APPENDIX F

Assimilative Capacity Study

Assimilative Capacity Study - Mixing Zone Modelling for Marine Discharge

February 9, 2023

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File: 121431287

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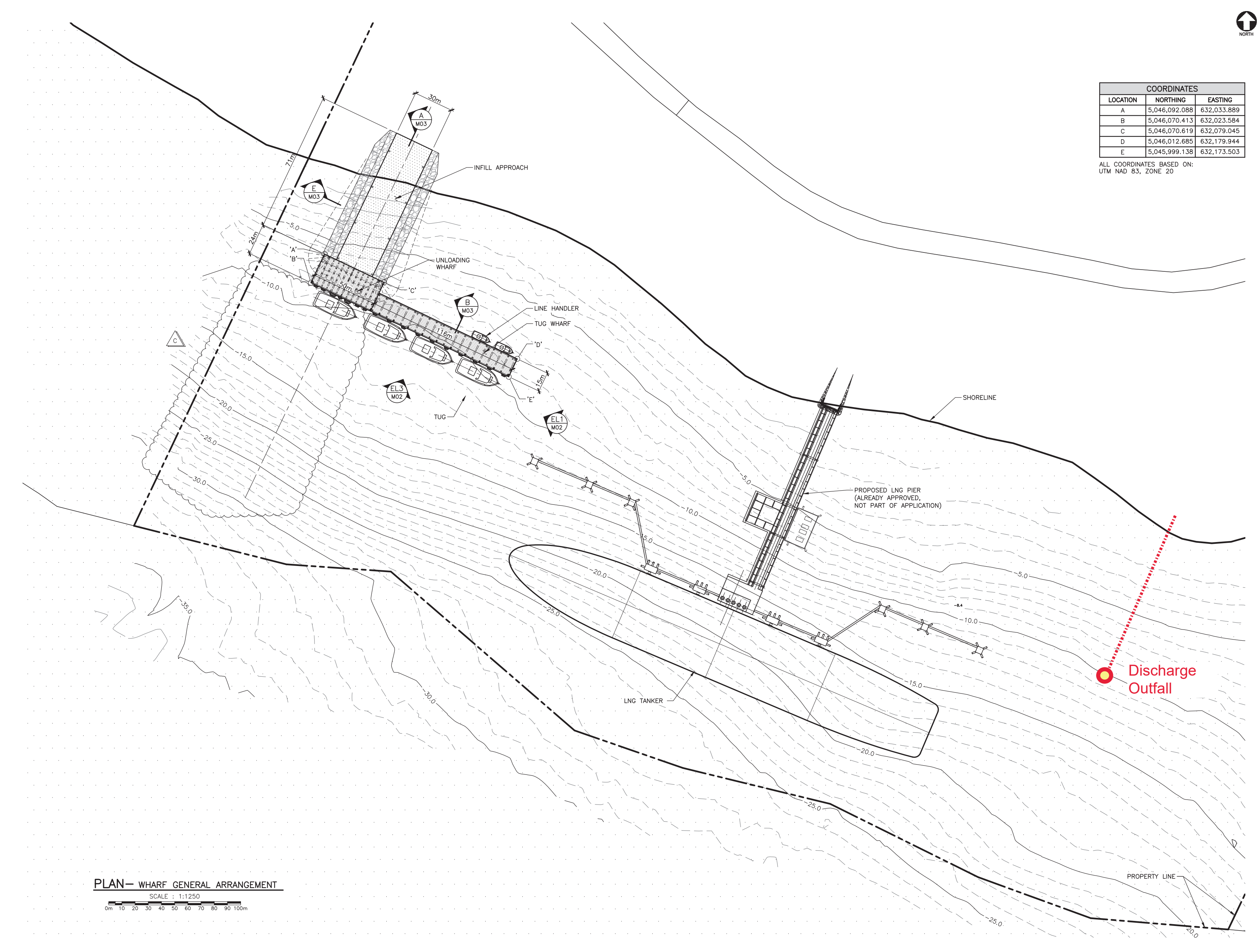
1.0 INTRODUCTION

Bear Head Energy Inc. (BHE) proposes to construct a green hydrogen and ammonia production, storage and loading facility (the Project). At full build-out, the green hydrogen and ammonia facility will be capable of producing 2 million tonnes per annum (mtpa) of green ammonia using renewable energy. The facility would include electrolysis units for green hydrogen production, air separation unit(s) for nitrogen generation, Haber-Bosch ammonia synthesis unit(s), ammonia bulk storage tank(s), and a marine terminal. The proposed marine terminal includes a jetty platform, ship berthing and trestle structure, loading facilities and marine offloading facility (MOF) to be developed within the water lot owned by BHE.

The production of hydrogen requires deionized water as a feedstock. Approximately 4 million gallons (15 million litres) of raw water will be treated on average through a two-stage reverse osmosis and deionization process prior to use in the electrolyser. It is estimated that the reject discharge volume per day from the treatment process will be approximately one-third the volume of the intake water (approximately 5 million litres per day on average). This reject process water (effluent from the water purification process prior to electrolysis) is proposed to be discharged through a marine outfall in the Strait of Canso east of the marine terminal approximately 120 m offshore (**Figure 1**).

