	0.21	0.24	0.24	0.24	0.24	0.24	0.21	0.21	0.21	0.21
Vanadium	µg/L	<30.0	<30	20	9.3	10	4.8	1.3	3.6	1.2	11	5.4	2	1.5	1.5	1.5	3.8	3.8	3.8	3.8	3.8	1.5	1.5	1.5	1.5
Zinc	µg/L	38.7	22.1	22	11.4	17	11	4.6	6.6	2.4	18	11	6	2.8	2.8	2.8	6.8	6.7	6.7	6.8	6.8	2.8	2.8	2.8	2.8
Dissolved Metals																									
Aluminum	µg/L	19	13.5	11.3	6.9	164	160	29	110	23	162	148	27	22	22	23	106	107	107	107	106	23	23	23	22
Antimony	µg/L	<0.5	<0.5	0.23	0.22	0.05	0.06	0.08	0.04	0.04	0.06	0.06	0.09	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Arsenic	µg/L	<1.0	0.69	0.67	0.36	0.42	0.42	0.45	0.36	0.33	0.44	0.42	0.45	0.33	0.33	0.33	0.36	0.36	0.36	0.36	0.36	0.33	0.33	0.33	0.33
Barium	µg/L	<20	4.60	8.2	2.3	14	16	16	14	13	14	15	15	12	12	12	13	13	13	13	13	13	13	12	12
Beryllium	µg/L	<0.5	<0.5	0.3	0.14	0.01	0.01	<1	0.01	<0.01	0.10	0.12	1.07	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Boron	µg/L	195	144	118	73	3.8	18	60	5.3	<10	8.9	22	63	13	13	12	7.6	7.3	7.2	7.3	7.6	12	12	12	12
Cadmium	µg/L	2.0	<0.20	0.22	0.10	0.02	0.02	0.01	0.01	0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Chromium	µg/L	1.4	1.10	1.11	0.56	0.33	0.30	0.16	0.22	0.13	0.37	0.33	0.21	0.15	0.15	0.15	0.23	0.23	0.23	0.23	0.23	0.15	0.15	0.15	0.15
Cobalt	µg/L	<0.67	0.50	0.38	0.27	0.15	0.14	0.06	0.09	0.04	0.16	0.15	0.08	0.05	0.05	0.05	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.05
Copper	µg/L	21.4	9.7	9.7	4.7	1.6	1.7	0.89	1.2	0.83	2.0	2.1	1.4	0.99	0.99	0.98	1.3	1.3	1.3	1.3	1.3	0.96	0.97	0.97	0.98
Iron	µg/L	174	130	101	65	183	186	67	119	39	184	177	68	40	40	40	117	118	118	118	117	40	40	40	40
Lead	µg/L	<1.0	<0.5	0.40	0.27	0.14	0.09	0.05	0.07	0.02	0.15	0.10	0.07	0.03	0.03	0.03	0.08	0.08	0.08	0.08	0.08	0.03	0.03	0.03	0.03
Lithium	µg/L	<50	<50	33	16	0.82	1.3	2.8	0.85	0.89	2.2	2.8	4.7	1.5	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.5
Manganese	µg/L	68.9	49.5	45	26	12	11	16	8.8	6.0	14	13	18	6.8	6.8	6.7	9.4	9.3	9.3	9.3	9.4	6.7	6.7	6.7	6.8

Molybdenum	µg/L	<1.9	1.10	1.14	0.59	0.85	0.84	1.00	0.73	0.71	0.89	0.83	0.98	0.71	0.71	0.71	0.72	0.72	0.72	0.72	0.72	0.71	0.71	0.71	0.71
Nickel	µg/L	<5.0	2.70	2.5	1.33	1.1	1.0	0.69	1.0	0.50	1.16	1.04	0.78	0.54	0.54	0.54	1.02	1.02	1.02	1.02	1.02	0.53	0.53	0.53	0.54
Selenium	µg/L	<1.0	<0.5	0.41	0.27	0.09	0.12	0.32	0.08	0.09	0.11	0.13	0.32	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Silver	µg/L	<0.5	<0.5	0.38	0.24	0.002	0.005	<0.05	0.002	<0.005	0.02	0.02	0.07	0.015	0.014	0.014	0.010	0.008	0.008	0.009	0.010	0.013	0.013	0.014	0.014
Strontium	µg/L	37.1	36.5	16	16	73	90	175	73	80	73	84	161	77	77	77	71	72	72	72	71	78	78	77	77
Thallium	µg/L	<0.5	<0.2	0.23	0.13	0.005	0.007	0.009	0.004	0.004	0.015	0.018	0.023	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.009	0.008	0.008	0.009	0.009
Uranium	µg/L	<0.5	<0.2	0.23	0.13	0.21	0.24	0.29	0.18	0.19	0.21	0.23	0.27	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19
Vanadium	µg/L	<30	<30	20	9.3	0.83	0.75	0.44	0.58	0.39	1.7	1.7	1.7	0.76	0.75	0.73	0.88	0.83	0.82	0.84	0.87	0.70	0.70	0.72	0.74
Zinc	µg/L	29.7	16.5	15	8.3	0.60	1.0	1.5	0.48	0.62	1.2	1.7	2.3	0.94	0.93	0.91	0.74	0.70	0.69	0.71	0.74	0.89	0.89	0.90	0.92
Pesticides																									
Cyanazine	ng/L	<8.38	<3.09	5.6	2.3	<4.6	<4.6	<4.6	<2.1	<2.1	4.8	4.5	4.5	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Endosulphan-total (alpha+beta)	ng/L	<1.37	<0.945	0.81	0.50	<1.1	<1.1	<1.1	<0.89	<0.89	1.12	1.05	1.06	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.87
Hexachlorobenzene	ng/L	<0.117	0.08	0.06	0.04	0.05	0.05	0.05	0.03	0.03	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Linuron	ng/L	<4.87	<1.47	3.0	1.36	<4.3	<4.3	<4.3	<4	<4	4.4	4.1	4.1	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Metribuzin	ng/L	<7.54	<1.26	4.2	1.5	<4.4	<4.4	<4.4	<0.63	<0.63	4.5	4.3	4.3	0.67	0.66	0.66	0.66	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66
Simazine	ng/L	5.44	2.52	2.3	1.31	<1.2	<1.2	<1.2	0.44	0.44	1.3	1.2	1.3	0.48	0.47	0.47	0.47	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.47
Aldicarb	ng/L	<2.44	<0.494	1.3	0.48	<0.56	<0.56	<0.56	<0.5	<0.5	0.61	0.58	0.59	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Captan	ng/L	<22.9	<2.98	11.6	3.6	<27	<27	<27	<4.3	<4.3	27	25	25	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Carbaryl	ng/L	<284	79.80	144	37	<0.56	<0.56	<0.56	<0.5	<0.5	6.7	7.4	8.8	2.0	2.0	1.9	1.8	1.5	1.5	1.6	1.7	1.8	1.8	1.9	1.9
Chlorpyriphos	ng/L	<3.7	<1.6	1.9	0.93	<1.8	<1.8	<1.8	<1.1	<1.1	1.9	1.8	1.8	1.09	1.09	1.09	1.09	1.10	1.10	1.09	1.09	1.09	1.09	1.09	1.09
HCH, alpha	ng/L	<0.66	<0.046	0.27	0.07	<0.086	<0.086	<0.086	0.05	0.05	0.10	0.09	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
HCH, beta	ng/L	<0.634	0.47	0.36	0.24	<0.15	<0.15	<0.15	<0.047	<0.047	0.16	0.16	0.16	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
HCH, delta	ng/L	<1.44	<0.050	0.53	0.13	<0.13	<0.13	<0.13	<0.041	<0.041	0.15	0.15	0.15	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
HCH, gamma	ng/L	1.5	0.46	0.76	0.23	<0.14	<0.14	<0.14	<0.042	<0.042	0.17	0.16	0.17	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Imidacloprid	ng/L	101	54.1	47	27	<1.1	<1.1	<1.1	<1	<1	3.3	3.6	5.2	2.1	2.1	2.0	1.9	1.7	1.7	1.8	1.9	1.9	1.9	2.0	2.0
Malathion	ng/L	<6.2	<1.4	3.9	1.4	<5.6	<5.6	<5.6	<2.1	<2.1	5.7	5.4	5.3	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Methoprene	ng/L	<330	<87.2	147	63	<138	<138	<138	<21	<21	142	134	135	23	23	23	22	22	22	22	22	22	22	23	23
Hexachlorobutadiene	ng/L	<357	<133	0.22	0.09						0.010	0.011	0.014	3.66E-03	3.59E-03	3.37E-03	3.03E-03	2.53E-03	2.45E-03	2.64E-03	2.98E-03	3.10E-03	3.13E-03	3.25E-03	3.45E-03
Toxaphene	ng/L	<1.65	<0.852	0.86	0.48						0.04	0.04	0.06	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Pyrethroid Insecticides																									
Permethrin	ng/L	<19.1	13.40	9.3	6.9	<0.90	<0.90	<0.90	<0.51	<0.51	1.3	1.3	1.5	0.77	0.77	0.75	0.73	0.69	0.69	0.70	0.72	0.73	0.74	0.74	0.76
Deltamethrin	ng/L	<2.9	<1.2	1.5	0.74	<3.8	<3.8	<3.8	<1.2	<1.2	3.8	3.6	3.6	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Polybrominated Diphenyl Ethers																									
Tetra-BDE-47	ng/L	4.1	3.3	3.6	2.0	0.10	0.10	0.10	0.04	0.04	0.25	0.27	0.32	0.12	0.12	0.11	0.11	0.10	0.09	0.10	0.11	0.11	0.11	0.11	0.12
Penta-BDE-99	ng/L	4.0	3.1	3.6	1.9	0.09	0.09	0.09	0.04	0.04	0.24	0.26	0.31	0.11	0.11	0.11	0.10	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.11
Penta-BDE-100	ng/L	0.80	0.62	0.71	0.38	0.02	0.02	0.02	0.01	0.01	0.05	0.05	0.06	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Hexa-BDE-153	ng/L	0.38	0.28	0.34	0.18	<0.014	<0.014	<0.014	0.0042	0.0042	0.028	0.030	0.035	0.011	0.011	0.011	0.010	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.011
Deca-BDE-209	ng/L	6.64	4.39	5.85	2.73	0.56	0.56	0.56	0.31	0.31	0.80	0.80	0.87	0.41	0.41	0.40	0.40	0.38	0.38	0.38	0.39	0.40	0.40	0.40	0.41
Polychlorinated Biphenyls																									
PCB-77	pg/L	<3.01	1.74	1.9	1.06	<1.1	<1.1	<1.1	<0.32	<0.32	1.2	1.1	1.1	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35
PCB-105	pg/L	16.7	13.3	14	8.2	3.5	3.5	3.5	1.5	1.5	4.1	3.9	4.1	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.8
PCB-126	pg/L	<2.16	<0.49	1.4	0.55	<1.5	<1.5	<1.5	<0.43	<0.43	1.5	1.5	1.5	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
PCB-169	pg/L	<1.61	<0.35	1.14	0.42	<1.2	<1.2	<1.2	<0.35	<0.35	1.2	1.2	1.2	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
PCB-118	pg/L	43.6	34.7	36	21	8.6	8.6	8.6	3.6	3.6	10.0	9.7	10	4.3	4.3	4.3	4.2	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.3
PCB-156+157	pg/L	6.52	4.95	5.3	3.1	<1.4	<1.4	<1.4	0.36	0.36	1.6	1.6	1.6	0.47	0.47	0.46	0.45	0.44	0.43	0.44	0.45	0.45	0.46	0.46	0.46
PCB-167	pg/L	<2.11	1.55	1.7	0.95	<1.1	<1.1	<1.1	<0.25	<0.25	1.2	1.1	1.1	0.28	0.28	0.28	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.28	0.28
PCB-123	pg/L	<1.94	1.3	1.4	0.79	<1.5	<1.5	<1.5	<0.39	<0.39	1.5	1.5	1.5	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41
PCB-114	pg/L	<1.78	1.24	1.4	0.76	<1.5	<1.5	<1.5	<0.39	<0.39	1.5	1.5	1.5	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
PCB-81	pg/L	<1.53	<0.41	1.1	0.42	<1.1	<1.1	<1.1	<0.28	<0.28	1.1	1.1	1.1	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.29	0.29	0.29	0.29
PCB-189	pg/L	<2.15	<0.57	1.3	0.51	<1.3	<1.3	<1.3	<0.43	<0.43	1.3	1.3	1.3	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Total PCB	pg/L	1647	1158	1232	721	249	249	249	166	166	299	292	311	189	188	187	185	182	181	182	185	185	186	186	188
Polycyclic Aromatic Hydrocarbons																									
Acenaphthene	µg/L	<0.1	0.02	0.06	0.02	<0.04	<0.04	<0.04	<0.01	<0.01	0.04	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Acridine	µg/L	<0.04	0.02	0.02	0.012	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Anthracene	µg/L	<0.01	<0.01	0.007	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Benz(a)anthracene	µg/L	<0.01	<0.01	0.008	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Benzo(a)pyrene	µg/L	<0.01	<0.01	0.008	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chrysene	µg/L	<0.01	<0.01	0.008	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fluoranthene	µg/L	<0.02	0.01	0.02	0.008	<0.03	<0.03	<0.03	<0.01	<0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Fluorene	µg/L	<0.05	0.02	0.04	0.01	<0.03	<0.03	<0.03	<0.01	<0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
1-Methylnaphthalene	µg/L	<0.05	<0.05	0.04	0.03	0.05	0.05	0.05	<0.05	<0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2-Methylnaphthalene	µg/L	<0.05	<0.05	0.04	0.03	<0.07	<0.07	<0.07	<0.05	<0.05	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Naphthalene	µg/L	<0.06	<0.05	0.04	0.03	0.09	0.09	0.09	<0.05	<0.05	0.09	0.08	0.08	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Phenanthrene	µg/L	<0.02	<0.02	0.02	0.010	<0.09	<0.09	<0.09	<0.02	<0.02	0.09	0.08	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Pyrene	µg/L	<0.02	0.01	0.014	0.008	<0.03	<0.03	<0.03	<0.01	<0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Quinoline	µg/L	<0.25	<0.05	0.34	0.06	<0.05	<0.05	<0.05	<0.01	<0.01	0.06	0.06	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sterols and Hormones																									
17 α-Ethinyl-Estradiol	ng/L	<35.5	<8.0	13.9	5.6	<1.7	<1.7	<1.7	<0.88	<0.88	2.27	2.25	2.44	1.07	1.07	1.06	1.04	1.01	1.01	1.02	1.04	1.04	1.05	1.05	1.06
Cholestanol	ng/L	5333	3493	3712	1946	74	74	74	40	40	234	251	306	119	117	112	105	94	93	97	104	107	107	110	114
Cholesterol	ng/L	45070	30216	28406	16557	683	683	683	496	496	1915	2051	2527	1159	1145	1106	1044	953	939	972	1034	1057	1062	1084	1120
Desmosterol	ng/L	<2930	<1410	1679	863	95	95	95	51	51	167	172	198	85	84	82	79	74	73	75	78	79	80	81	83
Epicoprostanol	ng/L	<2261	1042.00	1224	557	25	25	25	11	11	78	84	101	34	33	32	30	27	26	27	29	30	30	31	32
Coprostanol	ng/L	60775	36150	35468	19382	200	200	200	94	94	1746	1963	2501	890	873	827	752	642	626	666	740	768	773	800	843
Alkylphenols																									
Nonylphenol TEQ	ng/L	1650	1158	749	519	80	80	80	<32	<32	111	113	125	52	52	51	49	46	45	46	48	49	49	50	51
Halogenated Organics																									
Carbon Tetrachloride	mg/L	<5.00E-04	<5.00E-04	2.40E-04	2.30E-04						1.11E-05	1.30E-05	2.08E-05	9.47E-06	9.28E-06	8.72E-06	7.83E-06	6.53E-06	6.33E-06	6.81E-06	7.69E-06	8.02E-06	8.09E-06	8.41E-06	8.92E-06
Chlorobenzene	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
Chloroethane	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
Chloroform	mg/L	0.002	0.002	1.06E-03	9.52E-04						4.80E-05	5.73E-05	8.76E-05	3.93E-05	3.85E-05	3.62E-05	3.25E-05	2.71E-05	2.62E-05	2.82E-05	3.19E-05	3.33E-05	3.35E-05	3.49E-05	3.70E-05
1,2-Dichlorobenzene	mg/L	<7.00E-04	<7.00E-04	4.75E-04	1.84E-04						2.06E-05	2.34E-05	3.04E-05	7.60E-06	7.44E-06	6.99E-06	6.28E-06	5.24E-06	5.08E-06	5.46E-06	6.17E-06	6.43E-06	6.49E-06	6.74E-06	7.15E-06
1,4-Dichlorobenzene	mg/L	<0.001	<0.001	5.93E-04	3.54E-04						2.60E-05	3.02E-05	4.08E-05	1.46E-05	1.43E-05	1.35E-05	1.21E-05	1.01E-05	9.77E-06	1.05E-05	1.19E-05	1.24E-05	1.25E-05	1.30E-05	1.38E-05

1,2-Dichloroethane	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
1,1-Dichloroethylene	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
Dichloromethane	mg/L	<0.005	<0.005	2.40E-03	2.30E-03						1.11E-04	1.30E-04	2.08E-04	9.47E-05	9.28E-05	8.72E-05	7.83E-05	6.53E-05	6.33E-05	6.81E-05	7.69E-05	8.02E-05	8.09E-05	8.41E-05	8.92E-05
Trichloroethylene	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
Vinyl Chloride	mg/L	<0.001	<0.001	4.81E-04	4.59E-04						2.21E-05	2.59E-05	4.17E-05	1.89E-05	1.86E-05	1.74E-05	1.57E-05	1.31E-05	1.27E-05	1.36E-05	1.54E-05	1.60E-05	1.62E-05	1.68E-05	1.78E-05
Diisopropanolamine	mg/L	<0.10	<0.10	4.81E-02	4.59E-02						2.21E-03	2.59E-03	4.17E-03	1.89E-03	1.86E-03	1.74E-03	1.57E-03	1.31E-03	1.27E-03	1.36E-03	1.54E-03	1.60E-03	1.62E-03	1.68E-03	1.78E-03
Aniline	ug/L	<5.0	<5.0	2.4	2.3	<5.0	<5.0	<5.0	<5.0	<5.0	5.024	4.735	4.757	4.888	4.891	4.897	4.908	4.923	4.925	4.920	4.909	4.906	4.905	4.901	4.895
Pentachlorophenol	mg/L	<1.00E-04	<1.00E-04	4.81E-05	4.59E-05						2.21E-06	2.59E-06	4.17E-06	1.89E-06	1.86E-06	1.74E-06	1.57E-06	1.31E-06	1.27E-06	1.36E-06	1.54E-06	1.60E-06	1.62E-06	1.68E-06	1.78E-06
2,3,4,6-Tetrachlorophenol	mg/L	1.10E-04	<1.00E-04	5.25E-05	4.71E-05						2.38E-06	2.83E-06	4.33E-06	1.94E-06	1.90E-06	1.79E-06	1.61E-06	1.34E-06	1.30E-06	1.40E-06	1.58E-06	1.65E-06	1.66E-06	1.72E-06	1.83E-06
2,3,6-Trichlorophenol	mg/L	<1.00E-04	<1.00E-04	4.81E-05	4.59E-05						2.21E-06	2.59E-06	4.17E-06	1.89E-06	1.86E-06	1.74E-06	1.57E-06	1.31E-06	1.27E-06	1.36E-06	1.54E-06	1.60E-06	1.62E-06	1.68E-06	1.78E-06
Monochlorophenols	mg/L	<6.50E-04	<6.50E-04	3.13E-04	2.99E-04						1.44E-05	1.69E-05	2.71E-05	1.23E-05	1.21E-05	1.13E-05	1.02E-05	8.49E-06	8.23E-06	8.86E-06	1.00E-05	1.04E-05	1.05E-05	1.09E-05	1.16E-05
Dichlorophenols	mg/L	<4.00E-04	<3.75E-04	1.97E-04	1.69E-04						8.83E-06	1.06E-05	1.57E-05	6.96E-06	6.82E-06	6.41E-06	5.76E-06	4.80E-06	4.65E-06	5.01E-06	5.65E-06	5.90E-06	5.94E-06	6.18E-06	6.56E-06
Trichlorophenols	mg/L	<6.00E-04	<6.00E-04	2.89E-04	2.76E-04						1.33E-05	1.56E-05	2.50E-05	1.14E-05	1.11E-05	1.05E-05	9.40E-06	7.84E-06	7.60E-06	8.18E-06	9.23E-06	9.63E-06	9.71E-06	1.01E-05	1.07E-05
Tetrachlorophenols	mg/L	<5.10E-04	<5.00E-04	2.44E-04	2.31E-04						1.12E-05	1.32E-05	2.10E-05	9.52E-06	9.33E-06	8.77E-06	7.87E-06	6.56E-06	6.36E-06	6.85E-06	7.73E-06	8.07E-06	8.13E-06	8.45E-06	8.97E-06
Organometallics																									
Tributyltin Chloride	µg/L	<0.001	<0.001	4.89E-04	4.51E-04						2.23E-05	2.64E-05	4.12E-05	1.86E-05	1.82E-05	1.71E-05	1.54E-05	1.28E-05	1.24E-05	1.34E-05	1.51E-05	1.57E-05	1.59E-05	1.65E-05	1.75E-05
Triphenyltin chloride	µg/L	<0.01	<0.01	4.89E-03	4.51E-03						2.23E-04	2.64E-04	4.12E-04	1.86E-04	1.82E-04	1.71E-04	1.54E-04	1.28E-04	1.24E-04	1.34E-04	1.51E-04	1.57E-04	1.59E-04	1.65E-04	1.75E-04
Toxaphene	ng/L	<1.65	<0.852	0.86	0.48						0.04	0.04	0.06	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
PFOS	ng/L	8.5	6.51	6.6	4.2						0.29	0.34	0.46	0.17	0.17	0.16	0.14	0.12	0.12	0.12	0.14	0.15	0.15	0.15	0.16
2,4'-DDE	ng/L	<0.199	<0.0608	0.08	0.04	<0.13	<0.13	<0.13	<0.048	<0.048	0.13	0.12	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Total DDD	ng/L	<0.5840	<0.2676	0.31	0.17	<0.80	<0.80	<0.80	<0.18	<0.18	0.80	0.75	0.75	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Total DDT	ng/L	<1.336	<0.429	0.64	0.26	<2.2	<2.2	<2.2	<0.42	<0.42	2.19	2.06	2.04	0.41	0.41	0.41	0.41	0.42	0.42	0.42	0.41	0.41	0.41	0.41	0.41
Methyl Mercury	ng/L	1.170	0.988	0.5770	0.4612						0.0257	0.0308	0.0441	0.0190	0.0186	0.0175	0.0157	0.0131	0.0127	0.0137	0.0155	0.0161	0.0162	0.0169	0.0179
2,3,7,8-TCDD	ng/L	0.002	<0.001248	1.09E-03	5.57E-04						4.76E-05	5.47E-05	7.20E-05	2.30E-05	2.25E-05	2.12E-05	1.90E-05	1.58E-05	1.54E-05	1.65E-05	1.87E-05	1.95E-05	1.96E-05	2.04E-05	2.17E-05
1,2,3,7,8-PCDD	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,4,7,8-HCDD	ng/L	<5.66E-04	<5.05E-04	2.60E-04	2.37E-04						1.18E-05	1.41E-05	2.17E-05	9.76E-06	9.56E-06	8.98E-06	8.07E-06	6.73E-06	6.52E-06	7.02E-06	7.92E-06	8.26E-06	8.33E-06	8.66E-06	9.19E-06
1,2,3,6,7,8-HCDD	ng/L	<9.00E-04	<5.70E-04	4.93E-04	3.02E-04						2.17E-05	2.51E-05	3.40E-05	1.25E-05	1.22E-05	1.15E-05	1.03E-05	8.59E-06	8.33E-06	8.96E-06	1.01E-05	1.06E-05	1.06E-05	1.11E-05	1.17E-05
1,2,3,7,8,9-HCDD	ng/L	<5.70E-04	<5.10E-04	2.60E-04	2.37E-04						1.18E-05	1.41E-05	2.17E-05	9.76E-06	9.56E-06	8.98E-06	8.07E-06	6.73E-06	6.52E-06	7.02E-06	7.92E-06	8.26E-06	8.33E-06	8.66E-06	9.19E-06
1,2,3,4,6,7,8-HCDD	ng/L	<1.14E-02	<6.55E-03	6.53E-03	3.19E-03						2.85E-04	3.27E-04	4.30E-04	1.31E-04	1.29E-04	1.21E-04	1.09E-04	9.06E-05	8.78E-05	9.45E-05	1.07E-04	1.11E-04	1.12E-04	1.17E-04	1.24E-04
OCDD	ng/L	<3.99E-02	<3.11E-02	2.29E-02	1.41E-02						1.01E-03	1.17E-03	1.58E-03	5.80E-04	5.68E-04	5.34E-04	4.79E-04	4.00E-04	3.88E-04	4.17E-04	4.71E-04	4.91E-04	4.95E-04	5.15E-04	5.46E-04
2,3,7,8-TCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,7,8-PCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
2,3,4,7,8-PCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,4,7,8-HCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,6,7,8-HCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,7,8,9-HCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
2,3,4,6,7,8-HCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
1,2,3,4,6,7,8-HCDF	ng/L	<1.68E-03	<1.10E-03	8.26E-04	5.70E-04						3.64E-05	4.29E-05	5.91E-05	2.35E-05	2.30E-05	2.17E-05	1.95E-05	1.62E-05	1.57E-05	1.69E-05	1.91E-05	1.99E-05	2.01E-05	2.09E-05	2.22E-05
1,2,3,4,7,8,9-HCDF	ng/L	<5.05E-04	<5.05E-04	2.37E-04	2.27E-04						1.09E-05	1.28E-05	2.06E-05	9.37E-06	9.18E-06	8.63E-06	7.75E-06	6.46E-06	6.26E-06	6.74E-06	7.61E-06	7.94E-06	8.00E-06	8.32E-06	8.83E-06
OCDF	ng/L	0.002	<0.00144	1.05E-03	6.15E-04						4.62E-05	5.35E-05	7.18E-05	2.54E-05	2.49E-05	2.34E-05	2.10E-05	1.75E-05	1.70E-05	1.83E-05	2.06E-05	2.15E-05	2.17E-05	2.25E-05	2.39E-05
Aldrin	ng/L	<0.975	<0.0248	0.32	0.07	<0.014	<0.014	<0.014	<0.01	<0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Dieldrin	ng/L	<0.57	0.17	0.34	0.09	0.06	0.06	0.06	<0.019	<0.019	0.07	0.07	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chlordane Total	ng/L	<0.424	<0.115	0.19	0.08	<0.12	<0.12	<0.12	<0.029	<0.029	0.13	0.12	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Endrin	ng/L	<0.60	<0.0416	0.24	0.06	<0.037	<0.037	<0.037	<0.025	<0.025	0.05	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Heptachlor	ng/L	<0.787	<0.012	0.32	0.07	<0.016	<0.016	<0.016	<0.01	<0.01	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mirex	ng/L	<0.272	<0.029	0.12	0.04	<0.014	<0.014	<0.014	<0.01	<0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Trihalomethanes	mg/L	<0.00530	<0.00505	2.44E-03	2.33E-03						1.120E-04	1.314E-04	2.113E-04	9.612E-05	9.415E-05	8.850E-05	7.948E-05	6.625E-05	6.424E-05	6.913E-05	7.807E-05	8.141E-05	8.207E-05	8.532E-05	9.052E-05

