# Appendix E

## *Receiving Water Study*

Appendix E1 – Stantec Final Caribou Discharge Receiving Water Study
Appendix E2 – Stantec Response to Questions
Appendix E3 – Stantec Receiving Water Study Effluent Treatment Plant Replacement

# Appendix E1

*Stantec Final Caribou Discharge Receiving Water Study*

Stantec

# Addendum Receiving Water Study for Northern Pulp Effluent Treatment Facility Replacement Project – Additional Outfall Location CH-B, Caribou Point, Nova Scotia

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## Sign-off Sheet

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# Executive Summary

Stantec Consulting Ltd. (Stantec) was retained to undertake a preliminary receiving water study in Pictou Harbour, Nova Scotia to address the requirement of a new effluent pipeline and marine outfall for a wastewater treatment plant for Northern Pulp Nova Scotia Corporation (NPNS). The dispersion characteristics of the effluent discharged from four alternative locations (Alt-A, Alt-B, Alt-C and Alt-D) were investigated using two-dimensional (2D) hydrodynamic modelling. The discharge location Alt-D in Northumberland Strait was selected as the preferred option among the four locations investigated in that study (Stantec 2017).

After subsequent marine geophysical and geotechnical field investigations of the Alt-D location outside Pictou Road in Northumberland Strait, evidence for seabed ice scour was observed that indicated this location in a water depth of about 11 m was not technically feasible for the outfall. Therefore, NPNS required other marine outfall locations in deeper water to be investigated for the dispersion of effluent and a new alternative outfall area offshore of Caribou Harbour and off Caribou Point in Northumberland Strait was identified. Stantec conducted additional far-field dispersion modelling using the MIKE 21 2D model as described in Stantec (2017). The modelling conditions and results for the additional work are outlined in this technical addendum.

The far-field dispersion characteristics of effluent discharged from two alternative locations (CH-A and CH-B) off Caribou Point were investigated by 2D hydrodynamic modelling. CH-A and CH-B approximately 540 m apart and in 25 m and 20 m water depths, respectively, both provided sufficient dilution of the discharged effluent. However, CH-B exhibited superior dispersion characteristics and was chosen as the preferred location. Mixing and dilution at the outfall location is driven by water depth at the outfall, tides and currents. Outfall depth is often a bigger driver than exact position of the outfall.

The near-field mixing and dilution of the effluent within 200 m of the outfall was performed using a 3D CORMIX model. The CORMIX model was built for the CH-B location and one-port and three-port diffuser designs for the discharge of the effluent at the outfall were modelled and evaluated. Diffuser variables were iteratively adjusted during the design process to obtain maximum predicted dilution of the treated effluent. The preferred diffuser design was three ports, with each port having a 0.3 m opening, horizontal angle of 0˚ (ports pointing downstream with diffuser perpendicular to the ambient flow direction) and vertical angle of 20˚. The recommended spacing between ports is 25 m used in Stantec (2017). This preferred diffuser design at CH-B went to a three-port diffuser from a preferred six-port diffuser at Alt-D, which also resulted in a smaller footprint of 50 m on the seabed in comparison to 125 m that would have been required for the six-port diffuser at the Alt-D location.

The mixing zone for the discharged effluent was defined as the 100-m distance from the outfall pipe as per the Canadian Council of Ministers of the Environment (CCME) guidelines. The plume from the diffuser with three ports at CH-B reaches the surface water at about 25 m from the diffuser, where the plume is not expected to be visible at the surface. The dilution ratio in the receiving environment at CH-B is 50 times at 5 m from the port and 144 times at the end of the mixing zone (i.e., at 100 m).

The conservative proposed discharge at the maximum daily effluent flow rate and exaggerated quality for adsorbable organic halides (AOX), total nitrogen (TN), total phosphorus (TP), colour, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), water temperature, dissolved oxygen (DO), pH and salinity are anticipated to meet compliance at the end of the mixing zone for applicable federal water quality guidelines.