The objective of this assimilative capacity study is to conduct the near-field modelling using a three-dimensional (3D) dilution mixing model to determine the mixing zone for parameters of concern in the reject process water (effluent). The modelling has to confirm that concentration of allowable parameters at the end of the mixing zone (excluding metals that need to meet CCME guidelines at the end of pipe discharge) are protective of the environment and in compliance with the water quality guidelines for site-specific ambient marine conditions.



PLAN– WHARF GENERAL ARRANGEMENT

SCALE : 1:1250

0m 10 20 30 40 50 60 70 80 90 100m

COORDINATES		
LOCATION	NORTHING	EASTING
A	5,046,092.088	632,033.889
B	5,046,070.413	632,023.584
C	5,046,070.619	632,079.045
D	5,046,012.685	632,179.944
E	5,045,999.138	632,173.503

ALL COORDINATES BASED ON: UTM NAD 83, ZONE 20

NOTE:

1. ALL ELEVATIONS ARE WITH RESPECT TO CHART DATUM.

   10m — 10m; CHART DATUM 0m — 0m GEODETIC DATUM (710mm); −10m — −10m

2. DEBRIS & OBSTRUCTIONS SHALL BE REMOVED FROM THE EXISTING SURFACE PRIOR TO PLACING BACKFILL MATERIAL.

3. VESSEL PARTICULARS:

   TUG: LENGTH OVERALL – 33.6m; BREADTH MOULDED – 13.5m; DEPTH MOULDED – 6.03m; DESIGN DRAFT – 5.9m

   OFFLOAD BARGE: LENGTH OVERALL – 166.6m; BREADTH MOULDED – 39.8m; DEPTH MOULDED – 10.9m; DESIGN DRAFT – 7.5m

   LNG TANKER: VESSEL CAPACITY – 267,000m³; LENGTH OVERALL – 345m; BREADTH MOULDED – 55m; DEPTH MOULDED – 27.2m; DESIGN DRAFT – 12.5m

   LINE HANDLER: LENGTH OVERALL – 14.4m; BREADTH MOULDED – 4.73m; DEPTH MOULDED – 2.05m; DESIGN DRAFT – 1.7m

4. WATER ELEVATIONS:

   H.H.W.L.T. 2.0m
   H.H.W.M.T. 1.6m
   M.W.L. 0.9m
   L.L.W.M.T. 0.2m
   L.L.W.L.T. 0.0m (CHART = 0.71m GEO)

BEAR HEAD LNG
A subsidiary company of Liquefied Natural Gas Limited

No.	Description	Date	By
C	DOLPHINS REMOVED	JUN 03/16	RBT
B	ISSUED FOR FINAL REPORT	DEC 18/15	RBT
A	ISSUED FOR REVIEW	NOV 06/15	RBT

Revision or Issue

BEARHEAD LNG

UNLOADING/TUG WHARF CONCEPT DESIGN

STRUCTURAL

GENERAL ARRANGEMENT

CBCL LIMITED Consulting Engineers ISO 9001 CERTIFIED

CBCL No	Contract No	Date	Scale
152493.00		OCT. 2015	AS NOTED
		Designed: JNC	Drawn: JDP
		Checked: GKP	Approved: RBT
		Sheet No: 1 of 3	
		Drawing No: M01	

2.0 EFFLUENT CHARACTERIZATION

An analysis of the raw water and anticipated concentration of parameters in the reject process water provided in Appendix E for the Environmental Assessment Registration suggests no exceedance of metals above available CCME guidelines in the effluent to be discharged from the marine outfall. To achieve preferred performance and meet specifications of the reverse osmosis and deionization units, the process temperature should be in the range of 15 °C to 25 °C, which are the assumed minimum and maximum temperatures of the effluent anticipated to be discharged in winter and summer, respectively. In addition to temperature being different from ambient marine environment conditions, the effluent will have lower salinity and closer to fresh water because of the low total dissolved solids (TDS) concentration of the reject process effluent (0.087 g/L in Appendix E, Environmental Assessment Registration). Therefore, the two parameters of concern identified for the treated effluent are temperature (heated discharge) and salinity.

The Facility's treated effluent is proposed to discharge via a bottom-mounted pipe, extending into the Strait about 120 m (**Figure 1**). The effluent pipe design has not yet been finalized but for the purposes of this assessment, it has been assumed to be a 0.15 m diameter pipe located on risers approximately perpendicular to the shoreline and dominant tidal flow. The outfall crib was assumed to be at 0.5 m above seabed. Water depth at the outfall is 10 m at the Lower Low Water Large Tide (LLWLT).

The average effluent flow rate is 5 million liters a day or 0.0579 m^3/s.

3.0 RECEIVING MARINE ENVIRONMENT

3.1 PHYSICAL AND METOCEAN CHARACTERISTICS

This section summarizes the data used and the physical, hydrometric, and oceanographic characteristics of the receiving marine environment used to develop the 3D near-field model.