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Section 8

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Attachment A

Summary Statistics for 2011-2014 AIWWTP Effluent Quality Data

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Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
E. Coli	Bacteriological	MPN/100 mL	64	11	17%	18	39	<64	<659	1161
Enterococci	Bacteriological	MPN/100 mL	61	28	46%	10	18	<28	<157	312
Fecal Coliform	Bacteriological	MPN/100 mL	386	157	41%	<3.9	20	<27	<161	630
Aluminum	Dissolved Metals	µg/L	207	0	0%	8	13	13.5	19	22
Antimony	Dissolved Metals	µg/L	23	23	100%	<0.5	<0.5	<0.5*	NC	<0.5
Arsenic	Dissolved Metals	µg/L	171	20	12%	0.5	0.6	<0.69	<1.0	1.5
Barium	Dissolved Metals	µg/L	207	16	8%	1.2	3.2	<4.6	<20	<20
Beryllium	Dissolved Metals	µg/L	12	12	100%	<0.10	<0.5	<0.5*	NC	<0.5
Boron	Dissolved Metals	µg/L	207	0	0%	90	138	144	195	286
Cadmium	Dissolved Metals	µg/L	212	206	97%	0.0128	<0.20	<0.20*	NC	2.0
Calcium	Dissolved Metals	µg/L	171	0	0%	8460	11300	12089	16800	18500
Chromium	Dissolved Metals	µg/L	207	36	17%	0.5	0.6	<1.1	1.4	30.2
Cobalt	Dissolved Metals	µg/L	207	160	77%	0.5	0.5	0.5*	<0.67	1.2
Copper	Dissolved Metals	µg/L	207	0	0%	2.7	8.3	9.7	21.4	29.1
Iron	Dissolved Metals	µg/L	207	0	0%	81	130	130	174	285
Lead	Dissolved Metals	µg/L	207	207	100%	<0.5	<0.5	<0.5*	NC	<1.0
Lithium	Dissolved Metals	µg/L	23	23	100%	<2.0	<50	<50*	NC	<50
Magnesium	Dissolved Metals	µg/L	171	0	0%	2370	2900	3038	3920	4420
Manganese	Dissolved Metals	µg/L	207	0	0%	4.4	50	49.5	68.9	74.9
Mercury	Dissolved Metals	µg/L	17	17	100%	<0.005	<0.20	<0.20*	NC	<0.20
Molybdenum	Dissolved Metals	µg/L	207	13	6%	0.6	1.0	<1.1	<1.9	13.5
Nickel	Dissolved Metals	µg/L	207	16	8%	1.6	2.2	<2.7	<5.0	21.4
Potassium	Dissolved Metals	µg/L	16	0	0%	12100	12600	12950	14500	15700
Selenium	Dissolved Metals	µg/L	171	170	99%	<0.5	<0.5	<0.5*	NC	<1.0
Silver	Dissolved Metals	µg/L	207	207	100%	<0.05	<0.5	<0.5*	NC	<0.5
Sodium	Dissolved Metals	µg/L	171	0	0%	23100	40100	39986	52250	59300
Strontium	Dissolved Metals	µg/L	7	0	0%	35	37	36.5	NC	37.1
Thallium	Dissolved Metals	µg/L	23	23	100%	<0.2	<0.2	<0.2*	NC	<0.5
Titanium	Dissolved Metals	µg/L	16	16	100%	<50	<50	<50*	NC	<50
Uranium	Dissolved Metals	µg/L	23	23	100%	<0.2	<0.2	<0.2*	NC	<0.5
Vanadium	Dissolved Metals	µg/L	23	23	100%	<0.5	<30	<30*	NC	<30
Zinc	Dissolved Metals	µg/L	207	0	0%	9	14	16.5	29.7	51
2,4'-DDD	Herbicides	ng/l	17	10	59%	0.115	<0.183	<0.183*	<0.310	0.337
2,4'-DDE	Herbicides	ng/l	17	17	100%	<0.0296	<0.0608	<0.0608*	NC	<0.199
2,4'-DDT	Herbicides	ng/l	17	17	100%	<0.0845	<0.213	<0.213*	NC	<0.725
3[OH] Carbofuran	Herbicides	ng/l	11	10	91%	<0.482	<0.494	<0.494*	<2.59	2.78
4,4'-DDD	Herbicides	ng/l	17	17	100%	<0.0323	<0.0896	<0.0896*	NC	<0.281
4,4'-DDE	Herbicides	ng/l	17	8	47%	<0.169	<0.262	0.373	0.876	1.23
4,4'-DDT	Herbicides	ng/l	17	17	100%	<0.0701	<0.197	<0.197*	NC	<0.611
Total DDT	Herbicides	ng/l	17	17	100%	<0.155	<0.429	<0.429*	NC	<1.336
Total DDD	Herbicides	ng/l	17	17	100%	<0.1503	<0.2676	<0.2676*	NC	<0.5840
Alachlor	Herbicides	ng/l	11	11	100%	<0.95	<1.51	<1.501*	NC	<2.60
Atrazine	Herbicides	ng/L	8	8	100%	<0.504	<0.680	<0.680*	NC	<1.28
Cyanazine	Herbicides	ng/L	8	8	100%	<1.46	<3.09	<3.09*	NC	<8.38
Dacthal	Herbicides	ng/l	11	8	73%	0.042	<0.0992	<0.0992*	<0.1055	<0.110
Desethylatrazine	Herbicides	ng/L	8	8	100%	<0.189	<0.255	<0.255*	NC	<0.526
Diazinon	Herbicides	ng/l	12	0	0%	0.342	1.54	2.68	7.91	8.2
Diazinon-Oxon	Herbicides	ng/L	8	8	100%	<0.542	<1.23	<1.23*	NC	<2.7
Dieldrin	Herbicides	ng/l	17	8	47%	0.066	<0.10	<0.166	<0.57	<0.68
Dimethenamid	Herbicides	ng/l	11	11	100%	<0.099	<0.129	<0.129*	NC	<0.467
Dioxacarb	Herbicides	ng/l	11	11	100%	<0.337	<0.353	<0.353*	NC	<2.44
Endosulphan Sulphate	Herbicides	ng/l	17	17	100%	<0.0734	<0.214	<0.21*	NC	<0.68
Endrin	Herbicides	ng/l	17	16	94%	<0.0099	<0.0416	<0.0416*	<0.60	<0.72
Endrin Aldehyde	Herbicides	ng/l	6	6	100%	<0.101	<0.19	<0.19*	NC	<1.08
Endrin Ketone	Herbicides	ng/l	17	17	100%	<0.0112	<0.101	<0.101*	NC	<0.20
Ethalfluralin	Herbicides	ng/l	11	11	100%	<0.0996	<0.227	<0.227*	NC	<0.573
Flufenacet	Herbicides	ng/l	11	11	100%	<7.2	<20	<20*	NC	<101
Flutriafol	Herbicides	ng/l	11	11	100%	<0.72	<2.19	<2.19*	NC	<3.65
Hexachlorobenzene	Herbicides	ng/l	17	5	29%	0.050	0.071	<0.083	<0.117	0.133
Hexazinone	Herbicides	ng/L	8	8	100%	<0.64	<1.20	<1.20*	NC	<2.49
Linuron	Herbicides	ng/l	11	11	100%	<0.89	<1.47	<1.47*	NC	<4.87
Metribuzin	Herbicides	ng/L	8	8	100%	<0.899	<1.26	<1.26*	NC	<7.54
Pendimethalin	Herbicides	ng/l	11	11	100%	<1.38	<3.66	<3.66*	NC	<8.68
Quintozene	Herbicides	ng/l	11	11	100%	<0.0128	<0.0992	<0.0992*	NC	<0.1100
Simazine	Herbicides	ng/L	8	2	25%	0.932	2.16	<2.52	NC	5.44
Tebuconazol	Herbicides	ng/l	11	4	36%	6.98	<17.6	<18.8	<38.7	41.2
Tecnazene	Herbicides	ng/l	11	11	100%	<0.0101	<0.0992	<0.0992*	NC	<0.1100
Triallate	Herbicides	ng/l	11	11	100%	<0.0753	<0.120	<0.120*	NC	<0.219
Trifluralin	Herbicides	ng/l	11	8	73%	<0.0992	<0.0990	<0.0990*	<0.212	<0.219

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
Aldicarb	Insecticides	ng/l	11	11	100%	<0.482	<0.494	<0.494*	NC	<2.44
Aldicarb Sulfone	Insecticides	ng/l	11	11	100%	<0.963	<1.01	<1.01*	NC	<7.42
Aldicarb Sulfoxide	Insecticides	ng/l	11	11	100%	<0.482	<0.498	<0.498*	NC	<2.47
Aldrin	Insecticides	ng/l	17	17	100%	<0.0099	<0.0248	<0.0248*	NC	<0.975
Allethrin	Insecticides	ng/L	14	14	100%	<10.8	<61.2	<61.2*	NC	<155
alpha-Endosulphan	Insecticides	ng/l	17	**17**	**100%**	<0.24	<0.62	<0.62*	<0.8	<0.82
Ametryn	Insecticides	ng/L	8	8	100%	<0.106	<0.254	<0.254*	NC	<0.886
Aminocarb	Insecticides	ng/l	11	11	100%	<0.482	<0.494	<0.494*	NC	<2.44
Azinphos-Methyl	Insecticides	ng/L	7	7	100%	<3.94	<6.73	<6.73*	NC	<15.4
Bendiocarb	Insecticides	ng/l	11	11	100%	<0.963	<0.988	<0.988*	NC	<4.87
beta-Endosulphan	Insecticides	ng/l	17	17	100%	<0.128	<0.406	<0.406*	NC	<0.761
Bifenthrin	Insecticides	ng/L	12	**12**	**100%**	<0.995	<2.13	<2.13*	<3.58	<3.90
Butralin	Insecticides	ng/l	11	11	100%	<0.898	<2.15	<2.15*	NC	<6.28
Butylate	Insecticides	ng/l	11	11	100%	<0.115	<0.294	<0.294*	NC	<0.499
Captan	Insecticides	ng/l	11	11	100%	<1.33	<2.98	<2.98*	NC	<22.9
Carbaryl	Insecticides	ng/l	11	1	9%	<2.43	6.73	<79.8	<284	309
Carbofuran	Insecticides	ng/l	11	11	100%	<0.48	<0.49	<0.49*	NC	<2.44
Chlordane, alpha (cis)	Insecticides	ng/l	17	16	94%	<0.0121	<0.05	<0.05*	<0.192	<0.208
Chlordane, gamma (trans)	Insecticides	ng/l	17	15	88%	<0.0`53	<0.055	<0.055*	<0.193	<0.258
Chlordane Total	Insecticides	ng/l	17	17	100%	<0.031	<0.115	<0.115*	NC	<0.424
Chlordane, oxy-	Insecticides	ng/l	17	16	94%	<0.0099	<0.0531	<0.0531*	<1.614	<2.59
Chlorothalonil	Insecticides	ng/l	11	8	73%	0.0440	<0.0996	<0.0996*	<0.107	<0.110
Chlorpyriphos	Insecticides	ng/l	13	7	54%	0.77	<1.6	<1.6*	<3.7	<4.9
Chlorpyriphos-Methyl	Insecticides	ng/L	8	8	100%	<0.0989	<0.0997	<0.0997*	NC	<0.110
Chlorpyriphos-Oxon	Insecticides	ng/L	8	8	100%	<0.152	<0.206	<0.206*	NC	<2.37
Cinerin I	Insecticides	ng/L	14	14	100%	<1.70	<5.44	<5.44*	NC	<34.9
Cinerin II	Insecticides	ng/L	14	14	100%	<1.45	<4.93	<4.93*	NC	<16.7
Cyfluthrin	Insecticides	ng/L	14	14	100%	<1.6	<5.7	<5.7*	NC	<12.2
Cypermethrin	Insecticides	ng/L	18	18	100%	<0.47	<1.16	<1.16*	NC	<4.4
Deltamethrin	Insecticides	ng/L	14	14	100%	<0.50	<1.2	<1.2*	NC	<2.9
Dimethoate	Insecticides	ng/L	8	8	100%	<1.36	<3.07	<3.07*	NC	<19.7
Disulfoton	Insecticides	ng/L	8	8	100%	<0.506	<1.99	<1.99*	NC	<21.2
Disulfoton Sulfone	Insecticides	ng/L	8	**8**	**100%**	<0.251	1	0.792*	NC	<1.56
Ethion	Insecticides	ng/L	8	8	100%	<0.132	<0.448	<0.448*	NC	<2.23
Fenitrothion	Insecticides	ng/L	8	8	100%	<0.128	<0.282	<0.282*	NC	<1.08
Fenpropathrin	Insecticides	ng/L	14	14	100%	<5.04	<8.50	<8.50*	NC	<17.8
Fenvalerate	Insecticides	ng/L	14	14	100%	<0.52	<0.9	<0.9*	NC	<2.9
Flucythrinate	Insecticides	ng/L	14	14	100%	<0.50	<0.61	<0.61*	NC	<1.7
Fonofos	Insecticides	ng/L	8	8	100%	<0.0992	<0.0997	<0.0997*	NC	<0.110
HCH, alpha	Insecticides	ng/l	17	9	53%	0.024	<0.046	<0.046*	<0.66	<0.789
HCH, beta	Insecticides	ng/l	17	3	18%	0.273	0.49	<0.473	<0.634	<0.745
HCH, delta	Insecticides	ng/l	17	17	100%	<0.0179	<0.050	<0.050*	NC	<1.44
HCH, gamma	Insecticides	ng/l	17	7	41%	0.120	<0.23	<0.46	1.52	1.52
Heptachlor	Insecticides	ng/l	17	15	88%	<0.0056	<0.012	<0.012*	<0.787	0.954
Heptachlor Epoxide	Insecticides	ng/l	17	17	100%	<0.028	<0.074	<0.074*	NC	<1.13
Imidacloprid	Insecticides	ng/l	11	0	0%	19	38	54.1	101	101
Jasmolin I	Insecticides	ng/L	14	14	100%	<5.83	<18.9	<18.9*	NC	<129
Jasmolin II	Insecticides	ng/L	14	14	100%	<5.60	<19.0	<19.0*	NC	<77.7
L-Cyhalothrin	Insecticides	ng/L	14	14	100%	<0.50	<1.1	<1.1*	NC	<1.6
Malathion	Insecticides	ng/L	8	6	75%	<0.42	<1.4	<1.4*	NC	<6.2
Methiocarb	Insecticides	ng/l	11	11	100%	<0.963	<0.998	<0.998*	NC	<4.92
Methomyl	Insecticides	ng/l	11	11	100%	<0.482	<0.494	<0.494*	NC	<2.44
Methoprene	Insecticides	ng/l	11	11	100%	<51.4	<87.2	<87.2*	NC	<330
Methoxychlor	Insecticides	ng/l	17	15	88%	0.0156	<1.42	<1.42*	<4.12	<5.96
Metolachlor	Insecticides	ng/l	11	9	82%	0.47	0.717	0.717*	<2.50	<2.73
Mexacarbate	Insecticides	ng/l	11	11	100%	<0.482	<0.49	<0.49*	NC	<2.40
Mirex	Insecticides	ng/l	17	16	94%	<0.0100	<0.029	<0.029*	<0.272	<0.296
Nonachlor, cis-	Insecticides	ng/l	17	16	94%	<0.0100	<0.0512	<0.0512*	<0.0873	<0.0873
Nonachlor, trans-	Insecticides	ng/l	17	15	88%	<0.0127	0.0427	0.0427*	<0.0847	<0.0856
Oxamyl	Insecticides	ng/l	11	11	100%	<0.482	<0.504	<0.504*	NC	<2.49
Parathion-Ethyl	Insecticides	ng/L	8	8	100%	<0.369	<0.462	<0.462*	NC	<0.849
Parathion-Methyl	Insecticides	ng/L	8	8	100%	<1.80	<5.74	<5.74*	NC	<14.1
Permethrin	Insecticides	ng/L	16	**4**	**25%**	<6.37	12.9	<13.4	<19.1	19.9
Perthane	Insecticides	ng/l	11	11	100%	<0.872	<4.84	<4.84*	NC	<8.04
Phenothrin	Insecticides	ng/L	12	**11**	**92%**	<0.66	<1.83	<1.83*	<3.66	<4.09
Phorate	Insecticides	ng/L	8	**8**	**100%**	<0.311	<1.18	<1.19*	NC	<3.98
Phosmet	Insecticides	ng/L	8	8	100%	<0.374	<0.746	<0.746*	NC	<1.38
Piperonyl butoxide	Insecticides	ng/L	16	**8**	**50%**	61	129	<223.61	<544	<544
Pirimicarb	Insecticides	ng/l	10	10	100%	<0.482	<0.495	<0.495*	NC	<2.44
Pirimiphos-Methyl	Insecticides	ng/L	8	8	100%	<0.099	<0.106	<0.106*	NC	<0.322
Prallethrin	Insecticides	ng/L	14	14	100%	<57	<135	<135*	NC	<232
Promecarb	Insecticides	ng/l	11	11	100%	<0.963	<0.988	<0.988*	NC	<4.87
Propoxur	Insecticides	ng/l	11	2	18%	1.3	<2.4	<2.5	<3.8	4.3

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
Pyrethrin I	Insecticides	ng/L	14	14	100%	<4.50	<15.6	<15.6*	NC	<69.4
Pyrethrin II	Insecticides	ng/L	14	14	100%	<4.13	<12.9	<12.9*	NC	<48.7
Resmethrin	Insecticides	ng/L	14	**14**	**100%**	<1.60	<2.58	<2.58*	NC	<17.6
Terbufos	Insecticides	ng/L	8	**7**	**100%**	<0.171	<1.02	<1.02*	NC	<8.74
Tetramethrin	Insecticides	ng/L	14	14	100%	<1.27	<2.97	<2.97*	NC	<7.56
Calcium (Total)	Major Ions	µg/L	207	0	0%	8800	12400	12733	17540	19500
Fluoride (Total)	Major Ions	mg/L	24	8	33%	0.05	0.06	<0.07	<0.12	0.14
Magnesium (Total)	Major Ions	µg/L	207	0	0%	2440	3110	3184	4060	5610
Sodium (Total)	Major Ions	µg/L	171	0	0%	23700	41500	41393	52950	61800
Sulfate (Total)	Major Ions	mg/L	36	0	0%	12	18	17.0	20.2	21.1
12-Chlorodehydroabietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
14-Chlorodehydroabietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Abietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Arachidic Acid	Miscellaneous	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.005
Behenic Acid	Miscellaneous	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.005
Cyanide	Miscellaneous	mg/L	41	38	93%	0.0010	<0.02	<0.02*	<0.02	<0.02
DBT++	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Dehydroabietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Dibutyltin dichloride	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Dichlorodehydroabietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Diphenyltin dichloride	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
DPhT++	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
Hexachlorobutadiene	Miscellaneous	ng/l	6	5	83%	<0.029	<0.133	<0.133*	NC	<0.357
Isopimaric & Palustric Acids	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Lauric Acid	Miscellaneous	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.006
Levopimaric Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Lignoceric Acid	Miscellaneous	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.005
Linoleic Acid	Miscellaneous	mg/L	4	2	50%	<0.005	<0.009	<0.01	NC	0.02
Linolenic Acid	Miscellaneous	mg/L	4	4	100%	<0.005	<0.007	<0.007*	NC	<0.008
MBT+++	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Monobutyltin trichloride	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Monophenyltin trichloride	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
MPhT+++	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
Myristic Acid	Miscellaneous	mg/L	4	2	50%	<0.005	<0.01	<0.01	NC	0.02
Neoabietic Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Octachlorostyrene	Miscellaneous	ng/l	11	11	100%	<0.0099	<0.0105	<0.0105*	NC	<0.0220
Oleic Acid	Miscellaneous	mg/L	4	0	0%	0.01	0.03	0.03	NC	0.05
Palmitic Acid	Miscellaneous	mg/L	4	2	50%	0.03	<0.03	<0.04	NC	<0.07
Pimaric Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Sandaracopimaric Acid	Miscellaneous	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Stearic Acid	Miscellaneous	mg/L	4	0	0%	0.03	0.03	0.04	NC	0.05
TBT+	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Total Fatty Acids	Miscellaneous	mg/L	4	0	0%	0.06	0.09	0.09	NC	0.13
Total Resin Acids	Miscellaneous	mg/L	4	4	100%	<0.01	<0.01	<0.01*	NC	<0.01
TPhT+	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
Tributyltin Chloride	Miscellaneous	ug/L	3	3	100%	<0.001	<0.001	<0.001*	NC	<0.001
Triphenyltin chloride	Miscellaneous	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
WHO 2005 TOTAL (TEQ ND=0)	Miscellaneous	ng/l	3	0	0%	0.002	0.002	0.002	NC	0.002
WHO 2005 TOTAL (TEQ ND=1/2 DL)	Miscellaneous	ng/l	3	0	0%	0.10	0.11	0.11	NC	0.13
Ammonia (un-ionized)	Nutrients	mg/L	626	0	0%	0.11	0.53	0.52	0.78	0.93
Ammonia as N	Nutrients	mg/L	1163	0	0%	13	32	31.4	38.7	46.7
Dissolved Organic Carbon	Nutrients	mg/L	149	0	0%	7.1	12	11.6	14.6	20.4
Nitrogen - Nitrate as N	Nutrients	mg/L	432	177	41%	0.01	0.01	<0.02	<0.07	0.13
Nitrogen - Nitrite as N	Nutrients	mg/L	432	59	14%	0.01	0.04	<0.05	<0.12	0.39
Dissolved Phosphorus	Nutrients	µg/L	191	0	0%	482	2270	2276	3440	3980
Total Phosphorus	Nutrients	µg/L	247	0	0%	747	2640	2603	3690	4250
Total Kjeldahl Nitrogen	Nutrients	mg/L	247	0	0%	16	34	33.5	41	45.0
Total Organic Carbon	Nutrients	mg/L	134	0	0%	9.2	14	13.9	17.3	20.7
1,1,1,2-Tetrachloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,1,1-Trichloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,1,2,2-Tetrachloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,1,2-Trichloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,1-Dichloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,1-Dichloroethylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,2-Dichlorobenzene	Organics?	mg/L	7	5	71%	<2.01E-07	<7.00E-04	<7.00E-04*	NC	<7.00E-04
1,2-Dichloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,2-Dichloropropane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
1,3-Dichlorobenzene	Organics?	mg/L	7	6	86%	<2.01E-07	<1.00E-03	<1.00E-03*	NC	<1.00E-03
1,3-Dichloropropene (cis & trans)	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
1,4-Dichlorobenzene	Organics?	mg/L	7	4	57%	3.49E-04	<0.001	<0.001*	NC	<0.001
Aniline	Organics?	ug/L	4	4	100%	<5.0	<5.0	<5.0*	NC	<5.0
Bromodichloromethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Bromoform	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Carbon Tetrachloride	Organics?	mg/L	4	4	100%	<5.00E-04	<5.00E-04	<5.00E-04*	NC	<5.00E-04
Chlorobenzene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Chloroethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Chloroform	Organics?	mg/L	4	0	0%	0.002	0.002	0.002	NC	0.002
Chloromethane	Organics?	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.005
cis-1,2-Dichloroethylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
cis-1,3-Dichloropropylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Dibromochloromethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Dichloromethane	Organics?	mg/L	4	4	100%	<0.005	<0.005	<0.005*	NC	<0.005
Diisopropanolamine	Organics?	mg/L	4	4	100%	<0.10	<0.10	<0.10*	NC	<0.10
Tetrachloroethylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
trans-1,2-Dichloroethylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
trans-1,3-Dichloropropylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Trichloroethylene	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Trichlorofluoromethane	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
Vinyl Chloride	Organics?	mg/L	4	4	100%	<0.001	<0.001	<0.001*	NC	<0.001
2,3,4,5-Tetrachlorophenol	Phenols	mg/L	4	4	100%	<2.00E-04	<2.00E-04	<2.00E-04*	NC	<2.00E-04
2,3,4,6-Tetrachlorophenol	Phenols	mg/L	4	3	75%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	1.10E-04
2,3,4-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
2,3,5,6-Tetrachlorophenol	Phenols	mg/L	4	4	100%	<2.00E-04	<2.00E-04	<2.00E-04*	NC	<2.00E-04
2,3,5-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
2,3,6-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
2,3-Dichlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
2,4 & 2,5-Dichlorophenol	Phenols	mg/L	4	3	75%	1.21E-04	<1.75E-04	<1.75E-04*	NC	<2.00E-04
2,4,5-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
2,4,6-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
2,6-Dichlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
2-Chlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
3,4,5-Trichlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
3,4-Dichlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
3,5-Dichlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
3-Chlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
4-Chloro-3-methylphenol	Phenols	mg/L	4	4	100%	<5.00E-04	<5.00E-04	<5.00E-04*	NC	<5.00E-04
4-Chlorophenol	Phenols	mg/L	4	4	100%	<5.00E-05	<5.00E-05	<5.00E-05*	NC	<5.00E-05
4-Nonylphenol diethoxylates	Phenols	ng/L	38	3	8%	<23	914.5	<1183	<2568	3580
4-Nonylphenol monoethoxylates	Phenols	ng/L	38	0	0%	180	734.5	768	1317.5	1430
4-Nonylphenols	Phenols	ng/L	38	0	0%	463	847.5	848	1444.5	1530
Nonylphenol TEQ	Phenols	ng/L	10	0	0%	920	1105	1158	NC	1650
Octylphenol	Phenols	ng/L	38	37	97%	<1.6	<3.7	<3.7*	NC	<38.6
Pentachlorophenol	Phenols	mg/L	4	4	100%	<1.00E-04	<1.00E-04	<1.00E-04*	NC	<1.00E-04
Carbonaceous Biochemical Oxygen Demand (CBOD5)	Physical Parameters	mg/L	741	20	3%	4.0	7.0	<6.9	10.0	20.0
Conductivity (conventiona)	Physical Parameters	µmhos/cm	155	0	0%	343	561	559	647.3	722
Conductivity	Physical Parameters	µS/cm	92	0	0%	315	580	599	717	1486
Dissolved Oxygen	Physical Parameters	mg/L	92	0	0%	3.5	4.0	4.3	5.8	6.0
Dissolved Oxygen % Saturation	Physical Parameters	% Sat	89	0	0%	37	43	45.1	64.6	67.5
Hardness as CaCO3	Physical Parameters	mg/L	210	0	0%	32	45	44.8	59.3	64.2
Oil and Grease	Physical Parameters	mg/L	36	32	89%	3.0	3.0	3.0*	<4.0	4.0
pH (field)	Physical Parameters	pH units	92	0	0%	6.5	7.1	7.1	7.2	7.2
pH (lab)	Physical Parameters	pH units	155	0	0%	6.7	7.1	7.1	7.3	7.3
Salinity	Physical Parameters	ppt	89	0	0%	0.29	0.33	0.34	0.4	0.78