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# 1.0 INTRODUCTION

Stantec Consulting Ltd. (Stantec) completed a preliminary receiving water study in Pictou Harbour, Nova Scotia to address the requirement of a new effluent pipeline and outfall for a replacement effluent treatment facility for Northern Pulp Nova Scotia Corporation (NPNS) (Stantec 2017). The dispersion characteristics of the effluent discharged from four alternative locations (Alt-A, Alt-B, Alt-C and Alt-D) were investigated using two-dimensional (2D) hydrodynamic modelling. The discharge location Alt-D in Northumberland Strait was selected as the preferred option among the four locations investigated in that study.

After subsequent marine geophysical and geotechnical field investigations of the Alt-D location outside Pictou Road in Northumberland Strait, evidence for seabed ice scour was observed that indicated this location in a water depth of about 11 m was not technically feasible for the outfall. Therefore, NPNS required other marine outfall locations in deeper water to be investigated for the dispersion of effluent and a new alternative outfall area offshore of Caribou Harbour and off Caribou Point in Northumberland Strait was identified. The pipeline route to this area would be a land-based path along the Pictou Causeway and Highway 106 to the Caribou Ferry terminal, and then in the vicinity of the terminal an outfall pipe is proposed to be extended parallel to the ferry route to a deeper water location that might help avoid potential issues of ice scour. In response to the request of NPNS, Stantec conducted additional far-field dispersion modelling using the MIKE 21 2D model as described in Stantec (2017). The modelling conditions and results for the additional work are outlined in this technical addendum, as well as the results for the 3D CORMIX modelling of the effluent dispersion in the near-field using a one-port and three-port diffuser design for a discharge location off Caribou Point.

# 2.0 FAR-FIELD MODELLING

## 2.1 FAR-FIELD MODELLING CONDITIONS

As the new outfall location out of the Caribou Harbour and off Caribou Point is to be located very close to the west boundary of the model domain presented in the previous study (Stantec 2017), the 2D model domain was extended from Caribou Harbour for approximately 20 km further west in Northumberland Strait. Therefore, the model domain, mesh system and boundary setups were regenerated accordingly with the following efforts:

- Additional DFO Canadian Hydrographic Service (CHS) bathymetric data were obtained to cover areas in Caribou Harbour and Northumberland Strait.
- LiDAR 2016 data were obtained from CHS to cover the shoreline topography and near-shore bathymetry (to about 6 m water depth) in the surrounding area of Caribou Harbour (Figure 2.1).
- All available bathymetric data for the study area were compiled (Figure 2.2) for use in the present outfall dispersion modelling study.

- A computational domain with the bathymetry contours and mesh system was developed with finer mesh in the Caribou Harbour and estuary areas and along the shorelines (Figure 2.3). The mesh system contains 13,331 nodes and 24,645 elements.