The Environment Canada weather station closest to the Strait of Canso is Eddy Point. It is located southeast of the Strait of Canso and 8 km away from the Project site. Based on a 13-year time series (1971 to 1985), the prevailing wind direction is northwesterly with peak wind speeds in the range of 11 m/s to 17 m/s and the average wind speed of 5 m/s. The Strait of Canso is well sheltered from long period swells and the wave climate is predominately driven by wind (CBCL 2015).

Bear Head is situated on the north shore at the southern end of the Strait of Canso off Chedabucto Bay. The Strait of Canso is a tidal inlet and effectively an artificial harbour created by the construction of the Canso Causeway. The Strait of Canso at Bear Head is relatively deep, the maximum depth near the proposed terminal is approximately 44 m, the average depth is about 20 m. **Figure 1** provides the bathymetry around the BHE marine terminal.

Currents in the Strait of Canso southeast of the Canso Causeway are generally weak and are predominantly wind-driven (McCracken 1979). Local data collected by DFO in the 70s-80s indicated that, as expected, current direction is generally aligned with the Strait. Close to the coast, currents are generally aligned with the coastline, particularly in the deeper sections where the wind influence is less. In the DFO study, typical values for current speed were from 0.05 to 0.1 m/s. Tidal analyses revealed that the tide accounts for only 10 to 20% of the total variance, the remainder of the energy being due to winds and low-frequency coastal circulation patterns (CBCL 2015).

The prevailing direction of the surface and bottom currents when the tide is flooding is northwesterly, with the strongest currents measured on the surface. During the ebbing tide, the strongest currents are also on the surface, but flowing primarily in a southeasterly direction. Bottom currents are much weaker.

The Acoustic Doppler Current Profiler (ADCP) measurements conducted by CBCL (2015) at the proposed marine terminal from December 2005 to March of 2006 showed that the depth averaged current speed is 0.05 m/s with the lowest observed speed of 0.003 m/s at a 10 m depth and 0.02 m/s towards the surface, which is still conservative for the surface layer and below the average current speed for the water column. For conservative modeling purposes the lowest observed current speeds were used for the bottom and surface.

The Strait of Canso and Chedabucto Bay are ice free in winter (O'Neill 1977); ice does not therefore interfere with typical wave and current patterns and mixing. Therefore, ice conditions were not evaluated in the 3D model.

3.2 AMBIENT SEAWATER QUALITY

Salinity in the Strait ranges from approximately 29 g/L (or parts per thousand, ppt) at the surface to 31 g/L near the bottom (McCracken 1979). Similarly, salinity values collected by Stantec (2016) appear to have a relatively narrow range during the year within a water depth of 10 m. Salinity measured by Stantec (2016) was approximately between 29.5 g/L and 30.5 g/L. For modelling purposes to characterize ambient conditions in the marine environment during discharge of reject process water, a salinity of 30.5 g/L was used for both summer and winter modelling scenarios.

Stantec (2016) observed temperature of 15.8 °C in the Strait in September 2016. The temperature was very similar to DFO historical temperature of 15.7 °C obtained from available Ocean Data Inventory (ODI) database (DFO 2023). For modelling purposes to represent summer conditions at the marine outfall, a temperature of 15.8 °C was used in the model. Based on DFO historical data, during worst-case winter conditions, anticipated to occur in February, water temperature is approximately 1.7 °C. For modelling purposes to represent winter conditions at the marine outfall, a temperature of 1.7 °C was used in the model.

3.3 RECEIVING WATER QUALITY OBJECTIVES

The Province of Nova Scotia is a signatory party to the Canadian Council of Ministers of the Environment (CCME) and has supported the establishment of CCME Canadian Environmental Quality Guidelines, including those for the protection of aquatic life. The CCME marine water quality guidelines for temperature and salinity were used in this study.

The CCME water quality guidelines for the protection of aquatic life for temperature recommend that human activities should not cause changes in ambient temperature of marine and estuarine waters to exceed ±1ºC at any time, location, or depth.

The CCME water quality guidelines for the protection of aquatic life for salinity recommend that human activities should not cause the salinity (expressed as parts per thousand, ppt, or g/kg) of marine and estuarine waters to fluctuate by more than 10% of the natural level expected at that time and depth.

4.0 3D NEAR-FIELD MODELLING

The objective of near-field modelling is to undertake effluent dilution and mixing analysis of the reject water effluent under conservative conditions. Near-field modelling was conducted for the selected location as shown on **Figure 1.** The scale of the near-field modelling is on the order of several metres to about one hundred metres, which allows for a detailed prediction of the effluent plume discharging from the diffuser at the outfall location.

The near-field modelling was performed to determine the concentration of salinity and temperature in the near-field mixing zone. The objective was to confirm that salinity and temperature at the end of the mixing zone are protective of the environment and in compliance with the water quality guidelines.