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Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
Temperature	Physical Parameters	°C	91	0	0%	10	16	17.8	22.6	23.2
Total Residual Chlorine	Physical Parameters	mg/l	1100	1100	100%	<0.02	<0.02	<0.02*	NC	<0.10
Total Suspended Solids	Physical Parameters	mg/L	1982	0	0%	4.0	9.0	9.3	14.0	36.0
Volatile Suspended Solids	Physical Parameters	mg/L	152	0	0%	3.0	7.0	7.2	11.0	22.0
Deca-BDE-209	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	2090	4185	4387	6635	7350
Di-BDE-10	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<0.367	<0.694	<0.694*	NC	<1.09
Di-BDE-12 + 13	Polybrominated Diphenyl Ethers	pg/L	12	8	67%	<0.367	1.11	1.11	NC	<1.85
Di-BDE-15	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	3.95	5.06	5.16	6.54	6.77
Di-BDE-7	Polybrominated Diphenyl Ethers	pg/L	12	8	67%	<0.834	<1.46	<1.46*	1.84	1.9
Di-BDE-8 + 11	Polybrominated Diphenyl Ethers	pg/L	12	5	42%	<0.871	1.29	1.30	1.66	1.74
Hepta-BDE-181	Polybrominated Diphenyl Ethers	pg/L	12	11	92%	<0.675	<1.96	<1.96*	NC	<5.06
Hepta-BDE-183	Polybrominated Diphenyl Ethers	pg/L	12	2	17%	33.1	57.6	54.1	68.5	72.5
Hepta-BDE-190	Polybrominated Diphenyl Ethers	pg/L	12	10	83%	2.84	<8.32	<8.32*	NC	<9.54
Hexa-BDE-128	Polybrominated Diphenyl Ethers	pg/L	12	11	92%	<1.47	<5.04	<5.04*	NC	<7.04
Hexa-BDE-138 + 166	Polybrominated Diphenyl Ethers	pg/L	12	1	8%	20.6	34	35.9	53.3	54.8
Hexa-BDE-140	Polybrominated Diphenyl Ethers	pg/L	12	1	8%	6.40	9.27	9.87	14.1	14.3
Hexa-BDE-153	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	205	375	284	375	382
Hexa-BDE-154	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	160	223	228	283	292
Hexa-BDE-155	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	11.5	18.5	18.4	24.6	27.2
Nona-BDE-206	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<101	<327	<327*	NC	<505
Nona-BDE-207	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<99.1	<425	<425*	NC	<755
Nona-BDE-208	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<67.5	<293	<293*	NC	<594
Octa-BDE-203	Polybrominated Diphenyl Ethers	pg/L	12	3	25%	30.5	71.9	87.6	183	276
Penta-BDE-100	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	434	611	622	797	832
Penta-BDE-105	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<2.34	<4.35	<4.35*	NC	<7.65
Penta-BDE-116	Polybrominated Diphenyl Ethers	pg/L	12	9	75%	<3.23	<6.50	<6.50*	NC	67.4
Penta-BDE-119 + 120	Polybrominated Diphenyl Ethers	pg/L	12	2	17%	5.99	8.91	8.85	12.4	11.6
Penta-BDE-126	Polybrominated Diphenyl Ethers	pg/L	12	10	83%	<1.20	<2.32	<2.32*	NC	4.77
Penta-BDE-85	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	84.6	120.5	128	170	183
Penta-BDE-99	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	2160	3080	3099	4007	4150
Tetra-BDE-47	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	2310	3200	3270	4066	4220
Tetra-BDE-49	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	54.8	83.2	84.7	110	124
Tetra-BDE-51	Polybrominated Diphenyl Ethers	pg/L	12	1	8%	7.59	10.6	10.4	13.0	<14.7
Tetra-BDE-66	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	41.6	61.8	61.9	85.4	103
Tetra-BDE-71	Polybrominated Diphenyl Ethers	pg/L	12	2	17%	8.75	11.1	11.8	16.3	17.6
Tetra-BDE-75	Polybrominated Diphenyl Ethers	pg/L	12	5	42%	<3.13	4.05	4.36	6.14	7.02
Tetra-BDE-77	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<0.362	<0.645	<0.645*	NC	<1.54
Tetra-BDE-79	Polybrominated Diphenyl Ethers	pg/L	12	9	75%	<0.367	<2.45	<2.45*	NC	<29.5
Tri-BDE-17 + 25	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	28.8	34.9	37.8	48.2	52.7
Tri-BDE-28 + 33	Polybrominated Diphenyl Ethers	pg/L	12	0	0%	48.7	61.2	62.0	74.6	76.2
Tri-BDE-30	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<0.364	<0.518	<0.518*	NC	<1.03
Tri-BDE-32	Polybrominated Diphenyl Ethers	pg/L	12	12	100%	<0.364	<0.411	<0.411*	NC	<1.03

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
Tri-BDE-35	Polybrominated Diphenyl Ethers	pg/L	12	7	58%	<0.362	1.07	1.07*	NC	2.24
Tri-BDE-37	Polybrominated Diphenyl Ethers	pg/L	12	7	58%	1.43	<2.58	<2.58*	NC	5.20
Aroclor 1016	Polychlorinated Biphenyls	pg/L	8	8	100%	<0.493	<0.724	<0.724*	NC	<1.82
Aroclor 1242	Polychlorinated Biphenyls	pg/L	8	0	0%	157	269	301	NC	468
Aroclor 1254	Polychlorinated Biphenyls	pg/L	8	0	0%	290	415	432	NC	552
Aroclor 1260	Polychlorinated Biphenyls	pg/L	8	0	0%	20	100	110	NC	182
Decachloro Biphenyl	Polychlorinated Biphenyls	pg/L	9	0	0%	0.96	1.6	2.4	NC	7.9
PCB-1	Polychlorinated Biphenyls	pg/L	15	1	7%	<4.02	19.2	25.7	65.8	66.4
PCB-10	Polychlorinated Biphenyls	pg/L	15	4	27%	0.82	<3.9	<3.4	<6.3	6.7
PCB-103	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.34	0.76	0.76*	<1.5	<1.6
PCB-104	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.18	0.26	0.26*	<0.78	<0.83
PCB-105	Polychlorinated Biphenyls	pg/L	15	0	0%	8.9	13.9	13.3	16.7	16.7
PCB-106	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.47	<0.47*	<1.7	<1.7
PCB-107 + 124	Polychlorinated Biphenyls	pg/L	15	7	47%	<0.904	1.59	1.53	1.91	2
PCB-109	Polychlorinated Biphenyls	pg/L	15	3	20%	1.2	2.0	<2.1	<2.9	3.1
PCB-11	Polychlorinated Biphenyls	pg/L	15	0	0%	54	74	73.5	89.7	94.7
PCB-110 + 115	Polychlorinated Biphenyls	pg/L	15	0	0%	32.0	44.5	45.0	56.2	57.5
PCB-111	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.181	<0.375	<0.375*	NC	<1.37
PCB-112	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.181	<0.375	<0.375*	NC	<1.31
PCB-114	Polychlorinated Biphenyls	pg/L	15	6	40%	0.83	<1.21	<1.24	<1.78	<1.80
PCB-118	Polychlorinated Biphenyls	pg/L	15	0	0%	23.1	36.5	34.7	43.6	45.1
PCB-12 + 13	Polychlorinated Biphenyls	pg/L	15	6	40%	<2.36	3.80	3.93	5.72	6
PCB-120	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.35	<0.35*	NC	<1.3
PCB-121	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.26	<0.40	<0.40*	<1.4	<1.4
PCB-122	Polychlorinated Biphenyls	pg/L	15	11	73%	<0.26	<0.53	<0.53*	<1.9	<1.9
PCB-123	Polychlorinated Biphenyls	pg/L	15	10	67%	<0.50	1.30	1.30*	<1.94	<2.16
PCB-126	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.190	<0.49	<0.49*	NC	<2.16
PCB-127	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.20	<0.48	<0.48*	NC	<1.8
PCB-128 + 166	Polychlorinated Biphenyls	pg/L	15	2	13%	3.35	4.99	5.32	7.61	8.00
PCB-129 + 138 + 160 + 163	Polychlorinated Biphenyls	pg/L	15	0	0%	24.3	37.7	38.6	53.7	57.9
PCB-130	Polychlorinated Biphenyls	pg/L	15	7	47%	<1.31	<2.33	2.30	3.34	3.52
PCB-131	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.39	<0.83	<0.83*	<2.1	<2.3
PCB-132	Polychlorinated Biphenyls	pg/L	15	0	0%	7.8	13	12.3	17	18.3
PCB-133	Polychlorinated Biphenyls	pg/L	15	10	67%	<0.18	0.77	0.77*	<2	<2.2
PCB-134 + 143	Polychlorinated Biphenyls	pg/L	15	8	53%	<1.21	<2.03	<2.03*	2.49	2.61
PCB-135 + 151 + 154	Polychlorinated Biphenyls	pg/L	15	0	0%	7.81	12.3	12.4	17.1	18.8
PCB-136	Polychlorinated Biphenyls	pg/L	15	4	27%	3.4	4.7	<4.8	<6.8	7.2
PCB-137	Polychlorinated Biphenyls	pg/L	15	6	40%	<1.4	<2.0	<2.1	<2.7	<2.9
PCB-139 + 140	Polychlorinated Biphenyls	pg/L	15	9	60%	0.641	<1.12	<1.12*	1.91	<2.03
PCB-14	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.20	<0.71	<0.71*	NC	<4.3
PCB-141	Polychlorinated Biphenyls	pg/L	15	3	20%	<3.7	6.3	<6.2	<8.5	8.6
PCB-142	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.49	<0.49*	NC	<2.2
PCB-144	Polychlorinated Biphenyls	pg/L	15	7	47%	<0.42	<2.0	<1.9	<2.8	3.2
PCB-145	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.34	<0.34*	NC	<1.2
PCB-146	Polychlorinated Biphenyls	pg/L	15	2	13%	3.38	5.98	6.15	9.39	11.7
PCB-147 + 149	Polychlorinated Biphenyls	pg/L	15	0	0%	14.9	27.7	27.6	40.6	43.8
PCB-148	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.18	<0.45	<0.45*	<1.4	<1.5
PCB-15	Polychlorinated Biphenyls	pg/L	15	0	0%	19	26	29.1	45.3	45.6
PCB-150	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.19	<0.32	<0.32*	<1.1	<1.1
PCB-152	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.181	<0.307	<0.307*	NC	<1.04
PCB-153 + 168	Polychlorinated Biphenyls	pg/L	15	0	0%	21.2	34.7	34.3	47.0	50.8
PCB-155	Polychlorinated Biphenyls	pg/L	15	4	27%	1.56	2.37	<2.56	<3.86	3.96
PCB-156+157	Polychlorinated Biphenyls	pg/L	15	1	7%	3.16	4.87	4.95	6.52	6.77
PCB-158	Polychlorinated Biphenyls	pg/L	15	3	20%	2.47	3.83	<3.69	<4.76	5.17
PCB-159	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.18	0.39	0.39*	<1.48	<1.54
PCB-16	Polychlorinated Biphenyls	pg/L	15	2	13%	6.3	13	<11.8	<16.5	17.3
PCB-161	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.182	<0.350	<0.350*	NC	<1.58
PCB-162	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.181	<0.375	<0.375*	<1.49	<1.57
PCB-164	Polychlorinated Biphenyls	pg/L	15	7	47%	<1.49	<2.05	2.18	3.04	3.61
PCB-165	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.181	<0.394	<0.394*	NC	<1.74
PCB-167	Polychlorinated Biphenyls	pg/L	15	5	33%	<0.93	1.45	<1.55	<2.11	2.12
PCB-169	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.181	<0.35	<0.35*	NC	<1.61
PCB-17	Polychlorinated Biphenyls	pg/L	15	0	0%	6.0	18	15.2	22.0	22.3
PCB-170	Polychlorinated Biphenyls	pg/L	15	3	20%	<3.91	<5.96	6.08	8.44	9.13
PCB-171 + 173	Polychlorinated Biphenyls	pg/L	15	6	40%	<1.08	1.72	1.83	2.64	2.98
PCB-172	Polychlorinated Biphenyls	pg/L	15	10	67%	<0.47	<1.3	<1.3*	<1.6	<1.8
PCB-174	Polychlorinated Biphenyls	pg/L	15	2	13%	3.3	5.3	<5.8	<7.7	7.9
PCB-175	Polychlorinated Biphenyls	pg/L	15	11	73%	<0.18	<0.46	<0.46*	<1.4	<1.6
PCB-176	Polychlorinated Biphenyls	pg/L	15	6	40%	<0.45	<1.1	<1.0	1.5	1.7
PCB-177	Polychlorinated Biphenyls	pg/L	15	6	40%	<1.6	3.4	<3.3	<4.7	5.2
PCB-178	Polychlorinated Biphenyls	pg/L	15	3	20%	1.2	1.8	<1.8	<2.4	2.8
PCB-179	Polychlorinated Biphenyls	pg/L	15	3	20%	2.4	<3.8	<3.7	<5	5.3
PCB-18 + 30	Polychlorinated Biphenyls	pg/L	15	0	0%	12.0	27	24.4	32.2	32.6
PCB-180 + 193	Polychlorinated Biphenyls	pg/L	15	2	13%	<9.55	15.0	15.0	19.9	20.5
PCB-181	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.18	<0.49	<0.49*	<1.5	<1.6
PCB-182	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.46	<0.46*	NC	<1.6

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
PCB-183 + 185	Polychlorinated Biphenyls	pg/L	15	4	27%	<0.182	4.44	4.47	6.68	<6.70
PCB-184	Polychlorinated Biphenyls	pg/L	15	2	13%	4.1	5.5	<6.2	<9.8	10.2
PCB-186	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.38	<0.38*	NC	<1.2
PCB-187	Polychlorinated Biphenyls	pg/L	15	2	13%	<5.1	10	<9.7	<13.7	14.9
PCB-188	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.28	<0.28*	NC	<1.1
PCB-189	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.57	<0.57*	NC	<2.15
PCB-19	Polychlorinated Biphenyls	pg/L	15	0	0%	2.7	11	10.1	17.4	17.4
PCB-190	Polychlorinated Biphenyls	pg/L	15	8	53%	<0.73	<1.4	<1.4*	<1.9	<2.2
PCB-191	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.37	<0.37*	<1.2	<1.3
PCB-192	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.40	<0.40*	NC	<1.4
PCB-194	Polychlorinated Biphenyls	pg/L	15	6	40%	<1.4	3.0	<3.1	<4.7	<5.0
PCB-195	Polychlorinated Biphenyls	pg/L	15	7	47%	<0.42	1.4	<1.21	<1.6	<1.9
PCB-196	Polychlorinated Biphenyls	pg/L	15	11	73%	<0.63	1.6	1.6*	<2.1	<2.2
PCB-197 + 200	Polychlorinated Biphenyls	pg/L	15	8	53%	<0.452	<0.882	<0.882*	NC	2.17
PCB-198 + 199	Polychlorinated Biphenyls	pg/L	15	1	7%	2.40	4.22	4.16	5.85	6.26
PCB-2	Polychlorinated Biphenyls	pg/L	15	1	7%	0.753	1.58	<1.56	<2.12	2.14
PCB-20 + 28	Polychlorinated Biphenyls	pg/L	15	0	0%	15	37	31.7	43	44.2
PCB-201	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.27	<0.60	<0.60*	<1.2	<1.2
PCB-202	Polychlorinated Biphenyls	pg/L	15	8	53%	<0.69	1.4	1.4*	<1.6	1.8
PCB-203	Polychlorinated Biphenyls	pg/L	15	7	47%	<1.4	2.6	<2.58	<3.7	3.8
PCB-204	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.18	<0.45	<0.45*	<1.2	<1.2
PCB-205	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.47	<0.47*	NC	<1.6
PCB-206	Polychlorinated Biphenyls	pg/L	15	7	47%	1.1	<2.1	<2.39	<3.8	<4.2
PCB-207	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.69	<0.69*	NC	<3.3
PCB-208	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.35	<.9	<.9*	<3.5	<3.7
PCB-209	Polychlorinated Biphenyls	pg/L	15	8	53%	0.96	1.8	1.8*	<2.6	<2.9
PCB-21 + 33	Polychlorinated Biphenyls	pg/L	15	0	0%	7.98	15.2	14.1	18.5	19.1
PCB-22	Polychlorinated Biphenyls	pg/L	15	0	0%	6.0	13	11.7	15.9	16.9
PCB-23	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.19	<0.19*	<1.1	<1.4
PCB-24	Polychlorinated Biphenyls	pg/L	15	9	60%	<0.19	<0.47	<0.47*	<0.8	<1.0
PCB-25	Polychlorinated Biphenyls	pg/L	15	0	0%	1.3	3.4	3.1	4.3	4.5
PCB-26 + 29	Polychlorinated Biphenyls	pg/L	15	0	0%	3.13	7.61	6.36	8.56	9.32
PCB-27	Polychlorinated Biphenyls	pg/L	15	3	20%	1.0	<3.5	<3.2	<5.2	5.4
PCB-3	Polychlorinated Biphenyls	pg/L	15	2	13%	1.27	<5.12	<4.89	<6.88	7.26
PCB-31	Polychlorinated Biphenyls	pg/L	15	0	0%	14	32	28.2	37.6	41
PCB-32	Polychlorinated Biphenyls	pg/L	15	0	0%	4.0	11	9.5	13.5	13.7
PCB-34	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.25	<0.25*	<1.1	<1.3
PCB-35	Polychlorinated Biphenyls	pg/L	15	4	27%	<1.6	2.4	<2.3	<3.1	3.6
PCB-36	Polychlorinated Biphenyls	pg/L	15	8	53%	0.35	<0.65	<0.65*	<1.1	<1.3
PCB-37	Polychlorinated Biphenyls	pg/L	15	0	0%	3.0	6.7	6.1	9.3	9.5
PCB-38	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.19	<0.19*	NC	<1.3
PCB-39	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.27	<0.27*	<1.1	<1.3
PCB-4	Polychlorinated Biphenyls	pg/L	15	0	0%	28	124	118	216	216
PCB-40 + 41 + 71	Polychlorinated Biphenyls	pg/L	15	0	0%	7.2	12.0	12.0	16	16.7
PCB-42	Polychlorinated Biphenyls	pg/L	15	1	7%	3.0	5.7	<5.5	<7.2	7.6
PCB-43	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.60	<0.91	<0.91*	<1.6	<1.9
PCB-44 + 47 + 65	Polychlorinated Biphenyls	pg/L	15	0	0%	24.8	39.5	37.5	46.0	46.6
PCB-45 + 51	Polychlorinated Biphenyls	pg/L	15	0	0%	4.42	7.66	7.40	10.1	11.1
PCB-46	Polychlorinated Biphenyls	pg/L	15	4	27%	0.77	1.6	<1.6	<2.5	2.7
PCB-48	Polychlorinated Biphenyls	pg/L	15	1	7%	2.7	4.8	<4.8	<6.6	<7.1
PCB-49 + 69	Polychlorinated Biphenyls	pg/L	15	0	0%	8.87	15.7	16.2	23.2	30.6
PCB-5	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.27	<0.77	<0.77*	<4.3	<4.8
PCB-50 + 53	Polychlorinated Biphenyls	pg/L	15	3	20%	<2.15	<4.07	4.18	6.45	7.39
PCB-52	Polychlorinated Biphenyls	pg/L	15	0	0%	31	49	48.4	73.8	82.1
PCB-54	Polychlorinated Biphenyls	pg/L	15	10	67%	<0.18	0.33	0.33*	<1.1	<1.3
PCB-55	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.19	<0.40	<0.40*	NC	<1.7
PCB-56	Polychlorinated Biphenyls	pg/L	15	1	7%	<4.9	8.7	<7.8	<9.8	10.5
PCB-57	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.19	<0.38	<0.38*	NC	<1.6
PCB-58	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.19	<0.41	<0.41*	NC	<1.5
PCB-59 + 62 + 75	Polychlorinated Biphenyls	pg/L	15	2	13%	1	<2.03	1.97	2.82	2.83
PCB-6	Polychlorinated Biphenyls	pg/L	15	0	0%	3.5	7.0	7.7	14.2	14.3
PCB-60	Polychlorinated Biphenyls	pg/L	15	1	7%	<3.0	4.9	<4.6	<5.8	5.9
PCB-61 + 70 + 74 + 76	Polychlorinated Biphenyls	pg/L	15	0	0%	28.7	45.6	43.5	58.5	67
PCB-63	Polychlorinated Biphenyls	pg/L	15	6	40%	0.46	<0.82	<0.8	<1.2	<1.5
PCB-64	Polychlorinated Biphenyls	pg/L	15	0	0%	6.4	11	10.3	13.3	13.4
PCB-66	Polychlorinated Biphenyls	pg/L	15	0	0%	10	18	15.9	20.5	22.2
PCB-67	Polychlorinated Biphenyls	pg/L	15	12	80%	<0.18	<0.58	<0.58*	<1.2	<1.4
PCB-68	Polychlorinated Biphenyls	pg/L	15	2	13%	1.0	1.8	<2.0	<3.5	3.8
PCB-7	Polychlorinated Biphenyls	pg/L	15	8	53%	<0.64	2.7	2.7*	<3.9	<4.3
PCB-72	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.19	<0.36	<0.36*	NC	<3.7
PCB-73	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	<0.29	<0.29*	<1	<1.5
PCB-77	Polychlorinated Biphenyls	pg/L	15	5	33%	<0.95	1.67	<1.74	<3.01	<3.31
PCB-78	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.19	<0.38	<0.38*	<1.6	2.5
PCB-79	Polychlorinated Biphenyls	pg/L	15	8	53%	0.36	0.66	0.66*	<1.5	<1.7
PCB-8	Polychlorinated Biphenyls	pg/L	15	0	0%	12	26	27.1	47.5	49.1
PCB-80	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.36	<0.36*	NC	<1.3
PCB-81	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.19	<0.41	<0.41*	<1.53	<1.63
PCB-82	Polychlorinated Biphenyls	pg/L	15	3	20%	<2.88	4.07	<4.10	<5.30	5.41
PCB-83 + 99	Polychlorinated Biphenyls	pg/L	15	0	0%	15.1	23.5	23.5	31.5	32