**Figure 2.1 LiDAR Topographic and Bathymetric Data and Extent in Caribou Harbour Area**

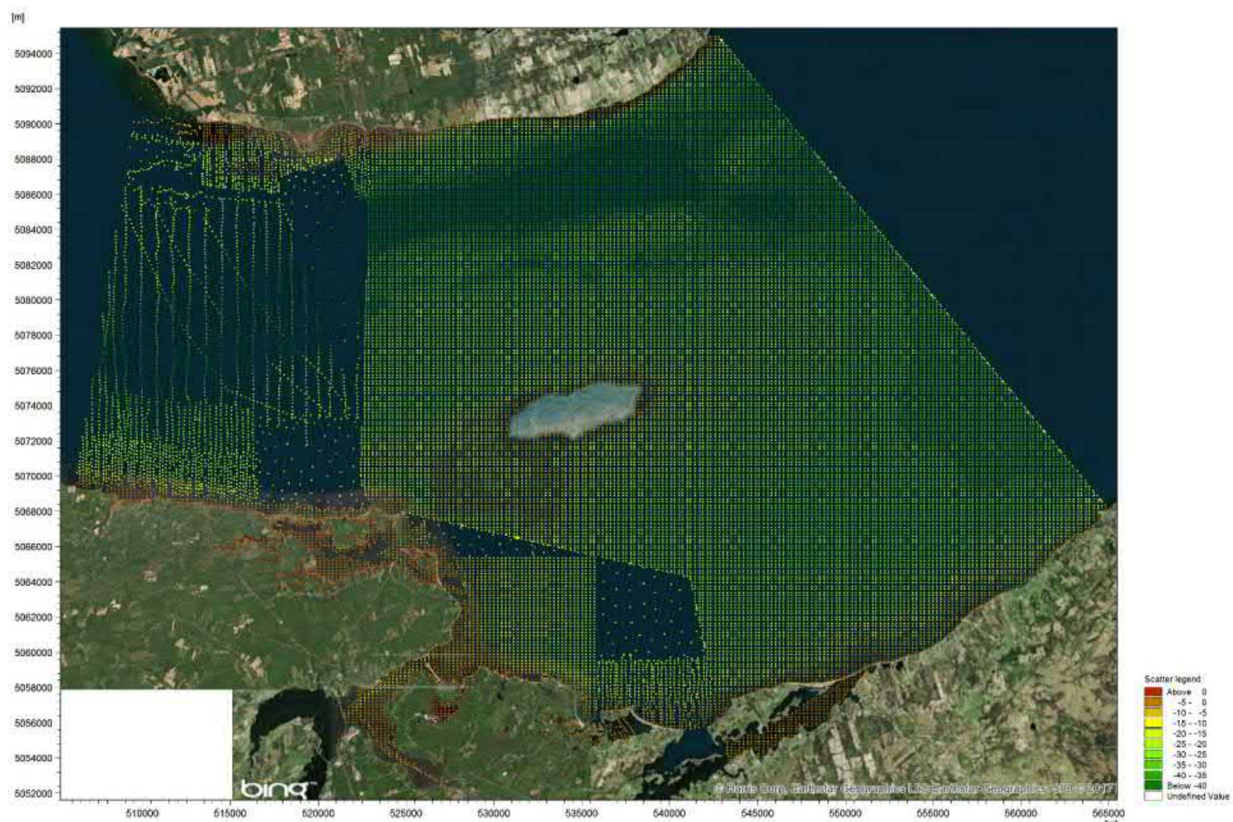
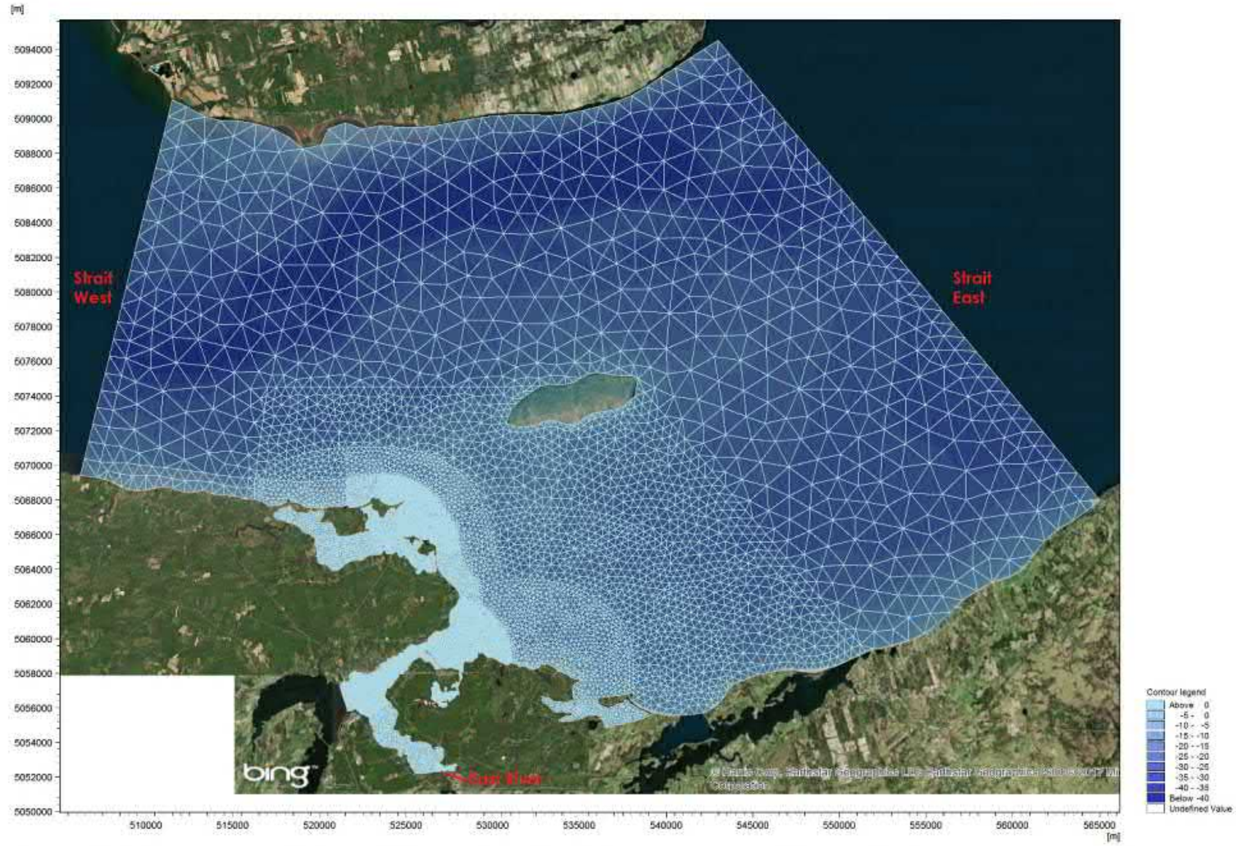