The Cornell Mixing Zone Expert System (CORMIX) was used for 3D near-field modelling. CORMIX is a USEPA-supported mixing zone model for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. For this assimilative capacity study, CORMIX modelling was undertaken for effluent quality parameters under conservative low current speed conditions for summer and winter seasons. Winter and summer scenarios were differentiated by ambient and effluent water temperatures and densities.

4.1 METHODOLOGY

4.1.1 CORMIX Model

CORMIX (Version 12.0) was used to analyze and assess near-field mixing (conditions at and near the initial mixing zone). CORMIX is a software system for the analysis, prediction, and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The major emphasis is on the geometry and dilution characteristics of the initial mixing zone, but the system can also predict the behavior of the discharge plume at larger distances. CORMIX is a 3D model which can be run in steady-state and tidal ambient conditions.

The CORMIX model was run through several iterations to identify the optimal end-of-pipe outfall configuration to reduce impact of treated effluent on water quality in the mixing zone. The modelling results were compared to the CCME marine water quality guidelines for temperature and salinity.

4.1.2 Mixing Zone Definition

The modelling of the near-field dilution mixing is aimed to confirm that the ambient seawater quality concentrations or the CCME marine water quality guidelines are met at the edge of the mixing zone. CCME (2003) defines the mixing zone as “an area contiguous with a point source (effluent) where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality guidelines or objectives”.

4.2 MODEL SETUP AND CALIBRATIONS

The CORMIX model requires three sets of input parameters to describe: 1) ambient conditions or receiving water body characteristics; 2) effluent discharge characteristics; and 3) diffuser specifications. Receiving water body characteristics were selected based on characterization of the receiving marine environment presented in Section 3. Effluent discharge characteristics are presented in Section 2. CORMIX iterative solutions were used to refine diffuser specification with an objective of obtaining optimal effluent mixing in the receiving water body.

4.2.1 Input Parameters

The required model input for the ambient conditions includes ocean water density, temperature, current speed, and average and outfall water depths. These characteristics affect the near-field transport and shape of the resulting plume geometry of the effluent discharge.

The water column at the outfall location and depth of 10 m was assumed non-stratified where the differential in water density between surface and bottom water layers are not significant. CORMIX was run at an ambient speed of 0.003 and 0.02 m/s to reflect stratification in the water column speeds from the bottom to the surface water layers.

The sediment in the Strait of Canso near the terminal is primarily silty sand in the deeper water and coarser sand and gravel sediments closer inshore (CBCL 2016). For modelling purposes the Manning’s “n”, which represents bottom roughness and dependent on the bottom substrate, was assumed to be 0.025 in the mixing zone.

Wind is a relatively insensitive parameter in CORMIX; it can affect the circulation, mixing and plume movement only in very shallow waters. The dominant wind direction in the region is from northwest (see Section 3). The average wind speed used in CORMIX is 5 m/s.

4.2.2 Outfall and Diffuser Configuration

Effluent from the Facility will be discharged via an outfall pipe with a diffuser at the end. Various outfall designs were modelled using CORMIX. Several diffuser variables were iteratively adjusted during the design process to increase predicted dilution of the treated effluent. The port was assumed to be located 0.5 m above the seabed on a crib (i.e., port height).

Based on modeling results the diffuser proposed is a single port with a 0.15 m diameter opening. The port diameter was selected based on acceptable exit velocity. A velocity range of 2 to 4 m/s provides entrainment, fast initial mixing, and a stable plume formation. The exist (jet) velocity for the proposed port is 3.3 m/s.

The discharge angle theta is the vertical angle of the discharge port relative to the seabed. An angle of 0° indicates that the diffuser jets discharge parallel to the seabed and 90° indicates an upward vertical discharge. Several vertical angles were modelled in CORMIX and compared. Generally, a smaller angle results in greater opportunity for mixing and dilution. However, angles less than 20° may scour and suspend bottom sediments and were not considered. An optimal horizontal angle of 30° provides better mixing and was used in this study.

Table 4-1 summarizes the results of the CORMIX model input data for winter and summer scenarios and **Figure 2** provides a conceptual sketch for the diffuser.

Table 4-1 CORMIX Input Data for Winter and Summer Scenarios

Characteristics	Winter	Summer
Water Depth at Outfall, m	10	
Effluent Flow, m^3/s	0.0579	
Number of Ports	1	
Effluent Temperature, °C	15	25
Effluent Salinity, g/L	0.087	
Effluent Density, kg/m3	999.169	997.114
Ambient Seawater Temperature, °C	1.7	15.8
Ambient Seawater Salinity, g/L	30.5	
Ambient Effluent Density, kg/m3	1024.39	1022.33
Low Current Speed, m/s	0.003 (bottom layer); 0.02 (surface layer)	
Port Diameter, m	0.15	
Vertical Pipe Angle (theta), deg.	30	
Horizontal Pipe Angle (sigma), deg.	0	
Alignment Angle (gamma), deg.	90	
Port Height Above Seabed, m	0.5	
Manning's n	0.025	
Average Wind Speed, m/s	5.0	
Heat Exchange Coef., W/m^2, °C	38	54