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
PCB-84	Polychlorinated Biphenyls	pg/L	15	1	7%	8.15	11.1	<11.3	14.0	14.8
PCB-85 + 116 + 117	Polychlorinated Biphenyls	pg/L	15	3	20%	4.59	7.14	6.76	8.27	8.86
PCB-86 + 87 + 97 + 108 + 119 + 125	Polychlorinated Biphenyls	pg/L	15	1	7%	21.2	29.2	29.6	36.8	37.1
PCB-88 + 91	Polychlorinated Biphenyls	pg/L	15	1	7%	4.11	5.52	5.64	7.21	7.49
PCB-89	Polychlorinated Biphenyls	pg/L	15	13	87%	<0.24	<0.54	<0.54*	<1.9	<1.9
PCB-9	Polychlorinated Biphenyls	pg/L	15	7	47%	<0.83	3.0	<2.88	<5.3	<6.5
PCB-90 + 101 + 113	Polychlorinated Biphenyls	pg/L	15	0	0%	32.6	45.3	44.7	56.3	58.3
PCB-92	Polychlorinated Biphenyls	pg/L	15	3	20%	<0.35	7.5	<7.4	<9.8	10.1
PCB-93 + 95 + 98 + 100 + 102	Polychlorinated Biphenyls	pg/L	15	1	7%	<0.515	35.5	35.7	49.4	50.9
PCB-94	Polychlorinated Biphenyls	pg/L	15	15	100%	<0.18	<0.57	<0.57*	NC	<2.0
PCB-96	Polychlorinated Biphenyls	pg/L	15	14	93%	<0.18	0.33	0.33*	<0.87	<0.93
Total Dichloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	141	276	266	420	422
Total Heptachloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	14	47	49.1	82.3	88.4
Total Hexachloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	90	160	163	234	259
Total Monochloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	3.5	28	32.5	74.2	74.7
Total Nonachloro Biphenyls	Polychlorinated Biphenyls	pg/L	10	0	0%	0.6	2.1	3.8	NC	11.8
Total Octachloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	2.4	8.4	9.2	13.8	13.8
Total PCB	Polychlorinated Biphenyls	pg/L	12	0	0%	681	1115	1158	1647	1680
Total Pentachloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	185	270	263	336	343
Total Tetrachloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	159	248	227	294	301
Total Trichloro Biphenyls	Polychlorinated Biphenyls	pg/L	13	0	0%	84	211	177	235	240
1-Methylnaphthalene	Polycyclic Aromatic Hydrocarbons	µg/L	14	14	100%	<0.01	<0.05	<0.05*	NC	<0.05
2-Methylnaphthalene	Polycyclic Aromatic Hydrocarbons	µg/L	14	14	100%	<0.01	<0.05	<0.05*	NC	<0.05
Acenaphthene	Polycyclic Aromatic Hydrocarbons	µg/L	18	12	67%	<0.01	0.02	0.02*	<0.1	<0.10
Acenaphthylene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.01	<0.01	<0.01*	NC	<0.01
Acridine	Polycyclic Aromatic Hydrocarbons	µg/L	18	12	67%	<0.01	0.02	0.02*	<0.04	<0.05
Anthracene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.01	<0.01	<0.01*	NC	<0.01
Benz(a)anthracene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.005	<0.01	<0.01*	NC	<0.01
Benzo(a)pyrene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.001	<0.01	<0.01*	NC	<0.01
Benzo(b)fluoranthene	Polycyclic Aromatic Hydrocarbons	µg/L	15	15	100%	<0.01	<0.01	<0.01*	NC	<0.10
Benzo(b+j)fluoranthene	Polycyclic Aromatic Hydrocarbons	µg/L	3	3	100%	<0.005	<0.005	<0.005*	NC	<0.005
Benzo(ghi)perylene	Polycyclic Aromatic Hydrocarbons	µg/L	18	17	94%	<0.005	<0.01	<0.01*	<0.01	0.02
Benzo(k)fluoranthene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.005	<0.01	<0.01*	NC	<0.01
Chrysene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.005	<0.01	<0.01*	NC	<0.01
Dibenz(a,h)anthracene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.005	<0.01	<0.01*	NC	<0.01
Fluoranthene	Polycyclic Aromatic Hydrocarbons	µg/L	18	9	50%	<0.005	0.011	<0.01	<0.02	0.04
Fluorene	Polycyclic Aromatic Hydrocarbons	µg/L	18	12	67%	<0.01	0.02	0.02*	<0.05	<0.10
Indeno(1,2,3-cd)pyrene	Polycyclic Aromatic Hydrocarbons	µg/L	18	18	100%	<0.005	<0.01	<0.01*	NC	<0.04
Methylnaphthalene	Polycyclic Aromatic Hydrocarbons	µg/L	3	1	33%	<0.01	0.01	<0.01	NC	0.01
Naphthalene	Polycyclic Aromatic Hydrocarbons	µg/L	18	14	78%	0.02	<0.05	<0.05*	<0.06	0.08
Perylene	Polycyclic Aromatic Hydrocarbons	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
Phenanthrene	Polycyclic Aromatic Hydrocarbons	µg/L	18	16	89%	<0.005	<0.02	<0.02*	<0.02	<0.03
Pyrene	Polycyclic Aromatic Hydrocarbons	µg/L	18	9	50%	<0.005	0.01	<0.01	<0.02	0.03
Quinoline	Polycyclic Aromatic Hydrocarbons	µg/L	18	12	67%	<0.01	<0.05	<0.05*	<0.25	1.3
Retene	Polycyclic Aromatic Hydrocarbons	ug/L	3	3	100%	<0.01	<0.01	<0.01*	NC	<0.01
17 α-Dihydroequilin	Sterols and Hormones	ng/L	32	30	94%	7.0	<26	<26*	<53.3	<190
17 α-Estradiol	Sterols and Hormones	ng/L	32	32	100%	<1.4	<7.1	<7.1*	NC	<23.2
17 α-Ethinyl-Estradiol	Sterols and Hormones	ng/L	30	30	100%	<2.4	<8.0	<8.0*	NC	<35.5
17 β-Estradiol	Sterols and Hormones	ng/L	32	15	47%	<4.4	<12	<14.3	<33.3	35.6
Androstenedione	Sterols and Hormones	ng/L	32	32	100%	<13	<102.95	<102.95*	NC	<457
Androsterone	Sterols and Hormones	ng/L	32	32	100%	<0.64	<11	<11*	NC	<22.6

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
Campesterol	Sterols and Hormones	ng/L	32	4	13%	1830	<4305	<4478	<7133	7910
Cholestanol	Sterols and Hormones	ng/L	32	0	0%	1810	3355	3493	5333	5980
Cholesterol	Sterols and Hormones	ng/L	32	0	0%	15300	29950	30216	45070	51800
Coprostanol	Sterols and Hormones	ng/L	32	0	0%	14600	32700	36150	60775	83800
Desmosterol	Sterols and Hormones	ng/L	32	26	81%	<631	<1410	<1410*	<2930	<3990
Desogestrel	Sterols and Hormones	ng/L	32	32	100%	<1.1	<40	<40*	NC	<149
Epicoprostanol	Sterols and Hormones	ng/L	32	1	3%	<28	805	<1042	<2261	2580
Equilenin	Sterols and Hormones	ng/L	32	32	100%	<0.12	<17	<17*	NC	<51.7
Equilin	Sterols and Hormones	ng/L	32	32	100%	<14	<49	<49*	NC	<160
Ergosterol	Sterols and Hormones	ng/L	32	**28**	**88%**	<272	<1395	<1395	<2547	<3210
Estriol	Sterols and Hormones	ng/L	32	29	91%	<2.0	<23	<23*	<139	<295
Estrone	Sterols and Hormones	ng/L	32	1	3%	<11	117	<121	<197	289
Mestranol	Sterols and Hormones	ng/L	32	21	66%	<12.1	<31.6	<31.6*	57.0	<63.6
Norethindrone	Sterols and Hormones	ng/L	32	32	100%	<15.2	<62.1	<62.1*	NC	<153
Norgestrel	Sterols and Hormones	ng/L	32	29	91%	<16.5	<93.5	<93.5*	372	<480
Progesterone	Sterols and Hormones	ng/L	32	32	100%	<8.2	<75	<75*	NC	<985
Stigmasterol	Sterols and Hormones	ng/L	32	27	84%	<1790	<5845	<5845*	<30795	<37300
Testosterone	Sterols and Hormones	ng/L	32	32	100%	<4.5	<58	<58*	NC	<164
β-Estradiol 3-benzoate	Sterols and Hormones	ng/L	32	29	91%	<5.1	<27	<27*	<416	<713
β-Sitosterol	Sterols and Hormones	ng/L	32	27	84%	<5040	<15950	<15950*	<153750	185000
β-Stigmastanol	Sterols and Hormones	ng/L	32	27	84%	<698	1448	1448*	<3108	<3950
Aluminum	Total Metals	µg/L	207	0	0%	19	39	41.9	59.7	140
Antimony	Total Metals	µg/L	23	23	100%	<0.50	<0.50	<0.50*	NC	<0.50
Arsenic	Total Metals	µg/L	207	19	9%	0.50	0.70	<0.72	1.0	1.7
Barium	Total Metals	µg/L	207	16	8%	2.6	5.2	<6.3	<20.0	<20
Beryllium	Total Metals	µg/L	12	12	100%	<0.10	<0.5	<0.5*	NC	<0.5
Boron	Total Metals	µg/L	207	0	0%	93	146	151	211	303
Cadmium	Total Metals	µg/L	212	205	97%	0.0168	<0.20	<0.20*	NC	3.7
Chromium	Total Metals	µg/L	207	0	0%	0.50	0.90	1.7	2.1	44.9
Cobalt	Total Metals	µg/L	207	133	64%	0.50	0.50	0.50*	<0.7	1.3
Copper	Total Metals	µg/L	207	0	0%	8.2	17	18.3	31.4	43.2
Iron	Total Metals	µg/L	207	0	0%	248	469	484	666	1650
Lead	Total Metals	µg/L	207	135	65%	0.50	0.50	0.50*	<1.0	1.4
Lithium	Total Metals	µg/L	23	23	100%	<2.0	<50	<50*	NC	<50.0
Manganese	Total Metals	µg/L	207	0	0%	34	60	61.7	79.5	93.7
Mercury	Total Metals	µg/L	4	0	0%	0.006	0.0077	0.0075	NC	0.00869
Molybdenum	Total Metals	µg/L	207	9	4%	0.70	1.1	<1.3	<2.1	15.0
Nickel	Total Metals	µg/L	207	16	8%	1.7	2.4	<2.8	<5.0	22.3
Potassium (Total)	Total Metals	µg/L	16	0	0%	10200	13200	13394	15300	16500
Selenium	Total Metals	µg/L	207	203	98%	0.50	0.50	0.50*	NC	<1.0
Silver	Total Metals	µg/L	207	205	99%	<0.05	<0.50	<0.50*	NC	<0.50
Strontium	Total Metals	µg/L	7	0	0%	39	39	39.2	NC	39.9
Thallium	Total Metals	µg/L	23	23	100%	<0.20	<0.20	<0.20*	NC	<0.50
Titanium	Total Metals	µg/L	16	16	100%	<50	<50	<50*	NC	<50.0
Uranium	Total Metals	µg/L	23	23	100%	<0.20	<0.20	<0.20*	NC	<0.50
Vanadium	Total Metals	µg/L	23	23	100%	<0.50	<30	<30*	NC	<30.0
Zinc	Total Metals	µg/L	207	0	0%	10	19	22.1	38.7	67.0
Methyl Mercury	Total Metals	µg/L	5	0	0%	0.000805	0.00095	0.000998	NC	0.00117
Cyanide, Weak Acid Diss	Miscellaneous	mg/L	5	4	80%	<0.001	<0.001	<0.001*	NC	0.001
2,3,7,8-TCDD	Dioxin	pg/L	3	1	33%	<0.505	<1.300	1.248	NC	1.94
1,2,3,7,8-PCDD	Dioxin	pg/L	3	3	100%	<0.505	<0.505	<0.505*	NC	<0.505
1,2,3,4,7,8-HCDD	Dioxin	pg/L	3	3	100%	<0.505	<0.505	<0.505*	NC	<0.566
1,2,3,6,7,8-HCDD	Dioxin	pg/L	3	3	100%	<0.505	<0.57	<0.57*	NC	<0.9
1,2,3,7,8,9-HCDD	Dioxin	pg/L	3	3	100%	<0.505	<0.51	<0.51*	NC	<0.57
1,2,3,4,6,7,8-HCDD	Dioxin	pg/L	3	2	67%	<3.07	6.55	6.55*	NC	<11.4
OCDD	Dioxin	pg/L	3	0	0%	18.3	35.2	31.1	NC	39.9
2,3,7,8-TCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
1,2,3,7,8-PCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
2,3,4,7,8-PCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
1,2,3,4,7,8-HCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
1,2,3,6,7,8-HCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
1,2,3,7,8,9-HCDF	Furan	pg/L	3	3	100%	<0.505	<0.505	<0.505*	NC	<0.505
2,3,4,6,7,8-HCDF	Furan	pg/L	3	3	100%	<0.505	<0.505	<0.505*	NC	<0.505
1,2,3,4,6,7,8-HCDF	Furan	pg/L	3	2	67%	<1.03	1.10	1.10*	NC	<1.68
1,2,3,4,7,8,9-HCDF	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
OCDF	Furan	pg/L	3	2	67%	<0.745	<1.44	<1.44*	NC	1.94
TOTAL TETRA-DIOXINS	Dioxin	pg/L	3	1	33%	<0.505	1.3	<1.25	NC	1.94
TOTAL PENTA-DIOXINS	Dioxin	pg/L	3	2	67%	<0.503	<0.505	<0.505*	NC	7.12
TOTAL HEXA-DIOXINS	Dioxin	pg/L	3	2	67%	<0.505	<0.566	<0.566*	NC	2.16
TOTAL HEPTA-DIOXINS	Dioxin	pg/L	3	2	67%	<0.505	<0.505	<0.505*	NC	12.5
TOTAL TETRA-FURANS	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
TOTAL PENTA-FURANS	Furan	pg/L	3	3	100%	<0.503	<0.505	<0.505*	NC	<0.505
TOTAL HEXA-FURANS	Furan	pg/L	3	2	67%	<0.505	<0.505	<0.505*	NC	0.626
TOTAL HEPTA-FURANS	Furan	pg/L	3	2	67%	<0.51	<0.505	<0.505*	NC	1.93
Toxaphene	Insecticides	ng/L	3	3	100%	<0.686	<0.852	<0.852*	NC	<1.65
Pentachlorobenzene	Insecticides	ng/l	3	1	33%	0.041	0.043	0.043	NC	<0.057
1,3,5-Trichlorobenzene	Organics?	ng/l	3	3	100%	<0.20	<0.20	<0.20*	NC	<0.20

Parameter	Grouping	Units	# of Samples	Number of Samples w. flag or < MDL	Percent of Samples flagged or < MDL	Minimum	Median	Mean	95th Percentile to Report	Maximum
1,2,4-Trichlorobenzene	Organics?	ng/l	3	2	67%	<0.20	<0.20	<0.20*	NC	0.31
1,2,3-Trichlorobenzene	Organics?	ng/l	3	3	100%	<0.20	<0.20	<0.20*	NC	<0.20
1,2,4,5-/1,2,3,5-Tetrachlorobenzene	Organics?	ng/l	3	3	100%	<0.20	<0.20	<0.20*	NC	<0.20
1,2,3,4-Tetrachlorobenzene	Organics?	ng/l	3	3	100%	<0.20	<0.20	<0.20*	NC	<0.20
Nitrate + Nitrite	Nutrients	mg/L	432	177	41%	0.02	0.06	<0.07	<0.2	0.48
Total Nitrogen (calculated)	Nutrients	mg/L	191	51	27%	16	34	<33.4	<39.6	44.1
Endosulphan - total (alpha+beta)	Insecticides	ng/l	14	14	100%	<0.461	<0.945	<0.945*	NC	<1.37
Monochlorophenols	Organics?	mg/L	4	4	100%	<6.50E-04	<6.50E-04	<6.50E-04*	NC	<6.50E-04
Dichlorophenols	Organics?	mg/L	4	4	100%	<3.21E-04	<3.75E-04	<3.75E-04*	NC	<4.00E-04
Tetrachlorophenols	Organics?	mg/L	4	4	100%	<5.00E-04	<5.00E-04	<5.00E-04*	NC	<5.10E-04
Trichlorophenols	Organics?	mg/L	4	4	100%	<6.00E-04	<6.00E-04	<6.00E-04*	NC	<6.00E-04
Total Hepta-BDE (maximum)		pg/l	12	11	92%	<39.52	64.90	64.90*	<78.44	<85.77
PFBA		ng/L	3	0	0%	2.7	7.0	5.8	NC	7.6
PFPeA		ng/L	3	0	0%	5.4	6.0	6.2	NC	7.2
PFHxA		ng/L	3	0	0%	8.8	11	10.3	NC	11.2
PFHpA		ng/L	3	0	0%	2.8	3.7	3.5	NC	3.95
PFOA		ng/L	3	0	0%	8.2	9.3	9.4	NC	10.7
PFNA		ng/L	3	3	100%	<0.941	<1.38	<1.38*	NC	<1.85
PFDA		ng/L	3	1	33%	<1.9	2.5	<2.7	NC	3.6
PFUnA		ng/L	3	3	100%	<0.935	<0.941	<0.941*	NC	<1.85
PFDoA		ng/L	3	3	100%	<0.936	<0.941	<0.941*	NC	<1.85
PFBS		ng/L	3	3	100%	<1.87	<1.88	<1.88*	NC	<3.69
PFHxS		ng/L	3	1	33%	3.7	<3.7	<4.6	NC	6.5
PFOS		ng/L	3	1	33%	5.04	<5.95	<6.51	NC	8.53
PFOSA		ng/L	3	3	100%	<0.935	<0.941	<0.941*	NC	<1.85
Trihalomethanes	Organics?	mg/L	4	4	100%	<0.00490	<0.00505	<0.00505*	NC	<0.00530

Attachment B

Summary Statistics for 2011-2014 AIWWTP Effluent Flux Calculations

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Constituent	Load Units	Distribution Type	95th percentile Load	Average Load
1,1-Dichloroethylene	mg/D	Normal	612910.1164	585372.4
1,2,3,4,6,7,8-Hcdd	ng/D	Normal	8326565.222	4059493
1,2,3,4,6,7,8-Hcdf	ng/D	Normal	1053261.658	726897.6
1,2,3,4,7,8,9-Hcdf	ng/D	Normal	302279.4432	289522.3
1,2,3,4,7,8-Hcdd	ng/D	Normal	331912.3841	301424.7
1,2,3,4,7,8-Hcdf	ng/D	Normal	302279.4432	289522.3
1,2,3,6,7,8-Hcdd	ng/D	Normal	627895.1146	385081
1,2,3,6,7,8-Hcdf	ng/D	Normal	302279.4432	289522.3
1,2,3,7,8,9-Hcdd	ng/D	Normal	331912.3841	301424.7
1,2,3,7,8,9-Hcdf	ng/D	Normal	302279.4432	289522.3
1,2,3,7,8-Pcdd	ng/D	Normal	302279.4432	289522.3
1,2,3,7,8-Pcdf	ng/D	Normal	302279.4432	289522.3
1,2-Dichlorobenzene	mg/D	Normal	605136.9374	234688.2
1,2-Dichloroethane	mg/D	Normal	612910.1164	585372.4
1,4-Dichlorobenzene	mg/D	Normal	755469.4192	451446.6
17 A-Ethinyl-Estradiol	ng/D	Normal	17680321266	7.12E+09
1-Methylnaphthalene	µg/D	Normal	52815353.94	33816482
2,3,4,6,7,8-Hcdf	ng/D	Normal	302279.4432	289522.3
2,3,4,6-Tetrachlorophenol	mg/D	Normal	66888.59722	60030.81
2,3,4,7,8-Pcdf	ng/D	Normal	302279.4432	289522.3
2,3,6-Trichlorophenol	mg/D	Normal	61291.01164	58537.24
2,3,7,8-Tcdd	ng/D	Normal	1387596.975	710299.3
2,3,7,8-Tcdf	ng/D	Normal	302279.4432	289522.3
2,4'-Ddd	ng/D	Normal	220058915.5	1.33E+08
2,4'-Dde	ng/D	Normal	104909522.5	50308527
2,4'-Ddt	ng/D	Normal	441391062.4	1.74E+08
2-Methylnaphthalene	µg/D	Normal	52815353.94	33816482
4,4'-Ddd	ng/D	Normal	186342951.6	79867873
4,4'-Ddt	ng/D	Normal	377301868.4	1.56E+08
Acenaphthene	µg/D	Normal	72798396.84	26920693
Acridine	µg/D	Normal	27547781.95	15434595
Aldicarb	ng/D	Normal	1705093432	6.07E+08
Aldrin	ng/D	Normal	407032480.5	93618518
Aluminum Dissolved	µg/D	Johnson	14376777573	8.73E+09
Aluminum Total	µg/D	Johnson	59759000798	2.83E+10
Ammonia (Un-Ionized)	mg-N/D	Johnson	373615305.1	2.65E+08
Aniline	ug/D	Normal	3064550582	2.93E+09
Anthracene	µg/D	Normal	9364546.897	6751185
Antimony Dissolved	µg/D	Normal	296957737.3	2.79E+08
Antimony Total	µg/D	Normal	296957737.3	2.79E+08
Arsenic Dissolved	µg/D	Johnson	850375558.9	4.53E+08
Arsenic Total	µg/D	Johnson	895833100.7	4.75E+08
Barium Dissolved	µg/D	Johnson	10391533373	2.99E+09
Barium Total	µg/D	Johnson	10608184041	4.15E+09
Benz(A)Anthracene	µg/D	Normal	9938398.328	6282590
Benzo(A)Pyrene	µg/D	Normal	10746739.45	5907715
Beryllium Dissolved	µg/D	Normal	369191771.7	1.84E+08
Beryllium Total	µg/D	Normal	397569276	2.45E+08
Boron Dissolved	µg/D	Johnson	1.5E+11	9.28E+10
Boron Total	µg/D	Johnson	1.56E+11	9.72E+10
Cadmium Dissolved	µg/D	Normal	278914790	1.26E+08
Cadmium Total	µg/D	Normal	404901625.3	1.32E+08
Calcium (Total) Total	mg/D	Johnson	15739942415	8.5E+09
Captan	ng/D	Normal	14838051986	4.62E+09
Carbaryl	ng/D	Johnson	1.84E+11	4.77E+10
Carbon Tetrachloride	mg/D	Normal	306455.0582	292686.2
Chlordane Total	ng/D	Normal	244104936.2	99673636
Chlorobenzene	mg/D	Normal	612910.1164	585372.4
Chloroethane	mg/D	Normal	612910.1164	585372.4
Chloroform	mg/D	Normal	1350530.254	1213321
Chlorpyriphos	ng/D	Normal	2399426541	1.18E+09
Cholestanol	ng/D	Johnson	4.73E+12	2.48E+12
Cholesterol	ng/D	Johnson	3.62E+13	2.11E+13
Chromium Dissolved	µg/D	Johnson	1412352707	7.15E+08
Chromium Total	µg/D	Johnson	2068105368	1.05E+09
Chrysene	µg/D	Normal	9938398.328	6282590
Cobalt Dissolved	µg/D	Normal	489288750.1	3.42E+08
Cobalt Total	µg/D	Normal	518761734.4	3.53E+08
Conductivity (Field)	NOT MASS	Johnson	NA	NA
Copper Dissolved	µg/D	Johnson	12309625901	6.01E+09
Copper Total	µg/D	Johnson	20693045121	1.17E+10
Coprostanol	ng/D	Johnson	4.52E+13	2.47E+13
Cyanazine	ng/D	Normal	7121237477	2.93E+09
Deca-Bde-209	ng/D	Johnson	7456044812	3.48E+09
Deltamethrin	ng/D	Normal	1968600392	9.38E+08
Desmosterol	ng/D	Normal	2.14E+12	1.1E+12
Dichloromethane	mg/D	Normal	3064550.582	2926862
Dichlorophenols	mg/D	Normal	250807.6391	215055.1
Dieldrin	ng/D	Johnson	429709119.5	1.11E+08
Diisopropanolamine	mg/D	Normal	61291011.64	58537245
Dissolved Organic Carbon	mg/D	Johnson	10261670486	7.44E+09
Dissolved Oxygen	mg/D	Johnson	4404421625	2.71E+09