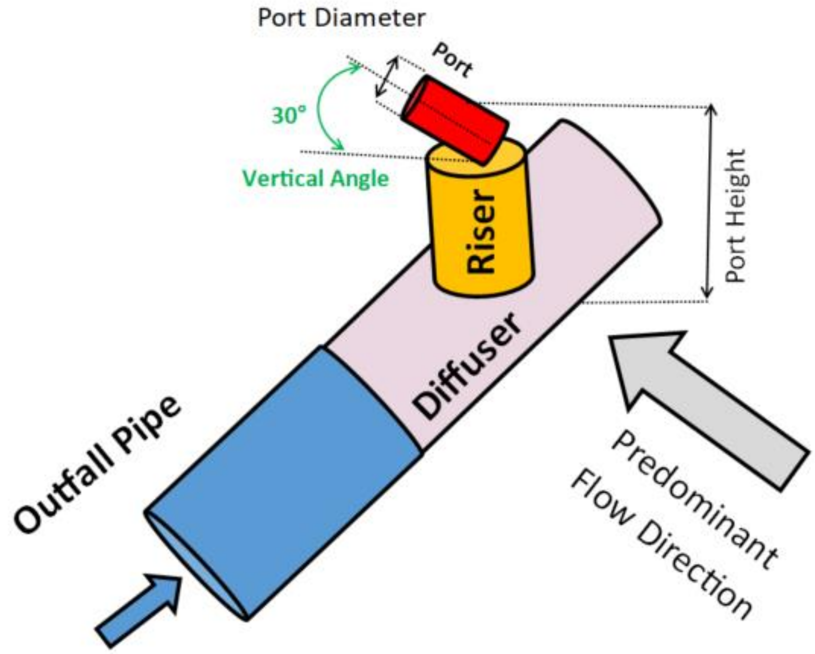


Figure 2 Conceptual Sketch of the Diffuser and Configuration for the Marine Outfall

4.3 NEAR-FIELD RESULTS

Dilution-mixing winter and summer scenarios with conservative ambient and effluent conditions for the Facility were run using a CORMIX model. Based on effluent and ambient conditions, the resulting water temperature in the near-field mixing zone was derived. Temperature results in the mixing zone for winter and summer scenarios are shown in **Table 4-2**. A schematic representation of effluent plume dispersion for temperature from the marine outfall is provided in **Appendix A**.

Table 4-2 Temperature Results in the Mixing Zone for Winter and Summer Scenarios

Scenario	Effluent Temp., °C	Ambient Temp., °C	CCME Guideline[1], °C	Temperature at Various Distances from Outfall, °C						
				1 m	3 m	4 m	5 m	6 m	10 m	50 m
Winter	15	1.7	2.7	11.2	4.4	3.4	2.9	2.4	2.2	2.1
Summer	25	15.8	16.8	22.4	17.7	17.0	16.6	16.3	16.1	16.0

Note:
[1] change of 1 °C from ambient temperature.

Salinity results in the mixing zone for winter and summer scenarios are shown in **Table 4-3**. A schematic representation of effluent plume dispersion for salinity from the marine outfall is provided in **Appendix A**.

Table 4-3 Salinity in the Mixing Zone for Winter and Summer Scenarios

Scenario	Effluent Salinity, g/L	Ambient Salinity, g/L	CCME Guideline[1], g/L	Salinity at Various Distances from Outfall, g/L						
				1 m	3 m	4 m	5 m	6 m	10 m	50 m
Winter	0.087	30.5	27.5	8.8	24.3	26.5	27.9	28.8	29.3	29.8
Summer	0.087	30.5	27.5	8.8	24.3	26.5	27.9	28.8	29.3	29.8

Note:
[1] change of 10% (3 g/L) from ambient salinity.

Near-field modelling using CORMIX indicates that the mixing zone extends 6 m for temperature and 5 m for salinity from the outfall before meeting the respective CCME guidelines. Using the conservative modelling parameters, it can be concluded that no exceedances of marine water quality objectives are observed at the end of the 6 m mixing zone.

Modelling predictions in this assimilative capacity study are based on conservative assumptions such as high effluent flow rate, lowest current speed, low tide in the receiving environment (water depth assumed at LLWLT), maximum expected temperature and salinity differential between effluent and ambient conditions, and small mixing zone in the relatively large receiving environment of the Strait of Canso.

5.0 CONCLUSIONS

Stantec completed the detailed mixing zone assessment of the reject process water effluent discharge from the Facility's reverse osmosis and deionization process.

The CCME marine water quality guidelines for the protection of aquatic life for temperature and salinity were used as water quality objectives in this assimilative capacity study.

The CORMIX (version 12.0) three-dimensional model was used to derive the mixing zone for the Facility effluent. Physical and metocean characteristics of the receiving environment were modelled conservatively based on available information. The outfall configuration was designed based on iterative CORMIX model runs.

Near-field modelling using CORMIX indicated that the mixing zone extends 6 m for temperature and 5 m for salinity from the outfall before meeting respective CCME guideline values. No exceedances of marine water quality objectives were observed at the end of the 6 m mixing zone.

6.0 CLOSURE

This report has been prepared for the sole benefit of Bear Head Energy Inc. This report may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and Bear Head Energy Inc.

Any use that a third party makes of this report, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this report.

The information and conclusions contained in this report are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this report should not be construed as legal advice.

The conclusions presented in this report represent the best technical judgment of Stantec Consulting Ltd. based on the data obtained from the work. If any conditions become apparent that differ from our understanding of conditions as presented in this report, we request that we be notified immediately to reassess the conclusions provided herein.

7.0 REFERENCES

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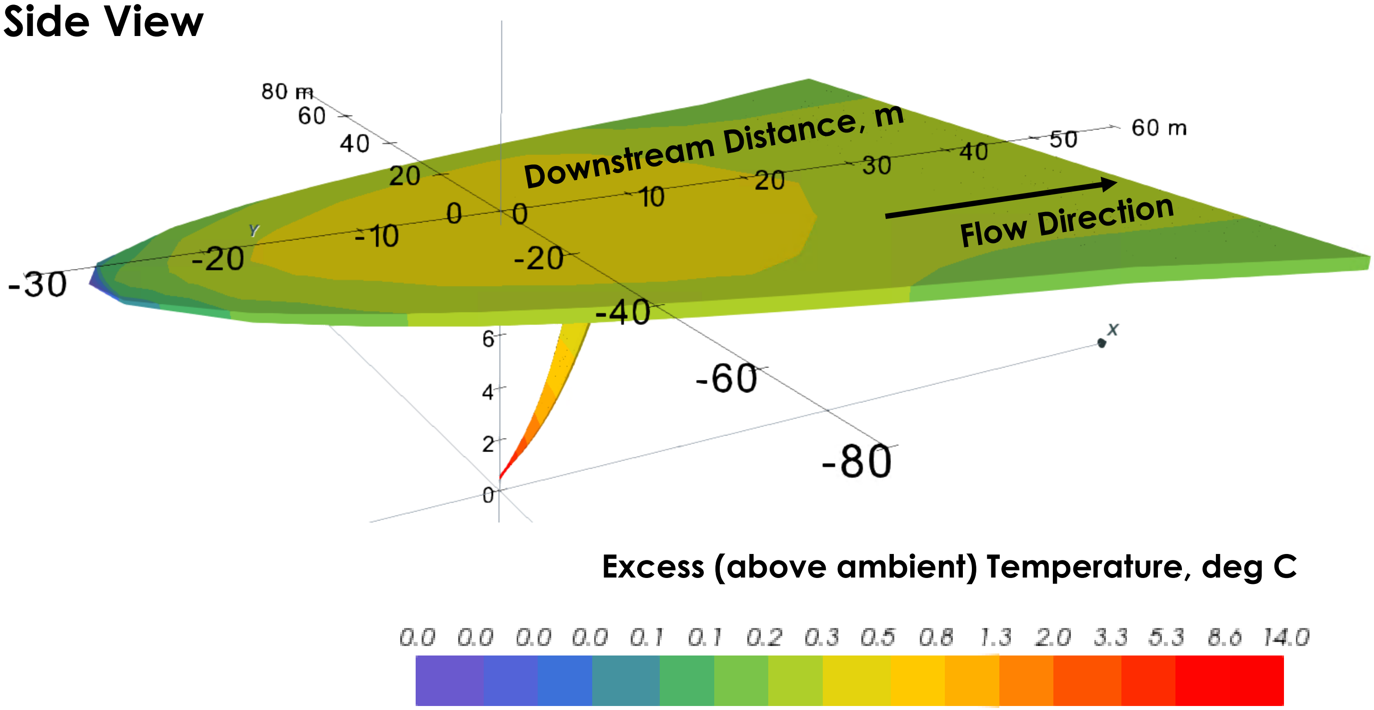
APPENDIX A