Constituent	Load Units	Distribution Type	95th percentile Load	Average Load
Dissolved Phosphorus	mg-P/D	Johnson	1702466391	1.42E+09
E. Coli	MPN*10^-1/D	Johnson		
Endosulphan - Total (Alpha+Beta)	ng/D	Normal	1033236872	6.33E+08
Endrin	ng/D	Normal	303753459.8	80774968
Enterococci	MPN*10^-1/D	Johnson		
Epicoprostanol	ng/D	Johnson	1.56E+12	7.1E+11
Fecal Coliform	MPN*10^-1/D	Johnson		
Fluoranthene	µg/D	Normal	19412968.06	9640458
Fluorene	µg/D	Normal	47805095.48	18688651
Fluoride (Total)	mg/D	Johnson	105247155	46198138
Hardness As Caco3	mg/D	Johnson	54217115052	2.97E+10
Hch, Alpha	ng/D	Normal	349872555.3	94816699
Hch, Beta	ng/D	Johnson	452866383.6	3.07E+08
Hch, Delta	ng/D	Normal	673544303.7	1.7E+08
Hch, Gamma	ng/D	Johnson	964695827.6	2.94E+08
Heptachlor	ng/D	Normal	409669843.1	90522403
Hexa-Bde-153	ng/D	Johnson	429691123.6	2.24E+08
Hexachlorobenzene	ng/D	Johnson	81253927.42	54497859
Hexachlorobutadiene	ng/D	Normal	285068419.8	1.13E+08
Imidacloprid	ng/D	Johnson	60339166596	3.44E+10
Iron Dissolved	µg/D	Johnson	1.29E+11	8.35E+10
Iron Total	µg/D	Johnson	6.1E+11	3.18E+11
Lead Dissolved	µg/D	Normal	508218816.8	3.46E+08
Lead Total	µg/D	Normal	658434571.8	3.9E+08
Linuron	ng/D	Normal	3761193816	1.73E+09
Lithium Dissolved	µg/D	Normal	41714566975	2E+10
Lithium Total	µg/D	Normal	41714566975	2E+10
Magnesium (Total) Total	mg/D	Johnson	3434072544	2.08E+09
Malathion	ng/D	Normal	5020885429	1.76E+09
Manganese Dissolved	µg/D	Johnson	57945877883	3.26E+10
Manganese Total	µg/D	Johnson	69980554689	4.06E+10
Mercury Total	µg/D	Normal	5836230.361	4493101
Methoprene	ng/D	Normal	1.87E+11	8.05E+10
Methyl Mercury	ng/D	Normal	735289924.6	5.88E+08
Metribuzin	ng/D	Normal	5298468488	1.89E+09
Mirex	ng/D	Normal	153353316.3	44810580
Molybdenum Dissolved	µg/D	Johnson	1454348252	7.54E+08
Molybdenum Total	µg/D	Johnson	1699638524	8.42E+08
Monochlorophenols	mg/D	Normal	398391.5757	380492.1
Naphthalene	µg/D	Normal	52224750.39	32383819
Nickel Dissolved	µg/D	Johnson	3196413859	1.69E+09
Nickel Total	µg/D	Johnson	3433225698	1.81E+09
Nitrate + Nitrite	mg-N/D	Johnson	114165925.1	45881975
Nitrogen - Nitrate As N	mg-N/D	Johnson	44212559.82	14064084
Nitrogen - Nitrite As N	mg-N/D	Johnson	84041113.5	31817891
Nonylphenol Teq	ng/D	Johnson	9.55E+11	6.62E+11
Ocdd	ng/D	Normal	29142674.89	17912681
Ocdf	ng/D	Normal	1342032.133	783990.3
Pcb-105	pg/D	Johnson	18034997348	1.04E+10
Pcb-114	pg/D	Johnson	1821351130	9.72E+08
Pcb-118	pg/D	Johnson	45973522698	2.72E+10
Pcb-123	pg/D	Normal	1843191383	1.01E+09
Pcb-126	pg/D	Normal	1811577838	6.96E+08
Pcb-156+157	pg/D	Johnson	6806229197	3.9E+09
Pcb-167	pg/D	Johnson	2132086862	1.22E+09
Pcb-169	pg/D	Normal	1448234142	5.3E+08
Pcb-189	pg/D	Normal	1712861376	6.56E+08
Pcb-77	pg/D	Johnson	2474715568	1.35E+09
Pcb-81	pg/D	Normal	1428136796	5.41E+08
Penta-Bde-100	ng/D	Johnson	898587440	4.86E+08
Penta-Bde-99	ng/D	Johnson	4532414132	2.43E+09
Pentachlorophenol	mg/D	Normal	61291.01164	58537.24
Permethrin	ng/D	Johnson	11874960196	8.8E+09
Pfos	ng/D	Normal	8423179799	5.33E+09
Phenanthrene	µg/D	Normal	20443008.67	13244503
Potassium (Total) Total	mg/D	Johnson	8788157867	7.56E+09
Pyrene	µg/D	Normal	17554719.96	9874856
Quinoline	µg/D	Normal	431719140.1	77620745
Salinity	NOT MASS	Johnson	308698796.2	2.13E+08
Selenium Dissolved	µg/D	Normal	518551936.6	3.5E+08
Selenium Total	µg/D	Normal	508314078.7	3.46E+08
Silver Dissolved	µg/D	Normal	486330455.8	3.05E+08
Silver Total	µg/D	Normal	486263268.5	3.05E+08
Simazine	ng/D	Normal	2985703112	1.66E+09
Sodium (Total) Total	mg/D	Johnson	38800829027	2.63E+10
Strontium Dissolved	µg/D	Normal	20578223738	1.98E+10
Strontium Total	µg/D	Normal	21969273725	2.13E+10
Sulfate (Total)	mg/D	Johnson	16970046270	1.12E+10
Temperature	NOT MASS	Johnson	NA	NA
Tetra-Bde-47	ng/D	Johnson	4542190646	2.53E+09

Constituent	Load Units	Distribution Type	95th percentile Load	Average Load
Tetrachlorophenols	mg/D	Normal	311038.6055	294179.8
Thallium Dissolved	µg/D	Normal	288549519.2	1.61E+08
Thallium Total	µg/D	Normal	288549519.2	1.61E+08
Total Ammonia As N	mg-N/D	Johnson	23561531132	1.98E+10
Total Ddd	ng/D	Normal	395210520.7	2.13E+08
Total Ddt	ng/D	Normal	817130020.9	3.29E+08
Total Kjeldahl Nitrogen	mg/D	Johnson	24989345323	2.12E+10
Total Nitrogen (Calculated)	mg-N/D	Johnson	24940048732	2.12E+10
Total Organic Carbon	mg/D	Johnson	12031418689	8.81E+09
Total Pcb	pg/D	Johnson	1.57E+12	9.19E+11
Total Phosphorus	mg-P/D	Johnson	2247728944	1.64E+09
Total Residual Chlorine	mg/D	Normal	55912131.9	21634774
Total Suspended Solids	mg/D	Johnson	11637561381	6.23E+09
Toxaphene	ng/D	Normal	1093567679	6.08E+08
Tributyltin Chloride	µg/D	Normal	623398.3675	574247.2
Trichloroethylene	mg/D	Normal	612910.1164	585372.4
Trichlorophenols	mg/D	Normal	367746.0699	351223.5
Trihalomethanes	mg/D	Normal	3102965.425	2969438
Triphenyltin Chloride	µg/D	Normal	6233983.675	5742472
Uranium Dissolved	µg/D	Normal	288549519.2	1.61E+08
Uranium Total	µg/D	Normal	288549519.2	1.61E+08
Vanadium Dissolved	µg/D	Normal	25215950589	1.19E+10
Vanadium Total	µg/D	Normal	25215950589	1.19E+10
Vinyl Chloride	mg/D	Normal	612910.1164	585372.4
Zinc Dissolved	µg/D	Johnson	19532019312	1.06E+10

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Attachment C

Hydraulic Design Analysis for Stage V Effluent Discharge

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Memorandum

To: *Project Files*

From: *Ron Miner, PE*

Date: *November 3, 2017 Update*

Subject: ***Stage V** Outfall and Diffuser Hydraulic Calculations Summary*

Annacis Outfall and Diffuser Configuration: STAGE V FLOW Q = 18.9 cms

A hydraulic analysis was completed for the Annacis Outfall and Diffuser configuration shown on Attachment C. The analysis was completed using Visual Hydraulics Treatment Plant Hydraulic Analysis Software by Innovative Hydraulics, Version 4.2. The analysis and results are summarized below

The goal of the Stage V hydraulic design is to maximize available head at the diffuser ports to provide sufficient jet velocities and mixing to satisfy water quality standards by gravity, without effluent pumping, for the design condition. Effluent pumping will be needed to convey the Stage VIII design flow of 25.3 cms.

Flow Path: Existing Chlorine Contact Tanks from a point just downstream of the static mixer, existing 7m wide channel sections, isolation gates, new 7m wide channel sections, new isolation gates, two Crest Gates (1 in service) discharging to a 7m diameter Effluent Shaft, 4.2m/3.8m diameter Effluent Tunnel sections to the 14m diameter Outfall Shaft (future pump station shaft), two 3m wide by 4m high flap gates, 4.2m/3.8m diameter Outfall Tunnel sections, 3.8m/4.2m diameter Riser Shaft connecting to the mid-point of a 2.5m diameter Diffuser Manifold, 1000 mm tee branches reduced to 750mm diameter risers to each diffuser port (duckbill valve). There are 24 diffuser ports, 18 will be active for Stage V. The remaining six will be opened in the future for Stage VIII flows.

Elevations are referenced to the Geodetic Datum plus 100m.

A Visual Hydraulics flow sheet was created for the piping configuration extending from the river (design Water Surface Elevation (WSE) 103.18 + 0.18 = **103.36m**) upstream to the chlorine contact tanks (Maximum WSE 105.84 – 0.14 m = **105.70m**). The hydraulic grade line elevation (HGLE) at the river was raised by 0.18m to account for higher river water density from partial saline and temperature effects. The maximum WSE at the chlorine contact tank was lowered by 0.14m to account for future settlement. The Visual Hydraulics manifold/diffuser tool was used to calculate the variation in diffuser port flows to validate that the assumption of equal flow distribution among the diffuser ports is reasonable.

Hydraulic losses for open channel flow sections were calculated using Manning's equation. A Manning's roughness value of n = 0.013 was used for open channels. The Darcy-Weisbach equation was used to calculate hydraulic losses for the shafts, tunnels and diffusers. For the near-term Stage V design period, an absolute roughness value of 0.00001m was used for the plastic diffuser manifold, diffusers and for the 3.8m diameter tunnel sections lined with polyethylene coated steel. Absolute roughness of 0.0003m was used for the 4.3m diameter concrete lined tunnel sections and 0.003m for the tunnel shafts.

These roughness values characterize newly constructed conduits in good condition and can be expected to be valid during the early years of service. As the tunnel and diffuser system ages the effective roughness may increase due to surface wear or possibly slime buildup or other reasons increasing head loss. In the future the increase in headloss due to aging conduits will be satisfied by the effluent pump station needed to convey increased Stage VIII design flows.

The Visual Hydraulics Summary Report "Annacis_38_2017_11-3-17_1_Gate.vhf" is attached and itemizes the head loss calculations summarized in the schematic flow sheet below and in an enlarged schematic flow sheet, attached.

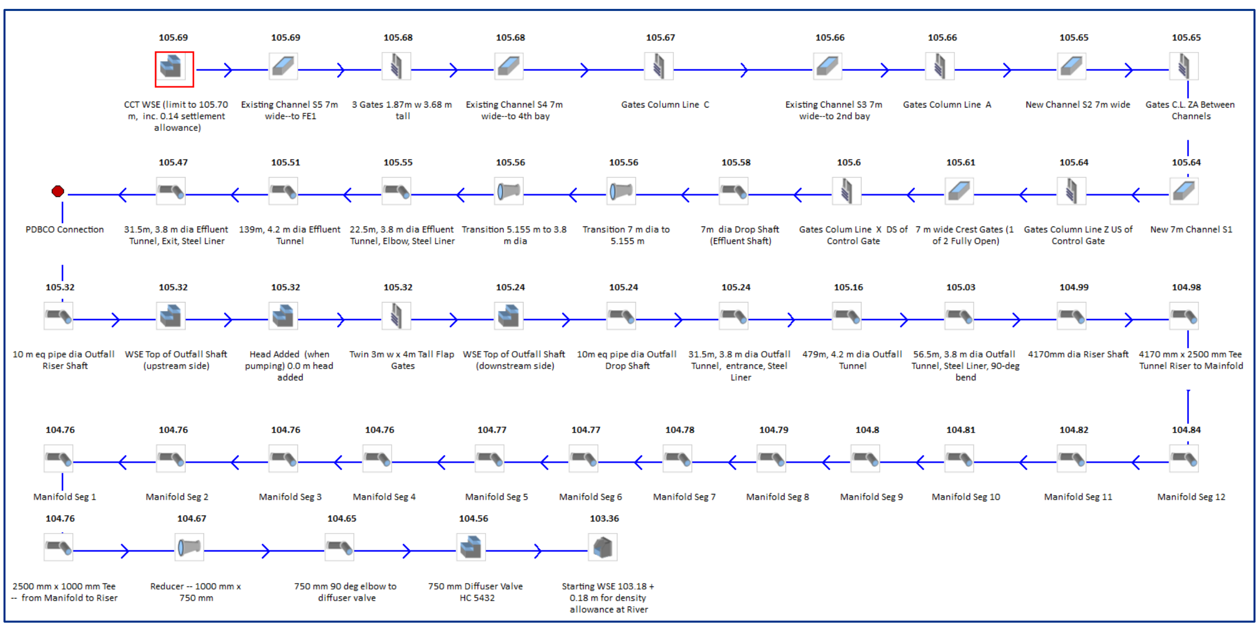


Figure 1: Visual Hydraulics Flow Sheet--Stage V, 18.9 cms

The calculated available headloss for the diffuser valves (only) is **1.20m** at 18.9 cms with the above configuration (See Attachment E).

The calculated head losses assume equal flow distribution to each of 18 diffuser ports (Stage V). The manifold/diffuser tool in Visual Hydraulics indicates less than 1% variation in diffuser port flow between the ports closest to and farthest from the Riser Shaft confirming that equal flow distribution is a reasonable assumption. These screen clips in Figures 2 through 4 present the system characteristics, manifold, riser and diffuser port parameters and resulting port flows, head loss and discharge velocities. Note that the manifold/diffuser tool does not include losses associated with the diffuser riser elbow. These losses are accounted for in the flow schematic shown in Figure 1. The manifold/diffuser tool is used here only to confirm the assumption of equal flow distribution among the diffuser ports.

The following configuration was evaluated:

Table 1: Diffuser Manifold and Port Configuration

Diffuser Length (m)	Port Spacing (m)	Total Number of Ports	Number of Ports Open (Stage V)	Max Stage V Flow per Port (m3/s)	Number of Ports open (Stage VIII)	Max Stage VIII Flow per Port, all Ports Open (m3/s)	Fixed Port Equivalent Diameter (mm) at 1.20 m Available Head
240	10	24	**18**	1.05	24	1.05	525

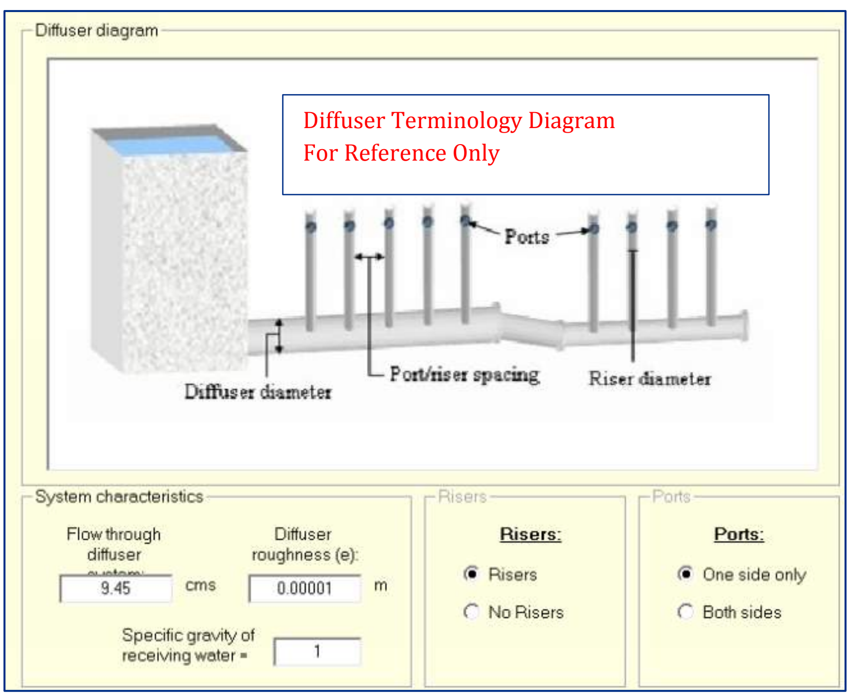


Figure 2: Flow through 2.5m manifold, ports discharging on one side only

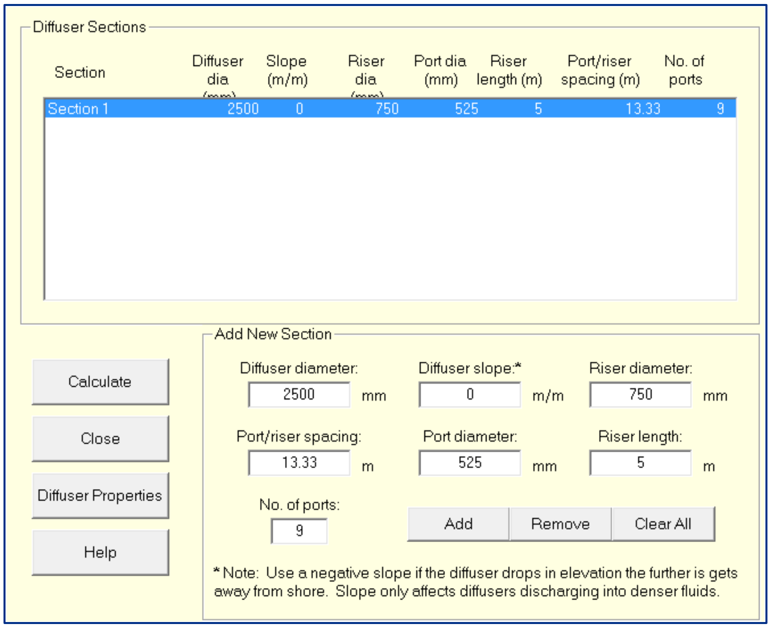
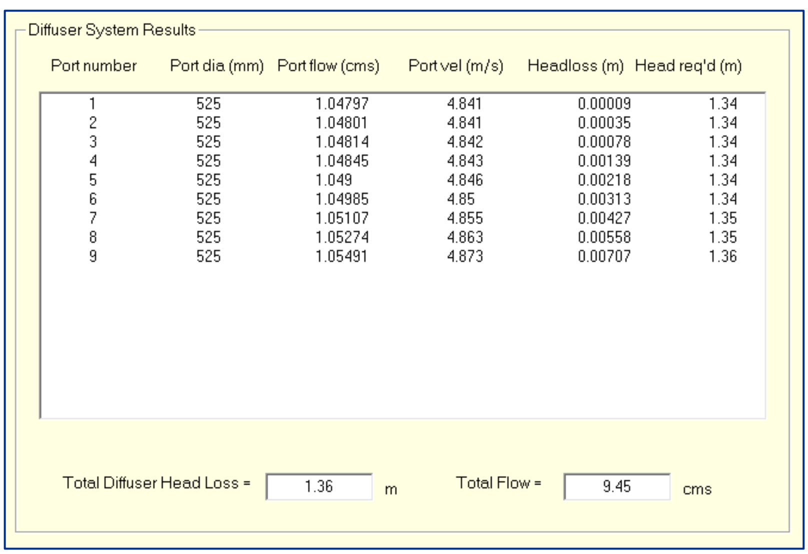


Figure 3: Diffuser Parameters: 240m long, 10m spacing, 18 of 24 @ 525mm ports open



Diffuser System Results

Port number	Port dia (mm)	Port flow (cms)	Port vel (m/s)	Headloss (m)	Head req'd (m)
1	525	1.04797	4.841	0.00009	1.34
2	525	1.04801	4.841	0.00035	1.34
3	525	1.04814	4.842	0.00078	1.34
4	525	1.04845	4.843	0.00139	1.34
5	525	1.049	4.846	0.00218	1.34
6	525	1.04985	4.85	0.00313	1.34
7	525	1.05107	4.855	0.00427	1.35
8	525	1.05274	4.863	0.00558	1.35
9	525	1.05491	4.873	0.00707	1.36

Total Diffuser Head Loss = 1.36 m Total Flow = 9.45 cms

Figure 4: Results showing flow, velocity and head required through manifold, risers and diffuser ports: 240m long, 10m spacing, 18 of 24 ports @ 525mm diameter open

Results summary table:

Table 2: Diffuser Port Flows and Velocities

Diffuser Length (m)	Port Spacing (m)	Total Number of Ports	Number of Ports Open (Stage V)	Fixed Port Diameter (mm) at 1.20 m Available Head	Range of Flow Per Port (m3/s)	Range of Port Velocities (m/s)
240	10	24	**18**	525	1.047 - 1.055	4.84 – 4.88

The summary table shows less than a 1% variation in diffuser port flow with port velocities ranging **4.84 to 4.88 m/s**.

cc:
Bernie Kolb, John Newby, Francis Bui, Brian Caufield; CDM Smith

Attachments:

A. Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage V, 18.9 cms
B. Hydraulic Profile Plot
C. Outfall Alignment Figure
D. Visual Hydraulics Summary Report
E. Tideflex Diffuser System Data Analysis

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Attachment A.

Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage V, 18.9 cms

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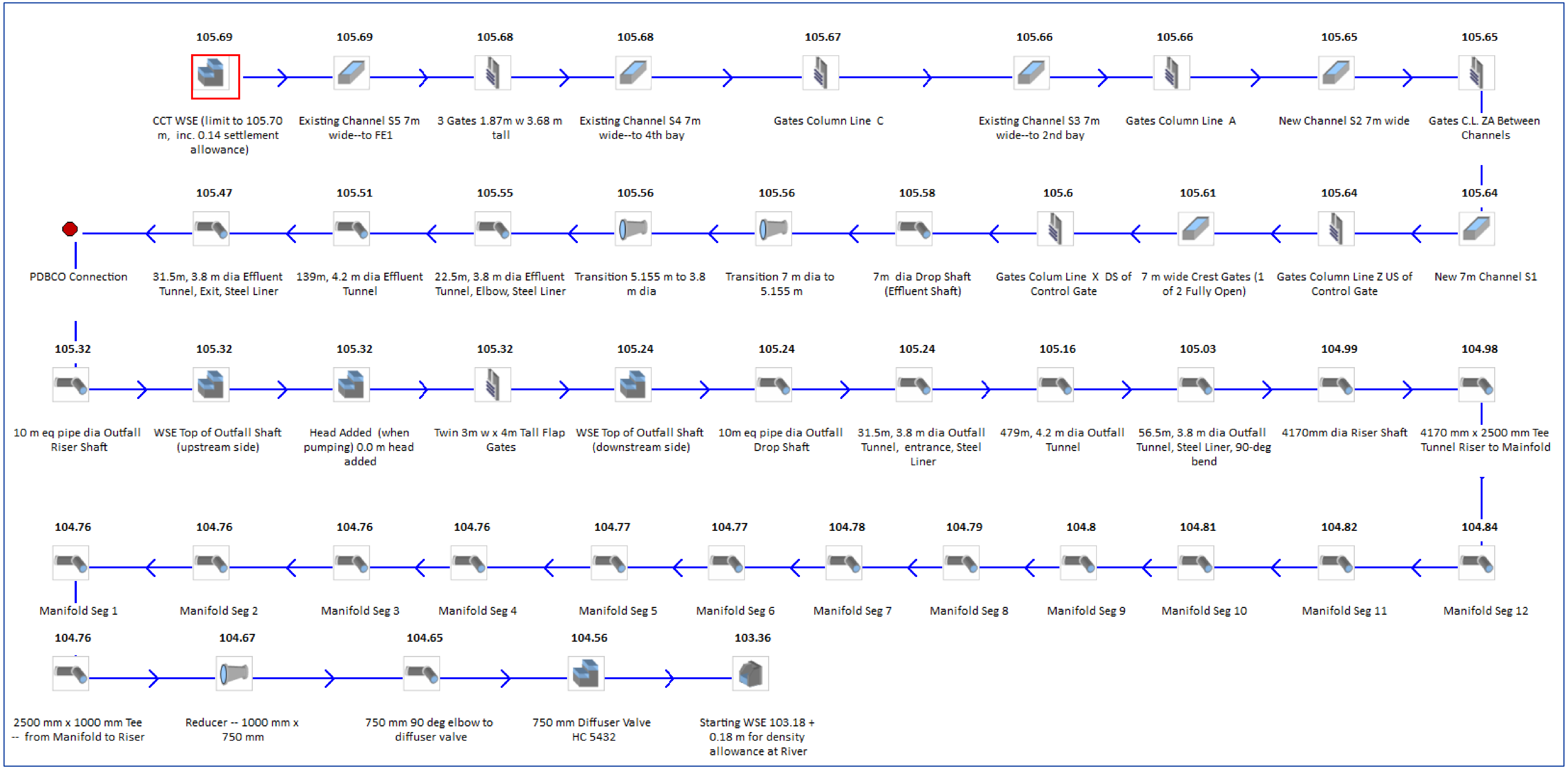
Attachment A.

Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage V, 18.9 cms



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Attachment B. Hydraulic Profile Plot

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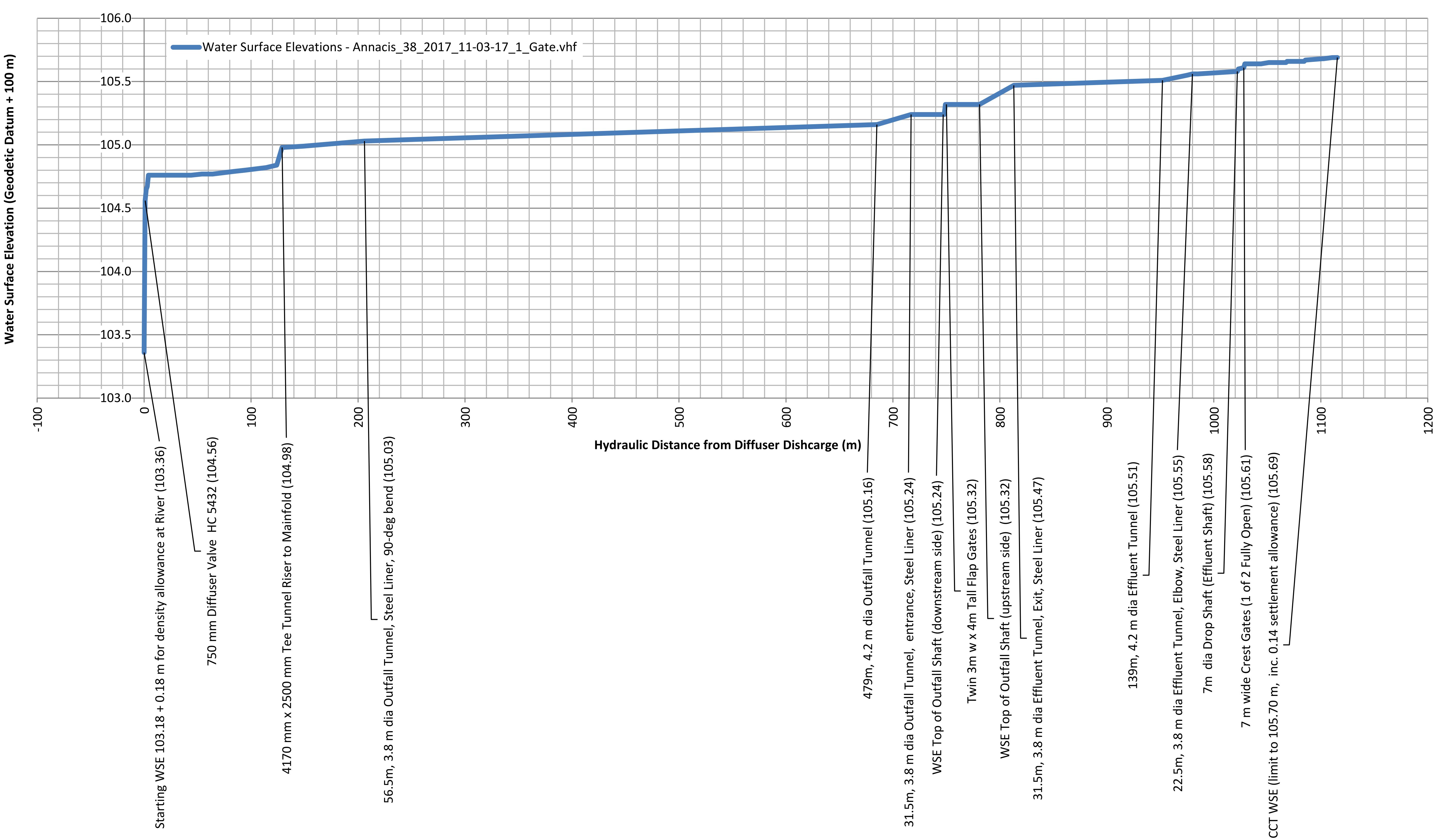
Outfall Hydraulic Profile - Annacis Stage V Q=18.9 cms 11-3-17



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Attachment C. Outfall Alignment Figure

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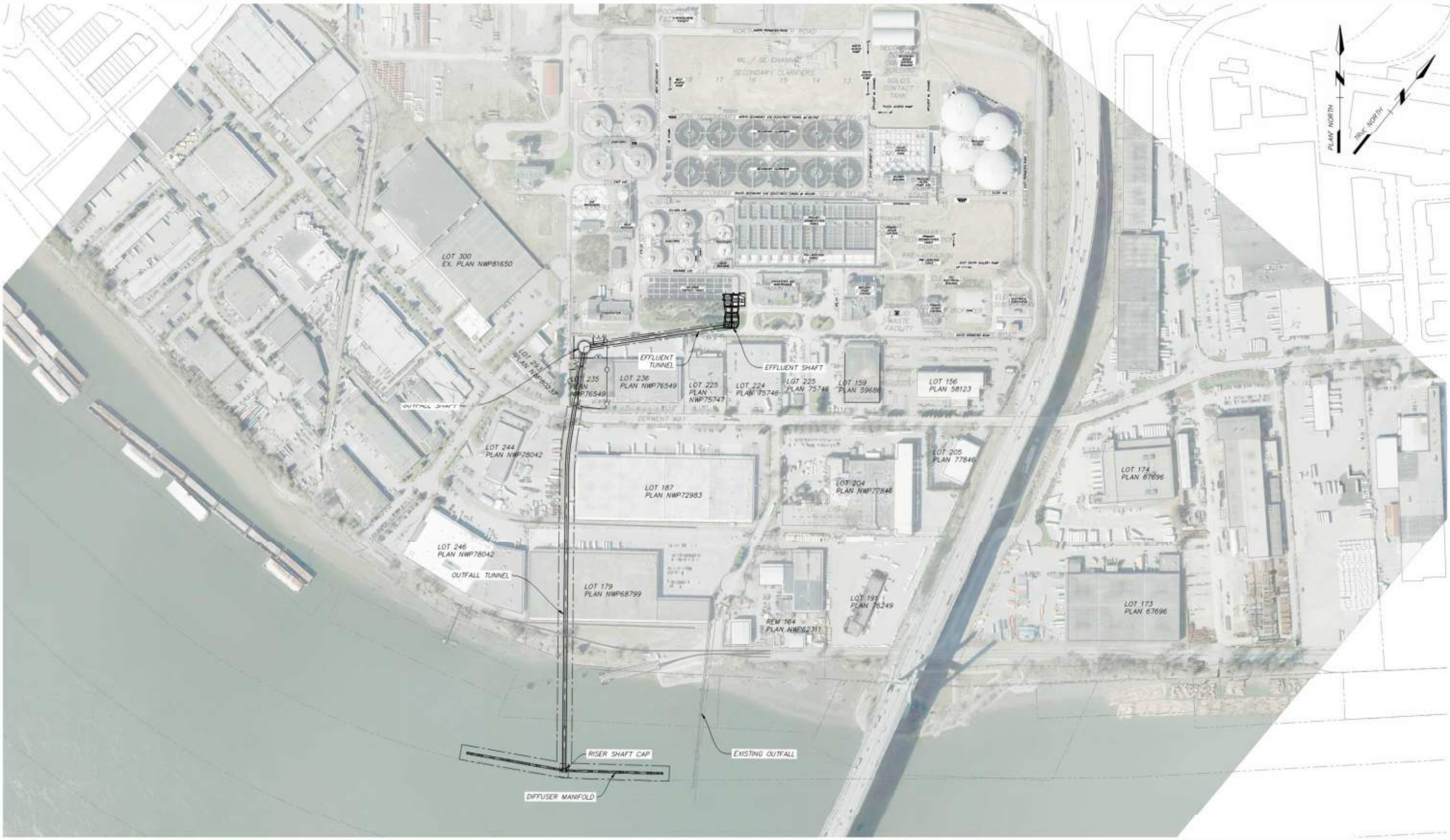

CDM Smith

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THIS DRAWING HAS NOT BEEN APPROVED, AND MAY CONTAIN ERRORS AND OMISSIONS.

Professional Seal

Issue	Date	Des'n	Dr'n	Chkd	App'd	Description

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

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

Design:
Drawn:
Checked:
Approved
Manager

ANNACIS ISLAND WWTP
TRANSIENT MITIGATION AND OUTFALL
CONTRACT XXXX – NEW OUTFALL SYSTEM
PACKAGE 5

A10 – GENERAL SITE WORKS
NOS AERIAL MAP

SCALE: 1:2500
DISTRICT FILE SF–1933
DRAWING NUMBER FIGURE 2

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Attachment D. Visual Hydraulics Summary Report

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Visual Hydraulics Summary Report - Hydraulic Analysis

Project: **Annacis_38_2017_11-03-17_1_Gate.vhf**
Company:
Date:

Stage V 18.9 cms
Scenario 1

Current flow conditions

Forward Flow =	18.9 cms
Return I Flow =	-----
Return II Flow =	-----
Return III Flow =	-----

Section Description	Water Surface Elevation
Starting WSE 103.18 + 0.18 m for density allowance at River	**103.36**
750 mm Diffuser Valve HC 5432	**104.56**
Change in elevation = 1.2 m	
750 mm 90 deg elbow to diffuser valve	**104.65**
Pipe shape = Circular	
Diameter = 750 mm	
Length = 2 m	
Flow = 1.05 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.3	
Pipe area = 0.44 m²	
Pipe hydraulic radius = 0.188	
Age factor = 1	
Solids factor = 1	
Velocity = 2.38 m/s	
Friction loss = 0.01 m	
Fitting loss = 0.09 m	
Total loss = 0.09 m	
Reducer -- 1000 mm x 750 mm	**104.67**
Diameter of smaller pipe = 750 mm	
Diameter of larger pipe = 1000 mm	
Flow through pipe = 1.05 cms	
Transition angle = 14.3 degrees	
Overall head loss = 0.01 m	

Section Description	**Water Surface Elevation**
Transition K value = 0.04	
Area of smaller pipe = 0.44 m^2	
Area of larger pipe = 0.79 m^2	
Velocity in smaller pipe = 2.38 m/s	
Velocity in larger pipe = 1.34 m/s	
Overall head loss = 0.013 m	
2500 mm x 1000 mm Tee -- from Manifold to Riser	**104.76**
Pipe shape = Circular	
Diameter = 1000 mm	
Length = 2 m	
Flow = 1.05 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 1	
Pipe area = 0.79 m²	
Pipe hydraulic radius = 0.25	
Age factor = 1	
Solids factor = 1	
Velocity = 1.34 m/s	
Friction loss = 0 m	
Fitting loss = 0.09 m	
Total loss = 0.09 m	
Manifold Seg 1	**104.76**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 1.05 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m²	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 0.21 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0 m	
Manifold Seg 2	**104.76**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 2.1 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	

Section Description	**Water Surface Elevation**
Total fitting K value = 0.05	
Pipe area = 4.91 m²	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 0.43 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0 m	
Manifold Seg 3	**104.76**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 2.1 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m²	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 0.43 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0 m	
Manifold Seg 4	**104.76**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 3.15 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m²	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 0.64 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0 m	
Manifold Seg 5	**104.77**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	

Section Description	Water Surface Elevation
Flow = 4.2 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 0.86 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
Manifold Seg 6	**104.77**
Pipe shape = Circular Diameter = 2500 mm Length = 10 m Flow = 5.25 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 1.07 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0.01 m	
Manifold Seg 7	**104.78**
Pipe shape = Circular Diameter = 2500 mm Length = 10 m Flow = 5.25 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 1.07 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0.01 m	
Manifold Seg 8	**104.79**

Section Description	Water Surface Elevation

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 6.3 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.28 m/s
Friction loss = 0 m
Fitting loss = 0 m
Total loss = 0.01 m

Manifold Seg 9 **104.8**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 7.35 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.5 m/s
Friction loss = 0 m
Fitting loss = 0.01 m
Total loss = 0.01 m

Manifold Seg 10 **104.81**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 8.4 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.71 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m

Section Description	Water Surface Elevation

Total loss = 0.01 m

Manifold Seg 11 **104.82**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 8.4 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.71 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m
Total loss = 0.01 m

Manifold Seg 12 **104.84**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 9.45 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.93 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m
Total loss = 0.02 m

4170 mm x 2500 mm Tee Tunnel Riser to Mainfold **104.98**

Pipe shape = Circular
Diameter = 2500 mm
Length = 5 m
Flow = 9.45 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.75
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1

Section Description	Water Surface Elevation

Velocity = 1.93 m/s
Friction loss = 0 m
Fitting loss = 0.14 m
Total loss = 0.15 m

4170mm dia Riser Shaft **104.99**

Pipe shape = Circular
Diameter = 4170 mm
Length = 13.25 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0
Pipe area = 13.66 m^2
Pipe hydraulic radius = 1.043
Age factor = 1
Solids factor = 1
Velocity = 1.38 m/s
Friction loss = 0 m
Fitting loss = 0 m
Total loss = 0 m

56.5m, 3.8 m dia Outfall Tunnel, Steel Liner, 90-deg bend **105.03**

Pipe shape = Circular
Diameter = 3820 mm
Length = 56.5 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.2
Pipe area = 11.46 m^2
Pipe hydraulic radius = 0.955
Age factor = 1
Solids factor = 1
Velocity = 1.65 m/s
Friction loss = 0.02 m
Fitting loss = 0.03 m
Total loss = 0.05 m

479m, 4.2 m dia Outfall Tunnel **105.16**

Pipe shape = Circular
Diameter = 4200 mm
Length = 479 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.0003
Total fitting K value = 0
Pipe area = 13.85 m^2

Section Description	**Water Surface Elevation**
Pipe hydraulic radius = 1.05 Age factor = 1 Solids factor = 1 Velocity = 1.36 m/s Friction loss = 0.13 m Fitting loss = 0 m Total loss = 0.13 m	
31.5m, 3.8 m dia Outfall Tunnel, entrance, Steel Liner	**105.24**
Pipe shape = Circular Diameter = 3820 mm Length = 31.5 m Flow = 18.9 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.5 Pipe area = 11.46 m² Pipe hydraulic radius = 0.955 Age factor = 1 Solids factor = 1 Velocity = 1.65 m/s Friction loss = 0.01 m Fitting loss = 0.07 m Total loss = 0.08 m	
10m eq pipe dia Outfall Drop Shaft	**105.24**
Pipe shape = Circular Diameter = 10617 mm Length = 30 m Flow = 18.9 cms Friction method = Colebrook-White Friction factor = 0.003 Total fitting K value = 0 Pipe area = 88.53 m² Pipe hydraulic radius = 2.654 Age factor = 1 Solids factor = 1 Velocity = 0.21 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
WSE Top of Outfall Shaft (downstream side)	**105.24**
Change in elevation = 0 m	
Twin 3m w x 4m Tall Flap Gates	**105.32**
Opening type = rectangular gate Opening diameter/width = 3000 mm	

Section Description	Water Surface Elevation
Gate height = 4000 mm Invert = 93.4 Number of gates = 2 Flow through gate(s) = 18.9 cms Total area of opening(s) = 24 m^2 Velocity through gate(s) = 0.79 m/s Flow behavior = orifice, downstream control Gate loss = 0.08 m Downstream water level = 105.24 Upstream water level = 105.32	
Head Added (when pumping) 0.0 m head added Change in elevation = 0 m	**105.32**
WSE Top of Outfall Shaft (upstream side) Change in elevation = 0 m	**105.32**
10 m eq pipe dia Outfall Riser Shaft Pipe shape = Circular Diameter = 10617 mm Length = 30 m Flow = 18.9 cms Friction method = Colebrook-White Friction factor = 0.003 Total fitting K value = 0 Pipe area = 88.53 m² Pipe hydraulic radius = 2.654 Age factor = 1 Solids factor = 1 Velocity = 0.21 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	**105.32**
31.5m, 3.8 m dia Effluent Tunnel, Exit, Steel Liner Pipe shape = Circular Diameter = 3820 mm Length = 31.5 m Flow = 18.9 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 1 Pipe area = 11.46 m² Pipe hydraulic radius = 0.955 Age factor = 1 Solids factor = 1 Velocity = 1.65 m/s	**105.47**

Section Description	**Water Surface Elevation**

Friction loss = 0.01 m
Fitting loss = 0.14 m
Total loss = 0.15 m

139m, 4.2 m dia Effluent Tunnel **105.51**

Pipe shape = Circular
Diameter = 4200 mm
Length = 139 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.0003
Total fitting K value = 0
Pipe area = 13.85 m²
Pipe hydraulic radius = 1.05
Age factor = 1
Solids factor = 1
Velocity = 1.36 m/s
Friction loss = 0.04 m
Fitting loss = 0 m
Total loss = 0.04 m

22.5m, 3.8 m dia Effluent Tunnel, Elbow, Steel Liner **105.55**

Pipe shape = Circular
Diameter = 3820 mm
Length = 22.5 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.25
Pipe area = 11.46 m²
Pipe hydraulic radius = 0.955
Age factor = 1
Solids factor = 1
Velocity = 1.65 m/s
Friction loss = 0.01 m
Fitting loss = 0.03 m
Total loss = 0.04 m

Transition 5.155 m to 3.8 m dia **105.56**

Diameter of smaller pipe = 3800 mm
Diameter of larger pipe = 5155 mm
Flow through pipe = 18.9 cms
Transition angle = 17.1 degrees
Overall head loss = 0.01 m
Transition K value = 0.05
Area of smaller pipe = 11.34 m^2
Area of larger pipe = 20.87 m^2
Velocity in smaller pipe = 2.23 m/s

Section Description	Water Surface Elevation

Velocity in larger pipe = 1.21 m/s
Overall head loss = 0.01 m

Transition 7 m dia to 5.155 m	**105.56**

Diameter of smaller pipe = 5155 mm
Diameter of larger pipe = 7000 mm
Flow through pipe = 18.9 cms
Transition angle = 31.7 degrees
Overall head loss = 0 m
Transition K value = 0.1
Area of smaller pipe = 20.87 m^2
Area of larger pipe = 38.48 m^2
Velocity in smaller pipe = 1.21 m/s
Velocity in larger pipe = 0.66 m/s
Overall head loss = 0.01 m

7m dia Drop Shaft (Effluent Shaft)	**105.58**

Pipe shape = Circular
Diameter = 7000 mm
Length = 37 m
Flow = 18.9 cms
Friction method = Colebrook-White
Friction factor = 0.003
Total fitting K value = 1.5
Pipe area = 38.48 m²
Pipe hydraulic radius = 1.75
Age factor = 1
Solids factor = 1
Velocity = 0.49 m/s
Friction loss = 0 m
Fitting loss = 0.02 m
Total loss = 0.02 m

Gates Colum Line X DS of Control Gate	**105.6**

Opening type = rectangular gate
Opening diameter/width = 1830 mm
Gate height = 4000 mm
Invert = 101.73
Number of gates = 3
Flow through gate(s) = 18.9 cms
Total area of opening(s) = 21.17 m^2
Velocity through gate(s) = 0.89 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.02 m
Downstream water level = 105.58
Upstream water level = 105.6

7 m wide Crest Gates (1 of 2 Fully Open)	**105.61**

Section Description	Water Surface Elevation
Channel shape = Rectangular Manning's 'n' = 0.013 Channel length = 20 m Channel width/diameter = 7 m Flow = 18.9 cms Downstream channel invert = 102.51 Channel slope = 0 m/m Channel side slope = not applicable Area of flow = 21.65 m^2 Hydraulic radius = 1.642 Normal depth = infinite Critical depth = 0.91 m Depth downstream = 3.09 m Bend loss = 0 m Depth upstream = 3.1 m Velocity = 0.87 m/s Flow profile = Horizontal	
Gates Column Line Z US of Control Gate	**105.64**
Opening type = rectangular gate Opening diameter/width = 1830 mm Gate height = 3500 mm Invert = 102.58 Number of gates = 3 Flow through gate(s) = 18.9 cms Total area of opening(s) = 16.62 m^2 Velocity through gate(s) = 1.14 m/s Flow behavior = orifice, downstream control Gate loss = 0.03 m Downstream water level = 105.61 Upstream water level = 105.64	
New 7m Channel S1	**105.64**
Channel shape = Rectangular Manning's 'n' = 0.013 Channel length = 8 m Channel width/diameter = 7 m Flow = 18.9 cms Downstream channel invert = 102.58 Channel slope = 0 m/m Channel side slope = not applicable Area of flow = 21.43 m^2 Hydraulic radius = 1.633 Normal depth = infinite Critical depth = 0.91 m Depth downstream = 3.06 m Bend loss = 0 m Depth upstream = 3.06 m	

Section Description	Water Surface Elevation

Velocity = 0.88 m/s
Flow profile = Horizontal

Gates C.L. ZA Between Channels **105.65**

Opening type = rectangular gate
Opening diameter/width = 1830 mm
Gate height = 3500 mm
Invert = 102.58
Number of gates = 3
Flow through gate(s) = 9.45 cms
Total area of opening(s) = 16.81 m^2
Velocity through gate(s) = 0.56 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.01 m
Downstream water level = 105.64
Upstream water level = 105.65

New Channel S2 7m wide **105.65**

Channel shape = Rectangular
Manning's 'n' = 0.013
Channel length = 9 m
Channel width/diameter = 7 m
Flow = 9.45 cms
Downstream channel invert = 102.58
Channel slope = 0 m/m
Channel side slope = not applicable
Area of flow = 21.48 m^2
Hydraulic radius = 1.635
Normal depth = infinite
Critical depth = 0.57 m
Depth downstream = 3.07 m
Bend loss = 0 m
Depth upstream = 3.07 m
Velocity = 0.44 m/s
Flow profile = Horizontal

Gates Column Line A **105.66**

Opening type = rectangular gate
Opening diameter/width = 1830 mm
Gate height = 3500 mm
Invert = 102.58
Number of gates = 3
Flow through gate(s) = 9.45 cms
Total area of opening(s) = 16.89 m^2
Velocity through gate(s) = 0.56 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.01 m
Downstream water level = 105.65

Section Description	Water Surface Elevation
Upstream water level = 105.66	
Existing Channel S3 7m wide--to 2nd bay	**105.66**
Channel shape = Rectangular	
Manning's 'n' = 0.013	
Channel length = 16 m	
Channel width/diameter = 7 m	
Flow = 9.45 cms	
Downstream channel invert = 102.58	
Channel slope = 0 m/m	
Channel side slope = not applicable	
Area of flow = 21.59 m^2	
Hydraulic radius = 1.64	
Normal depth = infinite	
Critical depth = 0.57 m	
Depth downstream = 3.08 m	
Bend loss = 0 m	
Depth upstream = 3.09 m	
Velocity = 0.44 m/s	
Flow profile = Horizontal	
Gates Column Line C	**105.67**
Opening type = rectangular gate	
Opening diameter/width = 1830 mm	
Gate height = 3500 mm	
Invert = 102.58	
Number of gates = 3	
Flow through gate(s) = 9.45 cms	
Total area of opening(s) = 16.93 m^2	
Velocity through gate(s) = 0.56 m/s	
Flow behavior = orifice, downstream control	
Gate loss = 0.01 m	
Downstream water level = 105.66	
Upstream water level = 105.67	
Existing Channel S4 7m wide--to 4th bay	**105.68**
Channel shape = Rectangular	
Manning's 'n' = 0.013	
Channel length = 16 m	
Channel width/diameter = 7 m	
Flow = 9.45 cms	
Downstream channel invert = 102.42	
Channel slope = 0 m/m	
Channel side slope = not applicable	
Area of flow = 22.77 m^2	
Hydraulic radius = 1.686	
Normal depth = infinite	
Critical depth = 0.57 m	

Section Description	**Water Surface Elevation**

Depth downstream = 3.25 m
Bend loss = 0 m
Depth upstream = 3.26 m
Velocity = 0.42 m/s
Flow profile = Horizontal

3 Gates 1.87m w 3.68 m tall **105.68**

Opening type = rectangular gate
Opening diameter/width = 1867 mm
Gate height = 3678 mm
Invert = 102.42
Number of gates = 3
Flow through gate(s) = 9.45 cms
Total area of opening(s) = 18.25 m^2
Velocity through gate(s) = 0.52 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.01 m
Downstream water level = 105.68
Upstream water level = 105.68

Existing Channel S5 7m wide--to FE1 **105.69**

Channel shape = Rectangular
Manning's 'n' = 0.013
Channel length = 20 m
Channel width/diameter = 7 m
Flow = 18.9 cms
Downstream channel invert = 102.42
Channel slope = 0 m/m
Channel side slope = not applicable
Area of flow = 22.84 m^2
Hydraulic radius = 1.689
Normal depth = infinite
Critical depth = 0.91 m
Depth downstream = 3.26 m
Bend loss = 0 m
Depth upstream = 3.27 m
Velocity = 0.83 m/s
Flow profile = Horizontal

CCT WSE (limit to 105.70 m, inc. 0.14 settlement allowance) **105.69**

Change in elevation = 0 m

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Attachment E. Tideflex Diffuser System Data Analysis

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TIDEFLEX DIFFUSER (TFD) SYSTEM DATA ANALYSIS

MEDIA:		**Effluent**	
Density or			**Kg/m^3**
Spec. Gravity		**1**	

FLOWS:

	m3/s =		**litres/sec**
	m3/s =		**litres/sec**
18.9	**m3/s =**	**18900**	**litres/sec**

AVAILABLE	**Minimum**		**metres**
HEADLOSS @	**Design**		**metres**
DIFFUSER:	**Maximum**		**metres**

MAX. BACKPRESSURE: **7.0** **metres**

TFD SIZE (mm)	**HYDRAULIC CODE**
750	**5432**

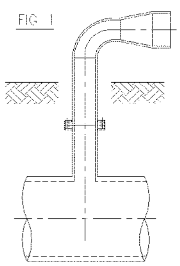
DATE: **10-May-2017**

CLIENT: Metro Vancouver
CONTACT:

ENGINEER: CDM Smith
CONTACT: Ron Miner

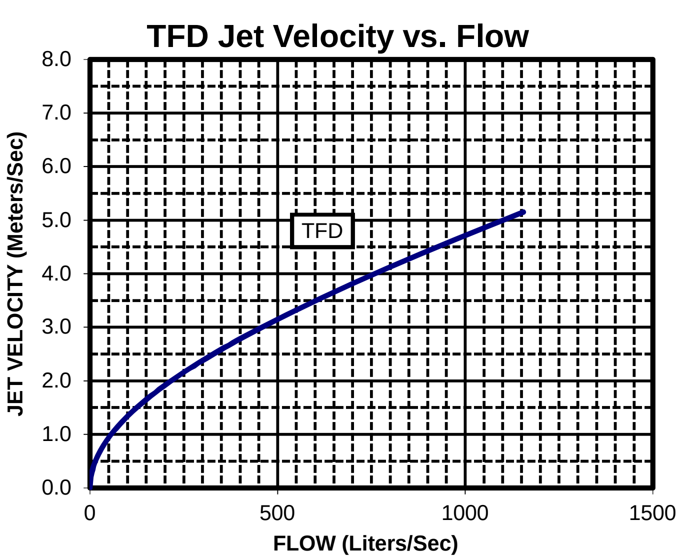
PROJECT: Annacis Island WWTP Outfall Diffuser

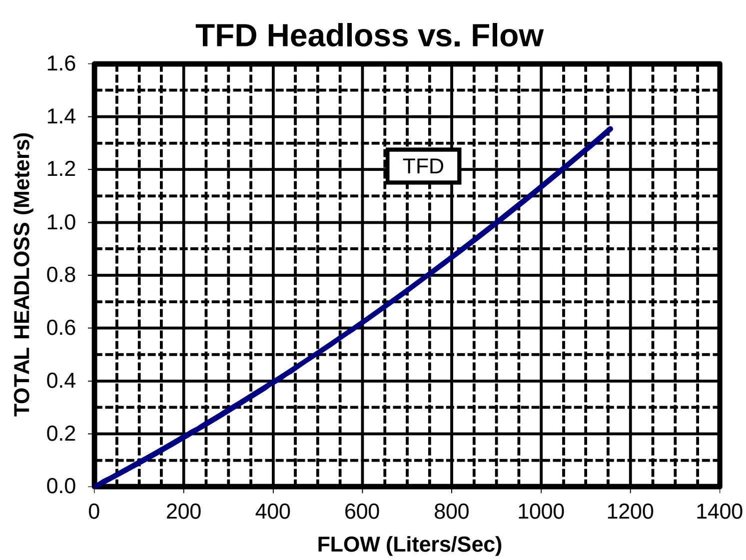
REP: Summit Valve & Controls
CONTACT: Craig Bridger



		PER TIDEFLEX DIFFUSER (TFD)			
*** TOTAL QUANTITY**	**TOTAL FLOW (litres/sec)**	**FLOW PER PORT (litres/sec)**	**JET VELOCITY (metres/sec)**	**TIDEFLEX DIFFUSER (TFD) HEADLOSS (metres)**	**EFFECTIVE AREA (cm^2)**
18					
	18900	**1050.00**	**4.86**	**1.20**	**2159.27**

RISER DIA.	**RISER QTY.**	**Flow per Port**	***Riser Velocity***	**0.5 (V^2/2g)** ***Entrance Loss***	**0.3 (V^2/2g)** ***Elbow Loss***	**TOTAL HEADLOSS (m)** ***TFD + Entrance + Elbow***
750 mm						
29.53	**18**					
		1050.00	**2.38**	**0.14**	**0.09**	**1.43**





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Attachment D

Hydraulic Design Analysis for Stage VIII Effluent Discharge

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Memorandum

To: *Project Files*

From: *Ron Miner, PE*

Date: *November 3, 2017 Update*

Subject: ***Stage VIII** Outfall and Diffuser Hydraulic Calculations Summary*

Annacis Outfall and Diffuser Configuration: STAGE VIII FLOW Q = 25.3 cms

A hydraulic analysis was completed for the Annacis Outfall and Diffuser configuration shown on Attachment C. The analysis was completed using Visual Hydraulics Treatment Plant Hydraulic Analysis Software by Innovative Hydraulics, Version 4.2. The analysis and results are summarized below

The goal of the Stage VIII hydraulic design is to determine the additional head needed (net pumping head) to discharge 25.3 cms through the tunnel and diffuser ports to provide sufficient jet velocities and mixing to satisfy water quality standards for the design condition.