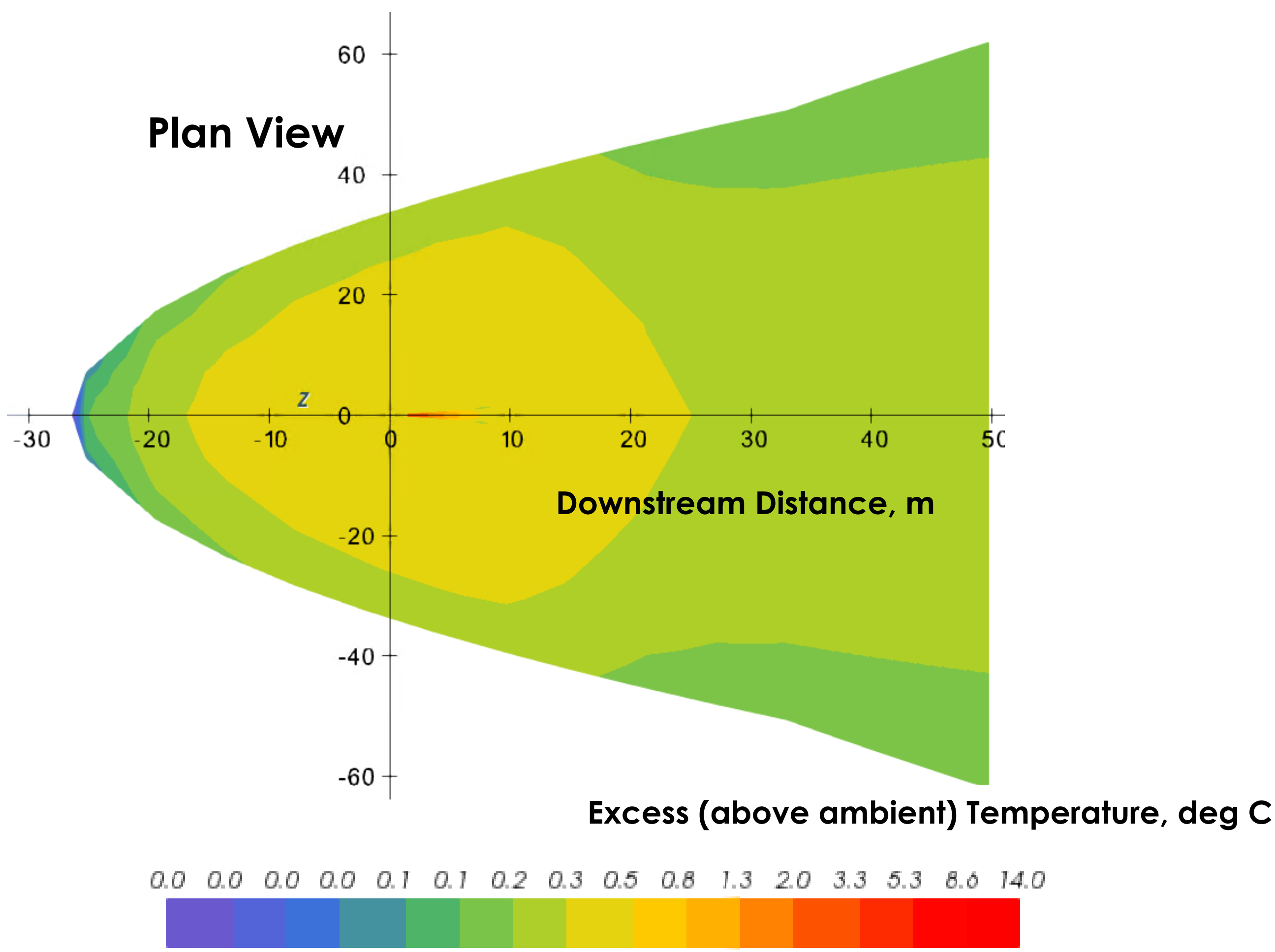
Schematic Representation of Effluent Plume Dispersion