Flow Path: Existing Chlorine Contact Tanks from a point just downstream of the static mixer, existing 7m wide channel sections, isolation gates, new 7m wide channel sections, new isolation gates, two Crest Gates (1 in service) discharging to a 7m diameter Effluent Shaft, 4.2m/3.8m diameter Effluent Tunnel sections to the 14m diameter Outfall Shaft (future pump station shaft), effluent pumps, two 3m wide by 4m high flap gates (closed when pumping), 4.2m/3.8m diameter Outfall Tunnel sections, 3.8m/4.2m diameter Riser Shaft connecting to the mid-point of a 2.5m diameter Diffuser Manifold, 1000 mm tee branches reduced to 750mm diameter risers to each diffuser port (duckbill valve). There are 24 diffuser ports and all will be active for Stage VIII.

Elevations are referenced to the Geodetic Datum plus 100m.

A Visual Hydraulics flow sheet was created for the piping configuration extending from the river (design Water Surface Elevation (WSE) 103.18 + 0.18 = **103.36m**) upstream to the chlorine contact tanks (Maximum WSE 105.84 – 0.14 m = **105.70m**). The hydraulic grade line elevation (HGLE) at the river was raised by 0.18m to account for higher river water density from partial saline and temperature effects. The maximum WSE at the chlorine contact tank was lowered by 0.14m to account for future settlement. The Visual Hydraulics manifold/diffuser tool was used to calculate the variation in diffuser port flows to validate that the assumption of equal flow distribution among the diffuser ports is reasonable.

Hydraulic losses for open channel flow sections were calculated using Manning's equation. A Manning's roughness value of n = 0.013 was used for open channels. The Darcy-Weisbach equation was used to calculate hydraulic losses for the shafts, tunnels and diffusers. For Stage VIII, the same absolute roughness values used for Stage V representative of newly constructed conduits in good condition were used to determine the minimum net pumping head needed. They are 0.00001m for the plastic diffuser manifold, diffusers and for the 3.8m diameter tunnel sections lined with polyethylene coated steel. Absolute roughness of 0.0003m was used for the 4.3m diameter concrete lined tunnel sections and 0.003m for the tunnel shafts.

These roughness values characterize newly constructed conduits in good condition and can be expected to be valid during the early years of service. As the tunnel and diffuser system ages the effective roughness may increase due to surface wear or possibly slime buildup or other reasons increasing head loss. For Stage VIII the increase in headloss due to aging conduits will be satisfied by the effluent pump station.

To estimate additional pumping head needed for an older "aged" tunnel and diffuser system, an absolute roughness of 0.003m representative of coarse concrete was applied to the shafts, risers, tunnels and diffusers assuming surface degradation, slime buildup or some other cause for increased roughness. Note that this is 300 times rougher than the value used for plastic pipe and linings in good condition and 10 time rougher than smooth concrete. The result is that net pumping head required increases from 0.56m to 0.91m, an additional 0.35m for the aged condition.

The Visual Hydraulics Summary Report "Annacis_38_2017_11-3-17_1_Gate.vhf" is attached and itemizes the head loss calculations summarized in the schematic flow sheet below and in an enlarged schematic flow sheet, attached.

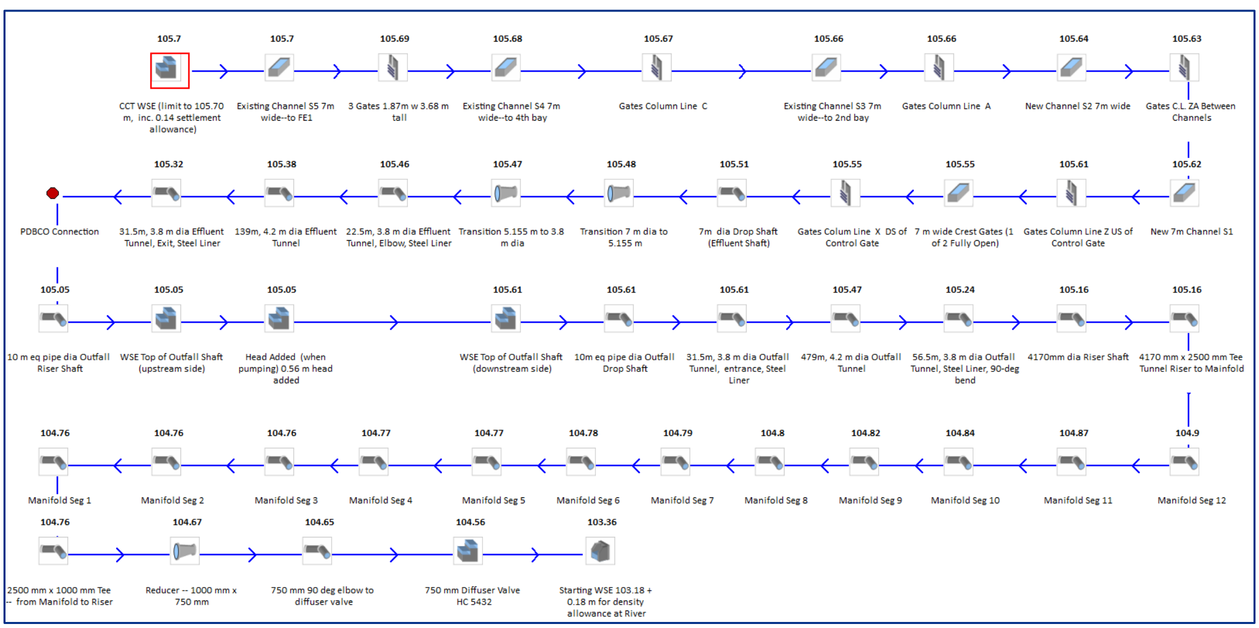


Figure 1: Visual Hydraulics Flow Sheet--Stage VIII, 25.3 cms

The calculated available headloss for the diffuser valves (only) is **1.20m** at 18.9 cms with the above configuration.

The calculated head losses assume equal flow distribution to each of 24 diffuser ports (Stage VIII). The manifold/diffuser tool in Visual Hydraulics indicates a 1.1% variation in diffuser port flow between the ports closest to and farthest from the Riser Shaft confirming that equal flow distribution is a reasonable assumption. These screen clips in Figures 2 through 4 present the system characteristics, manifold, riser and diffuser port parameters and resulting port flows, head loss and discharge velocities. Note that the manifold/diffuser tool does not include losses associated with the diffuser riser elbow. These losses are accounted for in the flow schematic shown in Figure 1. The manifold/diffuser tool is used here only to confirm the assumption of equal flow distribution among the diffuser ports.

The following configuration was evaluated:

Table 1: Diffuser Manifold and Port Configuration

Diffuser Length (m)	Port Spacing (m)	Total Number of Ports	Number of Ports Open (Stage V)	Max Stage V Flow per Port (m3/s)	Number of Ports open (Stage VIII)	Max Stage VIII Flow per Port, all Ports Open (m3/s)	Fixed Port Equivalent Diameter (mm) at 1.20 m Available Head
240	10	**24**	18	1.05	**24**	1.05	525

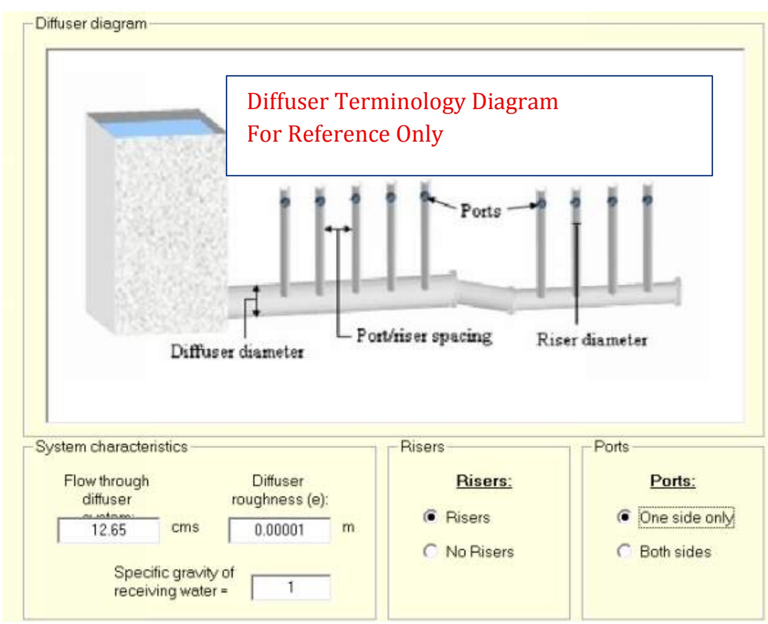


Figure 2: Flow through 2.5m manifold, ports discharging on one side only

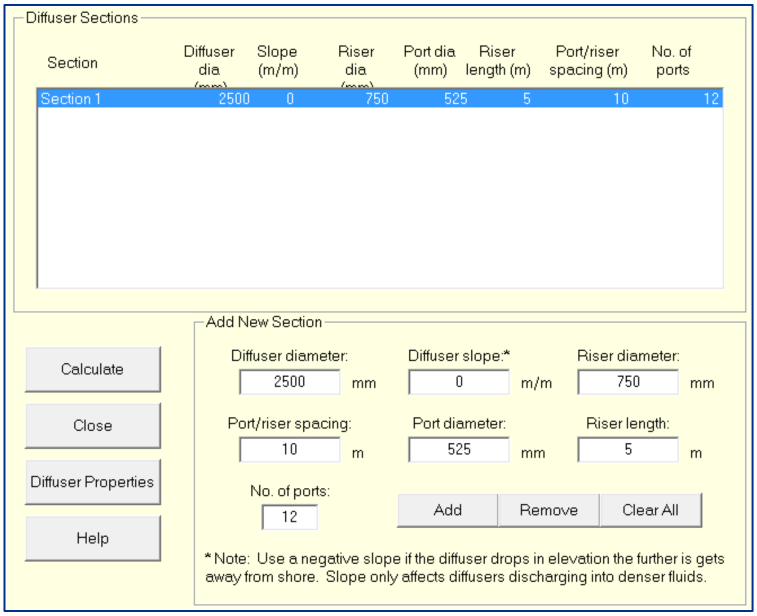
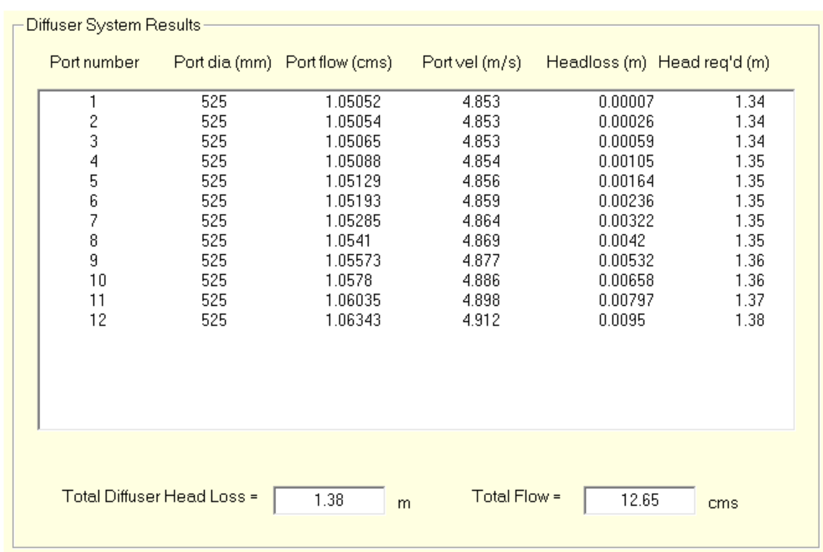


Figure 3: Diffuser Parameters: 240m long, 10m spacing, 24 of 24 @ 525mm ports open



Diffuser System Results

Port number	Port dia (mm)	Port flow (cms)	Port vel (m/s)	Headloss (m)	Head req'd (m)
1	525	1.05052	4.853	0.00007	1.34
2	525	1.05054	4.853	0.00026	1.34
3	525	1.05065	4.853	0.00059	1.34
4	525	1.05088	4.854	0.00105	1.35
5	525	1.05129	4.856	0.00164	1.35
6	525	1.05193	4.859	0.00236	1.35
7	525	1.05285	4.864	0.00322	1.35
8	525	1.0541	4.869	0.0042	1.35
9	525	1.05573	4.877	0.00532	1.36
10	525	1.0578	4.886	0.00658	1.36
11	525	1.06035	4.898	0.00797	1.37
12	525	1.06343	4.912	0.0095	1.38

Total Diffuser Head Loss = 1.38 m Total Flow = 12.65 cms

Figure 4: Results showing flow, velocity and head required through manifold, risers and diffuser ports: 240m long, 10m spacing, 24 of 24 ports @ 525mm diameter open

Results summary table:

Table 2: Diffuser Port Flows and Velocities

Diffuser Length (m)	Port Spacing (m)	Total Number of Ports	Number of Ports Open (Stage VIII)	Fixed Port Diameter (mm) at 1.20 m Available Head	Range of Flow Per Port (m3/s)	Range of Port Velocities (m/s)
240	10	24	24	525	1.051- 1.063	4.85 – 4.91

The summary table shows a 1.1% variation in diffuser port flow with port velocities ranging **4.85 to 4.91 m/s**.

Net pumping head for the system in new condition is calculated at 0.56m (not including pump station losses) and may rise to 0.91m for the system in an aged condition. Pumping will only be required under high river water surface elevations,

cc:
Bernie Kolb, John Newby, Francis Bui, Brian Caufield; CDM Smith

Attachments:

A. Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage VIII, 25.3 cms
B. Hydraulic Profile Plot
C. Outfall Alignment Figure
D. Visual Hydraulics Summary Report
E. Tideflex Diffuser System Data Analysis

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Attachment A.

Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage VIII, 25.3 cms

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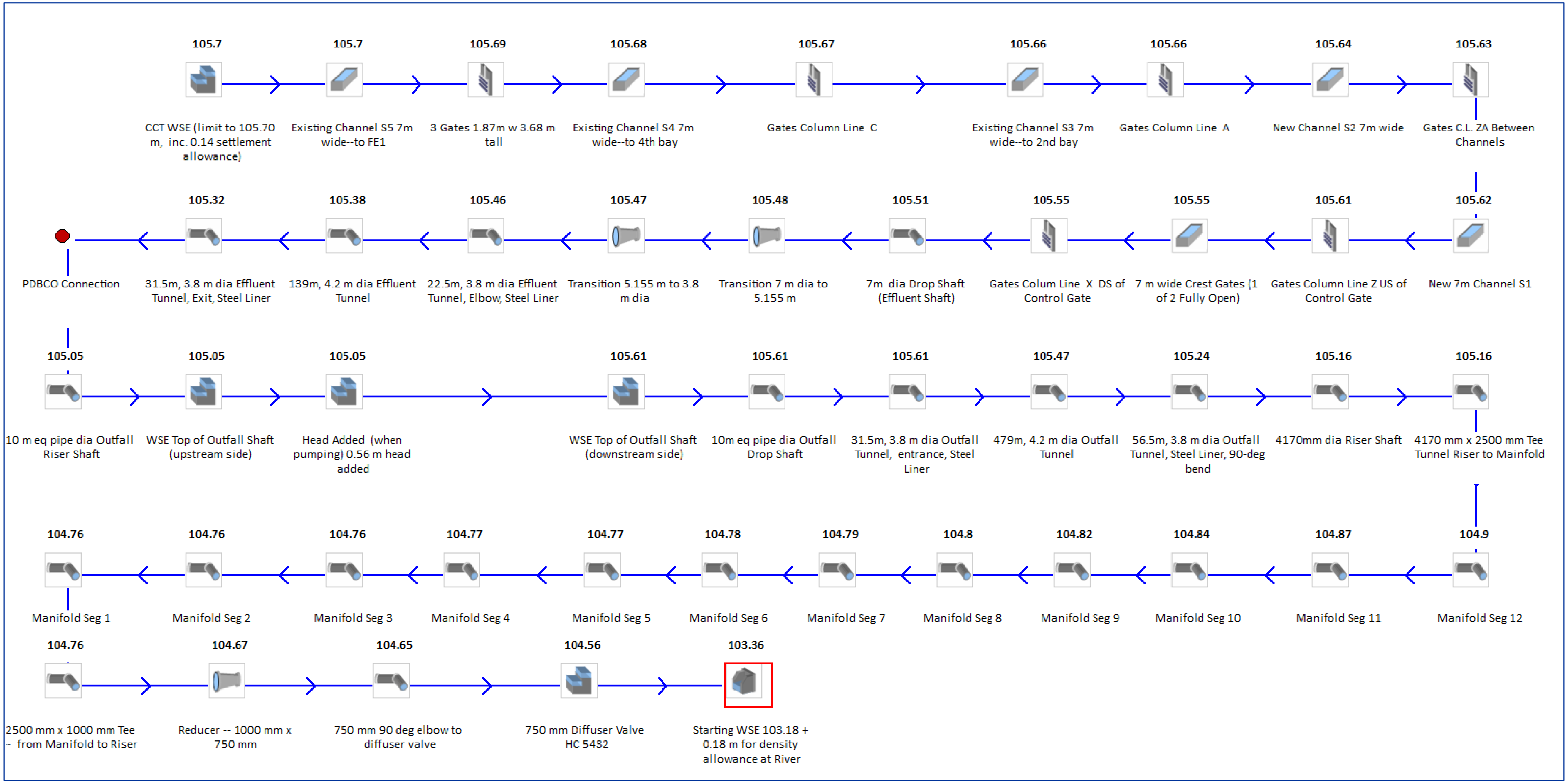
Attachment A.

Enlarged Figure 1: Visual Hydraulics Flow Sheet--Stage VIII, 25.3 cms



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Attachment B. Hydraulic Profile Plot

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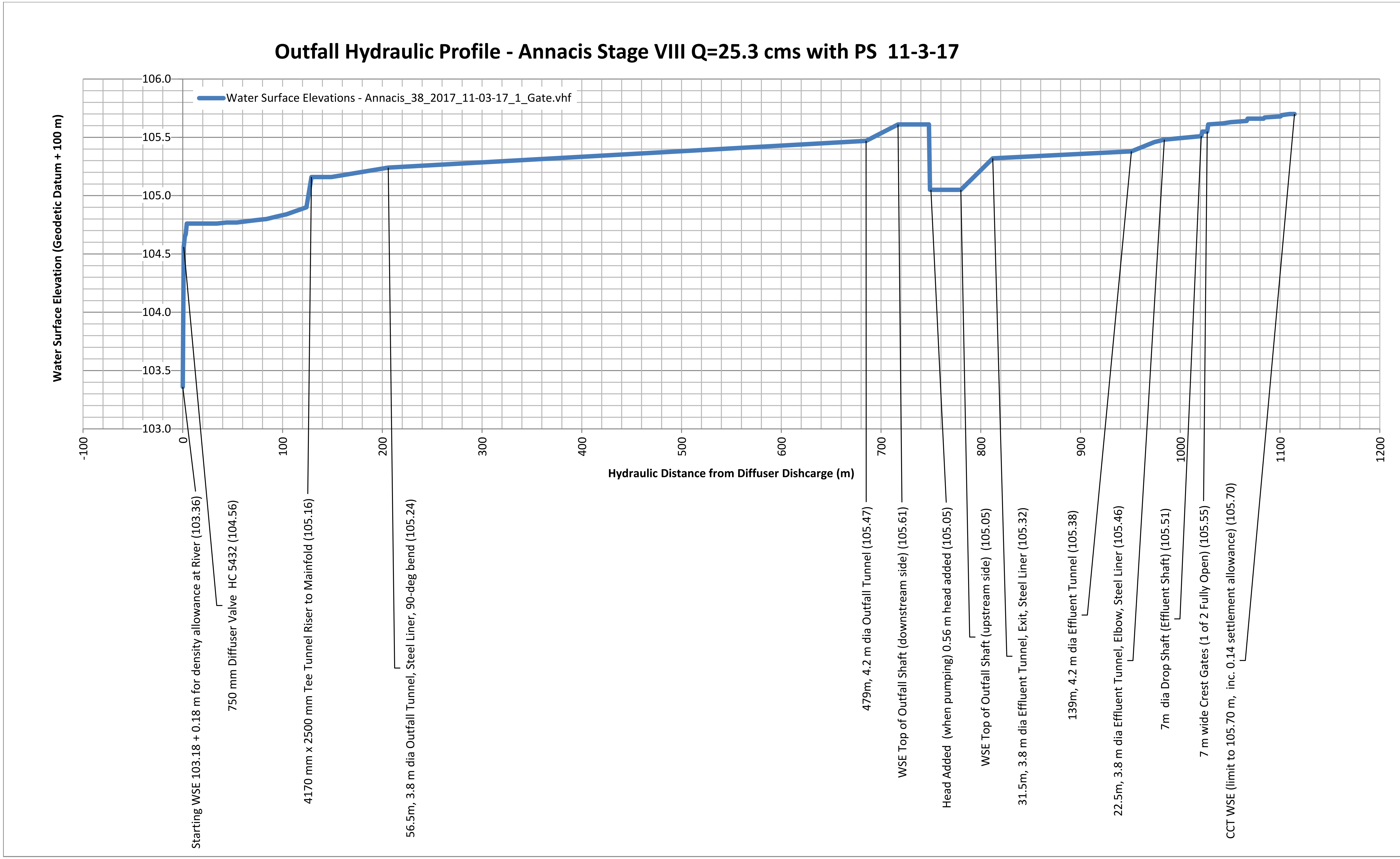

Outfall Hydraulic Profile - Annacis Stage VIII Q=25.3 cms with PS 11-3-17
Water Surface Elevations - Annacis_38_2017_11-03-17_1_Gate.vhf
Water Surface Elevation (Geodetic Datum + 100 m)
106.0
105.5
105.0
104.5
104.0
103.5
103.0
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
Hydraulic Distance from Diffuser Dishcarge (m)
Starting WSE 103.18 + 0.18 m for density allowance at River (103.36)
750 mm Diffuser Valve HC 5432 (104.56)
4170 mm x 2500 mm Tee Tunnel Riser to Mainfold (105.16)
56.5m, 3.8 m dia Outfall Tunnel, Steel Liner, 90-deg bend (105.24)
479m, 4.2 m dia Outfall Tunnel (105.47)
WSE Top of Outfall Shaft (downstream side) (105.61)
Head Added (when pumping) 0.56 m head added (105.05)
WSE Top of Outfall Shaft (upstream side) (105.05)
31.5m, 3.8 m dia Effluent Tunnel, Exit, Steel Liner (105.32)
139m, 4.2 m dia Effluent Tunnel (105.38)
22.5m, 3.8 m dia Effluent Tunnel, Elbow, Steel Liner (105.46)
7m dia Drop Shaft (Effluent Shaft) (105.51)
7 m wide Crest Gates (1 of 2 Fully Open) (105.55)
CCT WSE (limit to 105.70 m, inc. 0.14 settlement allowance) (105.70)

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Attachment C. Outfall Alignment Figure

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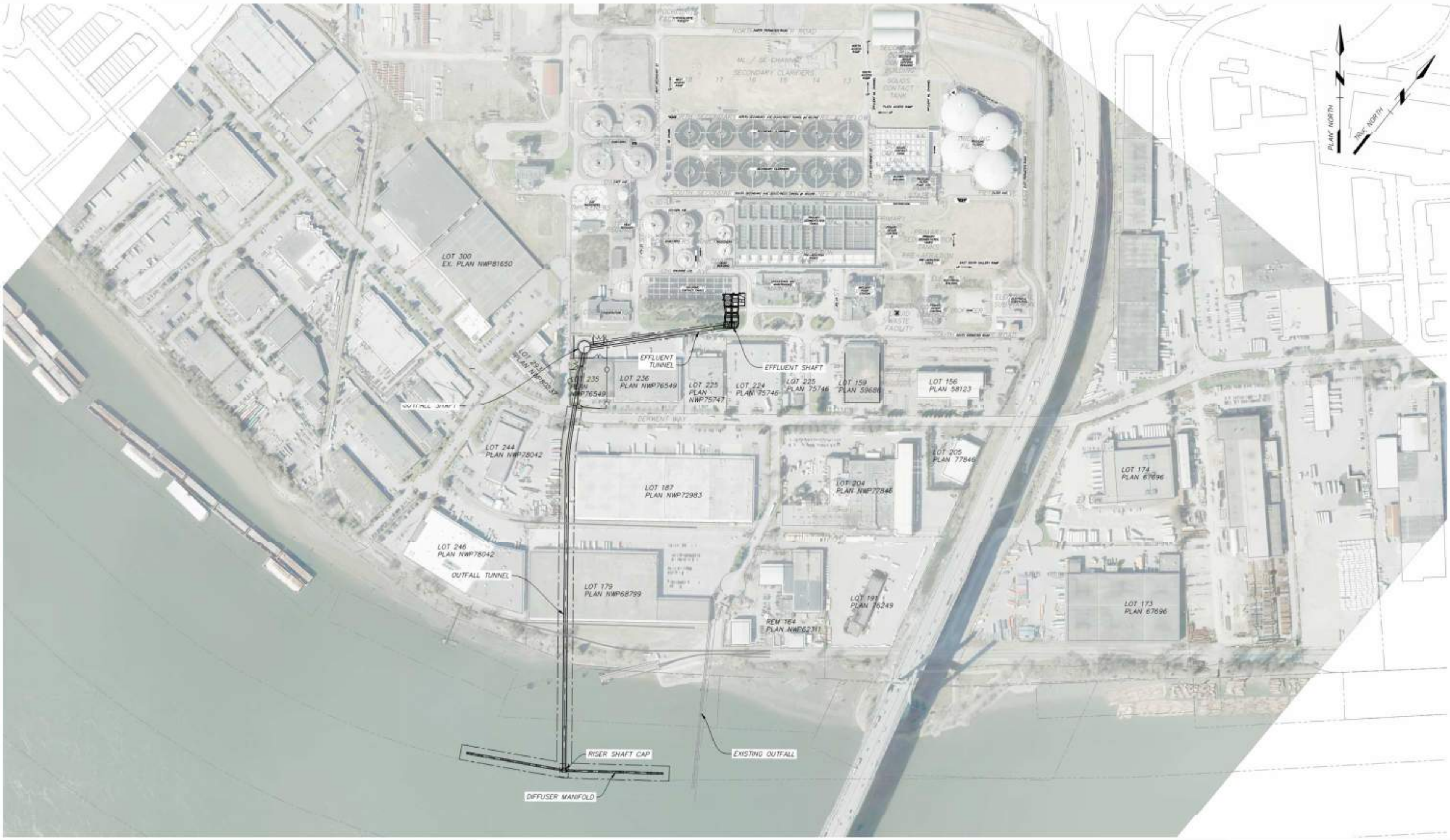

CDM Smith

1001–4710 Kingsway
Burnaby, BC V5H 4M2
Canada
Phone: 604–431–0242

CHECK PRINT

THIS DRAWING HAS NOT BEEN APPROVED, AND MAY CONTAIN ERRORS AND OMISSIONS.

Professional Seal

Issue	Date	Des'n	Dr'n	Chk'd	App'd	Description

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

GREATER VANCOUVER SEWERAGE AND DRAINAGE DISTRICT

Design:
Drawn:
Checked:
Approved
Manager

ANNACIS ISLAND WWTP
TRANSIENT MITIGATION AND OUTFALL
CONTRACT XXXX – NEW OUTFALL SYSTEM
PACKAGE 5

A10 – GENERAL SITE WORKS
NOS AERIAL MAP

SCALE: 1:2500

DISTRICT FILE SF–1933

DRAWING NUMBER FIGURE 2

SUPERSEDES PRINTS OF THIS DRAWING NUMBER WITH LETTERS PREVIOUS TO

XREFDWG

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Attachment D. Visual Hydraulics Summary Report

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Visual Hydraulics Summary Report - Hydraulic Analysis

Project: **Annacis_38_2017_11-03-17_1_Gate.vhf**
Company:
Date:

Stage VIII 25.3 cms
Scenario 2

Current flow conditions

Forward Flow =	25.3 cms
Return I Flow =	-----
Return II Flow =	-----
Return III Flow =	-----

Section Description	Water Surface Elevation
Starting WSE 103.18 + 0.18 m for density allowance at River	**103.36**
750 mm Diffuser Valve HC 5432	**104.56**
Change in elevation = 1.2 m	
750 mm 90 deg elbow to diffuser valve	**104.65**
Pipe shape = Circular	
Diameter = 750 mm	
Length = 2 m	
Flow = 1.05 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.3	
Pipe area = 0.44 m²	
Pipe hydraulic radius = 0.188	
Age factor = 1	
Solids factor = 1	
Velocity = 2.38 m/s	
Friction loss = 0.01 m	
Fitting loss = 0.09 m	
Total loss = 0.09 m	
Reducer -- 1000 mm x 750 mm	**104.67**
Diameter of smaller pipe = 750 mm	
Diameter of larger pipe = 1000 mm	
Flow through pipe = 1.05 cms	
Transition angle = 14.3 degrees	
Overall head loss = 0.01 m	

Section Description	Water Surface Elevation

Transition K value = 0.04
Area of smaller pipe = 0.44 m^2
Area of larger pipe = 0.79 m^2
Velocity in smaller pipe = 2.38 m/s
Velocity in larger pipe = 1.34 m/s
Overall head loss = 0.013 m

2500 mm x 1000 mm Tee -- from Manifold to Riser **104.76**

Pipe shape = Circular
Diameter = 1000 mm
Length = 2 m
Flow = 1.05 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 1
Pipe area = 0.79 m²
Pipe hydraulic radius = 0.25
Age factor = 1
Solids factor = 1
Velocity = 1.34 m/s
Friction loss = 0 m
Fitting loss = 0.09 m
Total loss = 0.09 m

Manifold Seg 1 **104.76**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 1.054 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 0.21 m/s
Friction loss = 0 m
Fitting loss = 0 m
Total loss = 0 m

Manifold Seg 2 **104.76**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 2.108 cms
Friction method = Colebrook-White
Friction factor = 0.00001

Section Description	**Water Surface Elevation**
Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 0.43 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
Manifold Seg 3	**104.76**
Pipe shape = Circular Diameter = 2500 mm Length = 10 m Flow = 3.163 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 0.64 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
Manifold Seg 4	**104.77**
Pipe shape = Circular Diameter = 2500 mm Length = 10 m Flow = 4.217 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.05 Pipe area = 4.91 m² Pipe hydraulic radius = 0.625 Age factor = 1 Solids factor = 1 Velocity = 0.86 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
Manifold Seg 5	**104.77**
Pipe shape = Circular Diameter = 2500 mm Length = 10 m	

Section Description	**Water Surface Elevation**
Flow = 5.271 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m^2	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 1.07 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0.01 m	
Manifold Seg 6	**104.78**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 6.325 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m^2	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 1.29 m/s	
Friction loss = 0 m	
Fitting loss = 0 m	
Total loss = 0.01 m	
Manifold Seg 7	**104.79**
Pipe shape = Circular	
Diameter = 2500 mm	
Length = 10 m	
Flow = 7.379 cms	
Friction method = Colebrook-White	
Friction factor = 0.00001	
Total fitting K value = 0.05	
Pipe area = 4.91 m^2	
Pipe hydraulic radius = 0.625	
Age factor = 1	
Solids factor = 1	
Velocity = 1.5 m/s	
Friction loss = 0 m	
Fitting loss = 0.01 m	
Total loss = 0.01 m	
Manifold Seg 8	**104.8**

Section Description	**Water Surface Elevation**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 8.433 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.72 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m
Total loss = 0.01 m

Manifold Seg 9 **104.82**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 9.488 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 1.93 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m
Total loss = 0.02 m

Manifold Seg 10 **104.84**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 10.542 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 2.15 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m

Section Description	**Water Surface Elevation**

Total loss = 0.02 m

Manifold Seg 11 **104.87**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 11.596 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 2.36 m/s
Friction loss = 0.01 m
Fitting loss = 0.01 m
Total loss = 0.02 m

Manifold Seg 12 **104.9**

Pipe shape = Circular
Diameter = 2500 mm
Length = 10 m
Flow = 12.65 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.05
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1
Velocity = 2.58 m/s
Friction loss = 0.01 m
Fitting loss = 0.02 m
Total loss = 0.03 m

4170 mm x 2500 mm Tee Tunnel Riser to Mainfold **105.16**

Pipe shape = Circular
Diameter = 2500 mm
Length = 5 m
Flow = 12.65 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.75
Pipe area = 4.91 m²
Pipe hydraulic radius = 0.625
Age factor = 1
Solids factor = 1

Section Description	Water Surface Elevation
Velocity = 2.58 m/s Friction loss = 0.01 m Fitting loss = 0.25 m Total loss = 0.26 m	
4170mm dia Riser Shaft	**105.16**
Pipe shape = Circular Diameter = 4170 mm Length = 13.25 m Flow = 25.3 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0 Pipe area = 13.66 m² Pipe hydraulic radius = 1.043 Age factor = 1 Solids factor = 1 Velocity = 1.85 m/s Friction loss = 0 m Fitting loss = 0 m Total loss = 0 m	
56.5m, 3.8 m dia Outfall Tunnel, Steel Liner, 90-deg bend	**105.24**
Pipe shape = Circular Diameter = 3820 mm Length = 56.5 m Flow = 25.3 cms Friction method = Colebrook-White Friction factor = 0.00001 Total fitting K value = 0.2 Pipe area = 11.46 m² Pipe hydraulic radius = 0.955 Age factor = 1 Solids factor = 1 Velocity = 2.21 m/s Friction loss = 0.03 m Fitting loss = 0.05 m Total loss = 0.08 m	
479m, 4.2 m dia Outfall Tunnel	**105.47**
Pipe shape = Circular Diameter = 4200 mm Length = 479 m Flow = 25.3 cms Friction method = Colebrook-White Friction factor = 0.0003 Total fitting K value = 0 Pipe area = 13.85 m²	

Section Description | **Water Surface Elevation**

Pipe hydraulic radius = 1.05
Age factor = 1
Solids factor = 1
Velocity = 1.83 m/s
Friction loss = 0.22 m
Fitting loss = 0 m
Total loss = 0.22 m

31.5m, 3.8 m dia Outfall Tunnel, entrance, Steel Liner **105.61**
Pipe shape = Circular
Diameter = 3820 mm
Length = 31.5 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.5
Pipe area = 11.46 m²
Pipe hydraulic radius = 0.955
Age factor = 1
Solids factor = 1
Velocity = 2.21 m/s
Friction loss = 0.02 m
Fitting loss = 0.12 m
Total loss = 0.14 m

10m eq pipe dia Outfall Drop Shaft **105.61**
Pipe shape = Circular
Diameter = 10617 mm
Length = 30 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.003
Total fitting K value = 0
Pipe area = 88.53 m²
Pipe hydraulic radius = 2.654
Age factor = 1
Solids factor = 1
Velocity = 0.29 m/s
Friction loss = 0 m
Fitting loss = 0 m
Total loss = 0 m

WSE Top of Outfall Shaft (downstream side) **105.61**
Change in elevation = 0 m

Head Added (when pumping) 0.56 m head added **105.05**
Change in elevation = -0.56 m

Section Description	**Water Surface Elevation**
WSE Top of Outfall Shaft (upstream side)	**105.05**

Change in elevation = 0 m

10 m eq pipe dia Outfall Riser Shaft	**105.05**

Pipe shape = Circular
Diameter = 10617 mm
Length = 30 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.003
Total fitting K value = 0
Pipe area = 88.53 m²
Pipe hydraulic radius = 2.654
Age factor = 1
Solids factor = 1
Velocity = 0.29 m/s
Friction loss = 0 m
Fitting loss = 0 m
Total loss = 0 m

31.5m, 3.8 m dia Effluent Tunnel, Exit, Steel Liner	**105.32**

Pipe shape = Circular
Diameter = 3820 mm
Length = 31.5 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 1
Pipe area = 11.46 m²
Pipe hydraulic radius = 0.955
Age factor = 1
Solids factor = 1
Velocity = 2.21 m/s
Friction loss = 0.02 m
Fitting loss = 0.25 m
Total loss = 0.27 m

139m, 4.2 m dia Effluent Tunnel	**105.38**

Pipe shape = Circular
Diameter = 4200 mm
Length = 139 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.0003
Total fitting K value = 0
Pipe area = 13.85 m²
Pipe hydraulic radius = 1.05

Section Description	Water Surface Elevation

Age factor = 1
Solids factor = 1
Velocity = 1.83 m/s
Friction loss = 0.07 m
Fitting loss = 0 m
Total loss = 0.07 m

22.5m, 3.8 m dia Effluent Tunnel, Elbow, Steel Liner **105.46**

Pipe shape = Circular
Diameter = 3820 mm
Length = 22.5 m
Flow = 25.3 cms
Friction method = Colebrook-White
Friction factor = 0.00001
Total fitting K value = 0.25
Pipe area = 11.46 m^2
Pipe hydraulic radius = 0.955
Age factor = 1
Solids factor = 1
Velocity = 2.21 m/s
Friction loss = 0.01 m
Fitting loss = 0.06 m
Total loss = 0.07 m

Transition 5.155 m to 3.8 m dia **105.47**

Diameter of smaller pipe = 3800 mm
Diameter of larger pipe = 5155 mm
Flow through pipe = 25.3 cms
Transition angle = 17.1 degrees
Overall head loss = 0.01 m
Transition K value = 0.05
Area of smaller pipe = 11.34 m^2
Area of larger pipe = 20.87 m^2
Velocity in smaller pipe = 2.23 m/s
Velocity in larger pipe = 1.21 m/s
Overall head loss = 0.01 m

Transition 7 m dia to 5.155 m **105.48**

Diameter of smaller pipe = 5155 mm
Diameter of larger pipe = 7000 mm
Flow through pipe = 25.3 cms
Transition angle = 31.7 degrees
Overall head loss = 0.01 m
Transition K value = 0.1
Area of smaller pipe = 20.87 m^2
Area of larger pipe = 38.48 m^2
Velocity in smaller pipe = 1.21 m/s
Velocity in larger pipe = 0.66 m/s

Section Description	**Water Surface Elevation**
Overall head loss = 0.01 m	
7m dia Drop Shaft (Effluent Shaft)	**105.51**
Pipe shape = Circular	
Diameter = 7000 mm	
Length = 37 m	
Flow = 25.3 cms	
Friction method = Colebrook-White	
Friction factor = 0.003	
Total fitting K value = 1.5	
Pipe area = 38.48 m²	
Pipe hydraulic radius = 1.75	
Age factor = 1	
Solids factor = 1	
Velocity = 0.66 m/s	
Friction loss = 0 m	
Fitting loss = 0.03 m	
Total loss = 0.03 m	
Gates Colum Line X DS of Control Gate	**105.55**
Opening type = rectangular gate	
Opening diameter/width = 1830 mm	
Gate height = 4000 mm	
Invert = 101.73	
Number of gates = 3	
Flow through gate(s) = 25.3 cms	
Total area of opening(s) = 20.78 m^2	
Velocity through gate(s) = 1.22 m/s	
Flow behavior = orifice, downstream control	
Gate loss = 0.04 m	
Downstream water level = 105.51	
Upstream water level = 105.55	
7 m wide Crest Gates (1 of 2 Fully Open)	**105.55**
Channel shape = Rectangular	
Manning's 'n' = 0.013	
Channel length = 20 m	
Channel width/diameter = 7 m	
Flow = 25.3 cms	
Downstream channel invert = 102.51	
Channel slope = 0 m/m	
Channel side slope = not applicable	
Area of flow = 21.28 m^2	
Hydraulic radius = 1.627	
Normal depth = infinite	
Critical depth = 1.1 m	
Depth downstream = 3.04 m	
Bend loss = 0 m	

Section Description	**Water Surface Elevation**
Depth upstream = 3.04 m Velocity = 1.19 m/s Flow profile = Horizontal	
Gates Column Line Z US of Control Gate	**105.61**
Opening type = rectangular gate Opening diameter/width = 1830 mm Gate height = 3500 mm Invert = 102.58 Number of gates = 3 Flow through gate(s) = 25.3 cms Total area of opening(s) = 16.33 m^2 Velocity through gate(s) = 1.55 m/s Flow behavior = orifice, downstream control Gate loss = 0.06 m Downstream water level = 105.55 Upstream water level = 105.61	
New 7m Channel S1	**105.62**
Channel shape = Rectangular Manning's 'n' = 0.013 Channel length = 8 m Channel width/diameter = 7 m Flow = 25.3 cms Downstream channel invert = 102.58 Channel slope = 0 m/m Channel side slope = not applicable Area of flow = 21.26 m^2 Hydraulic radius = 1.626 Normal depth = infinite Critical depth = 1.1 m Depth downstream = 3.04 m Bend loss = 0 m Depth upstream = 3.04 m Velocity = 1.19 m/s Flow profile = Horizontal	
Gates C.L. ZA Between Channels	**105.63**
Opening type = rectangular gate Opening diameter/width = 1830 mm Gate height = 3500 mm Invert = 102.58 Number of gates = 3 Flow through gate(s) = 12.65 cms Total area of opening(s) = 16.69 m^2 Velocity through gate(s) = 0.76 m/s Flow behavior = orifice, downstream control Gate loss = 0.01 m	

Section Description	Water Surface Elevation

Downstream water level = 105.62
Upstream water level = 105.63

New Channel S2 7m wide **105.64**

Channel shape = Rectangular
Manning's 'n' = 0.013
Channel length = 9 m
Channel width/diameter = 7 m
Flow = 12.65 cms
Downstream channel invert = 102.58
Channel slope = 0 m/m
Channel side slope = not applicable
Area of flow = 21.37 m^2
Hydraulic radius = 1.63
Normal depth = infinite
Critical depth = 0.69 m
Depth downstream = 3.05 m
Bend loss = 0.01 m
Depth upstream = 3.06 m
Velocity = 0.59 m/s
Flow profile = Horizontal

Gates Column Line A **105.66**

Opening type = rectangular gate
Opening diameter/width = 1830 mm
Gate height = 3500 mm
Invert = 102.58
Number of gates = 3
Flow through gate(s) = 12.65 cms
Total area of opening(s) = 16.82 m^2
Velocity through gate(s) = 0.75 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.01 m
Downstream water level = 105.64
Upstream water level = 105.66

Existing Channel S3 7m wide--to 2nd bay **105.66**

Channel shape = Rectangular
Manning's 'n' = 0.013
Channel length = 16 m
Channel width/diameter = 7 m
Flow = 12.65 cms
Downstream channel invert = 102.58
Channel slope = 0 m/m
Channel side slope = not applicable
Area of flow = 21.55 m^2
Hydraulic radius = 1.638
Normal depth = infinite

Section Description	Water Surface Elevation

Critical depth = 0.69 m
Depth downstream = 3.08 m
Bend loss = 0 m
Depth upstream = 3.08 m
Velocity = 0.59 m/s
Flow profile = Horizontal

Gates Column Line C — **105.67**

Opening type = rectangular gate
Opening diameter/width = 1830 mm
Gate height = 3500 mm
Invert = 102.58
Number of gates = 3
Flow through gate(s) = 12.65 cms
Total area of opening(s) = 16.9 m^2
Velocity through gate(s) = 0.75 m/s
Flow behavior = orifice, downstream control
Gate loss = 0.01 m
Downstream water level = 105.66
Upstream water level = 105.67

Existing Channel S4 7m wide--to 4th bay — **105.68**

Channel shape = Rectangular
Manning's 'n' = 0.013
Channel length = 16 m
Channel width/diameter = 7 m
Flow = 12.65 cms
Downstream channel invert = 102.42
Channel slope = 0 m/m
Channel side slope = not applicable
Area of flow = 22.77 m^2
Hydraulic radius = 1.686
Normal depth = infinite
Critical depth = 0.69 m
Depth downstream = 3.25 m
Bend loss = 0.01 m
Depth upstream = 3.26 m
Velocity = 0.56 m/s
Flow profile = Horizontal

3 Gates 1.87m w 3.68 m tall — **105.69**

Opening type = rectangular gate
Opening diameter/width = 1867 mm
Gate height = 3678 mm
Invert = 102.42
Number of gates = 3
Flow through gate(s) = 12.65 cms

Section Description	Water Surface Elevation
Total area of opening(s) = 18.26 m^2	
Velocity through gate(s) = 0.69 m/s	
Flow behavior = orifice, downstream control	
Gate loss = 0.01 m	
Downstream water level = 105.68	
Upstream water level = 105.69	
Existing Channel S5 7m wide--to FE1	**105.7**
Channel shape = Rectangular	
Manning's 'n' = 0.013	
Channel length = 20 m	
Channel width/diameter = 7 m	
Flow = 25.3 cms	
Downstream channel invert = 102.42	
Channel slope = 0 m/m	
Channel side slope = not applicable	
Area of flow = 22.9 m^2	
Hydraulic radius = 1.691	
Normal depth = infinite	
Critical depth = 1.1 m	
Depth downstream = 3.27 m	
Bend loss = 0 m	
Depth upstream = 3.27 m	
Velocity = 1.11 m/s	
Flow profile = Horizontal	
CCT WSE (limit to 105.70 m, inc. 0.14 settlement allowance)	**105.7**
Change in elevation = 0 m	

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Attachment E. Tideflex Diffuser System Data Analysis

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TIDEFLEX DIFFUSER (TFD) SYSTEM DATA ANALYSIS

MEDIA:		Effluent	
	Density or		Kg/m^3
	Spec. Gravity	1	

FLOWS:

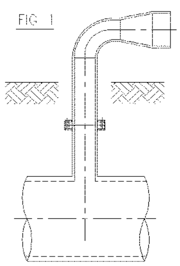
	m3/s =		litres/sec
	m3/s =		litres/sec
25.3	m3/s =	25300	litres/sec

AVAILABLE	Minimum		metres
HEADLOSS @	Design		metres
DIFFUSER:	Maximum		metres

MAX. BACKPRESSURE: 7.0 metres

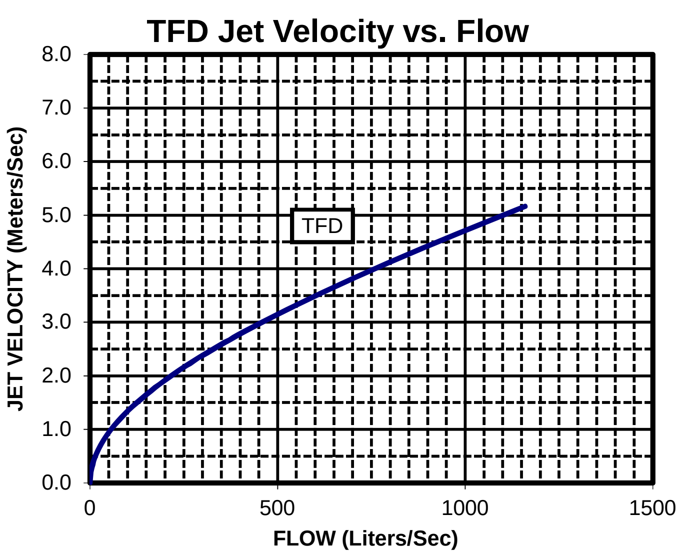
TFD SIZE (mm)	HYDRAULIC CODE
750	5432

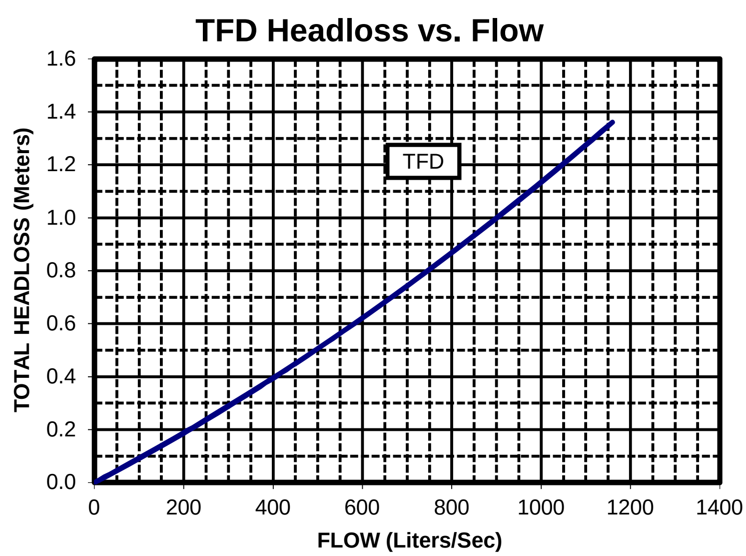
DATE:	10-May-2017
CLIENT:	Metro Vancouver
CONTACT:	
ENGINEER:	CDM Smith
CONTACT:	Ron Miner
PROJECT:	Annacis Island WWTP Outfall Diffuser
REP:	Summit Valve & Controls
CONTACT:	Craig Bridger



		PER TIDEFLEX DIFFUSER (TFD)			
* TOTAL QUANTITY	TOTAL FLOW (litres/sec)	FLOW PER PORT (litres/sec)	JET VELOCITY (metres/sec)	TIDEFLEX DIFFUSER (TFD) HEADLOSS (metres)	EFFECTIVE AREA (cm^2)
24	25300	1054.17	4.87	1.21	2162.59

RISER DIA.	RISER QTY.	Flow per Port	*Riser Velocity*	0.5 (V^2/2g) *Entrance Loss*	0.3 (V^2/2g) *Elbow Loss*	TOTAL HEADLOSS (m) *TFD + Entrance + Elbow*
750 mm						
29.53	24					
		1054.17	2.38	0.14	0.09	1.44





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