Temperature Results—Winter

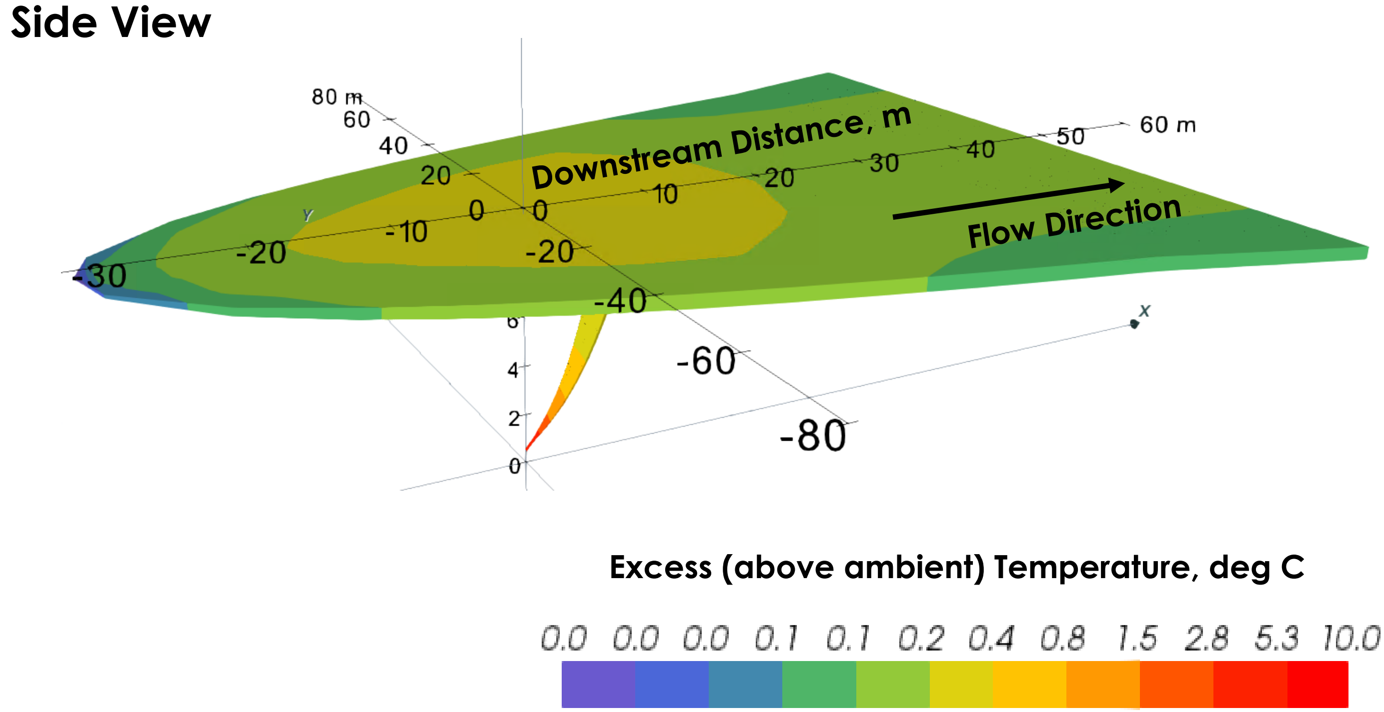
Side View

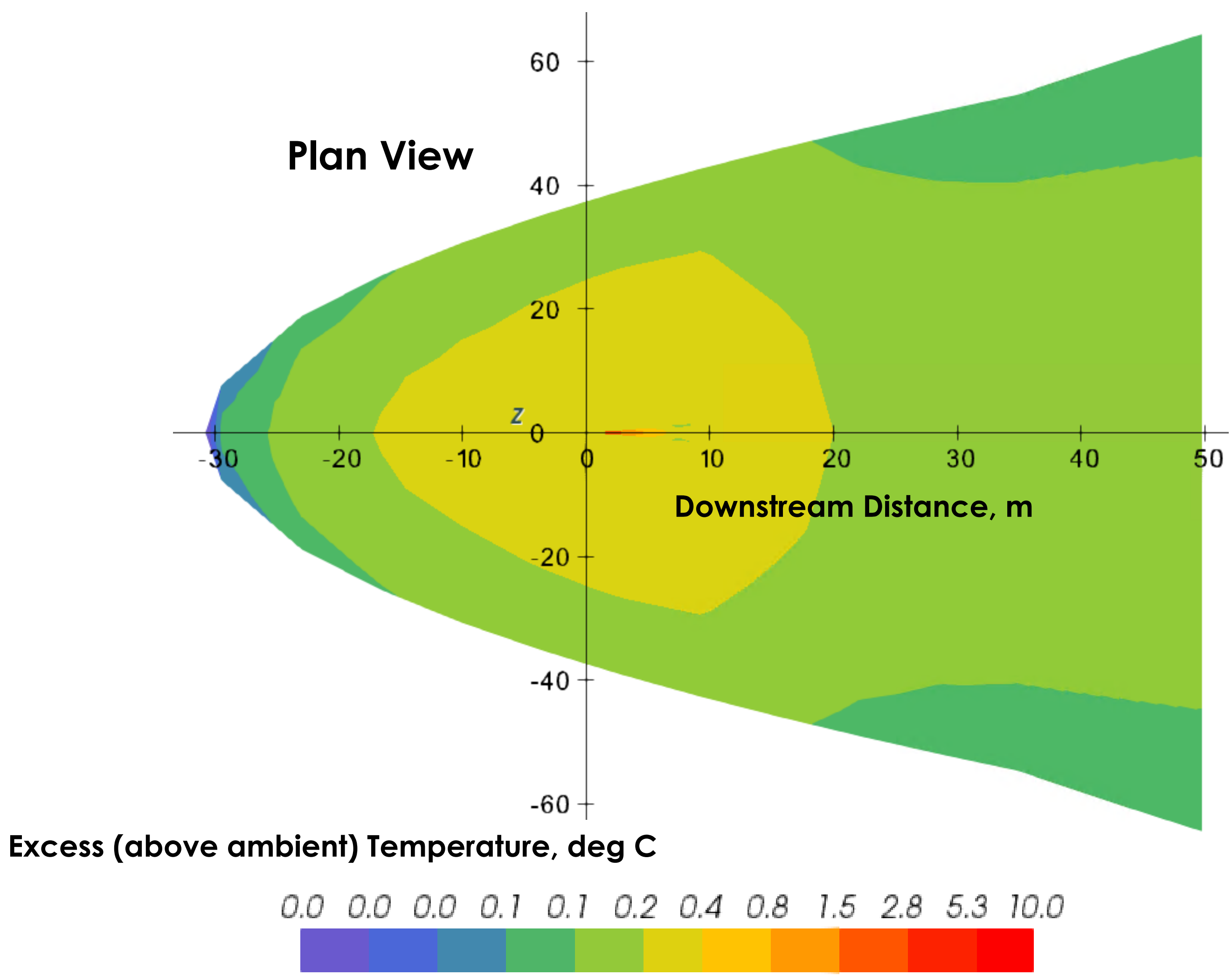


Plan View



Temperature Results—Summer





Salinity Results—Summer and Winter

Side View