**Figure 2.2 Available Bathymetric Data and Extent**




## Figure 2.3 Computational Domain, Mesh System, and Boundaries

The methodology and approaches to the 2D far-field plume dispersion modelling are the same as those described in Stantec (2017) where a more conservative case scenario was used when evaluating the mixing zone in the receiving environment. As detailed below, the conditions for the more conservative case are found to occur during the summer months when the temperature and density play a lessor role in effluent mixing. That is, a summertime scenario to the model was applied as there would be poorer effluent plume mixing due to the smaller temperature differences (and thus buoyant mixing). In addition, the potential effects of surface mixing were minimized by modelling and using smaller tidal ranges, warmer ambient waters, less wind-driven surface currents, and lower freshwater inflows from rivers. In winter, mixing is effectively enhanced due to the larger difference in temperature and salinity (density) conditions.

The receiving water conditions and the presence of ice during the winter season in Northumberland Strait are also expected to be more favourable for effluent mixing and dispersion, compared to summer discharge conditions. This is a result of the larger temperature difference with the ambient marine water in Northumberland Strait, leading to a larger density difference between the effluent and receiving water and an increased effect of plume buoyancy on the mixing process. Therefore, it is expected a higher dilution will be achieved during the winter season compared to the summer season. Furthermore, the presence of ice cover would increase turbulence at the ice/water interface by providing resistance to the ambient water currents, resulting in higher mixing and dilution.

The modelling scenario and conditions used for the Caribou area are summarized in Table 2.1. Two potential outfall locations, CH-A and CH-B in 25 m and 20 m water depths, respectively, off Caribou Point where the depths are deeper than 20 m (mean water level, MWL) were selected for effluent dispersion modelling and discussion (Figure 2.4). The two locations are approximately 540 m apart. The effluent was assumed to be discharged at a single point discharge from the end-of-pipe outfall location and at a constant arbitrary concentration of 100 mg/L to assess dilution potential in the far-field study area. Effluent transport was simulated by the MIKE 21 model in the particle tracking module (PT) which was dynamically coupled with the hydrodynamic circulation module (HD), similar to that used in Stantec (2017).

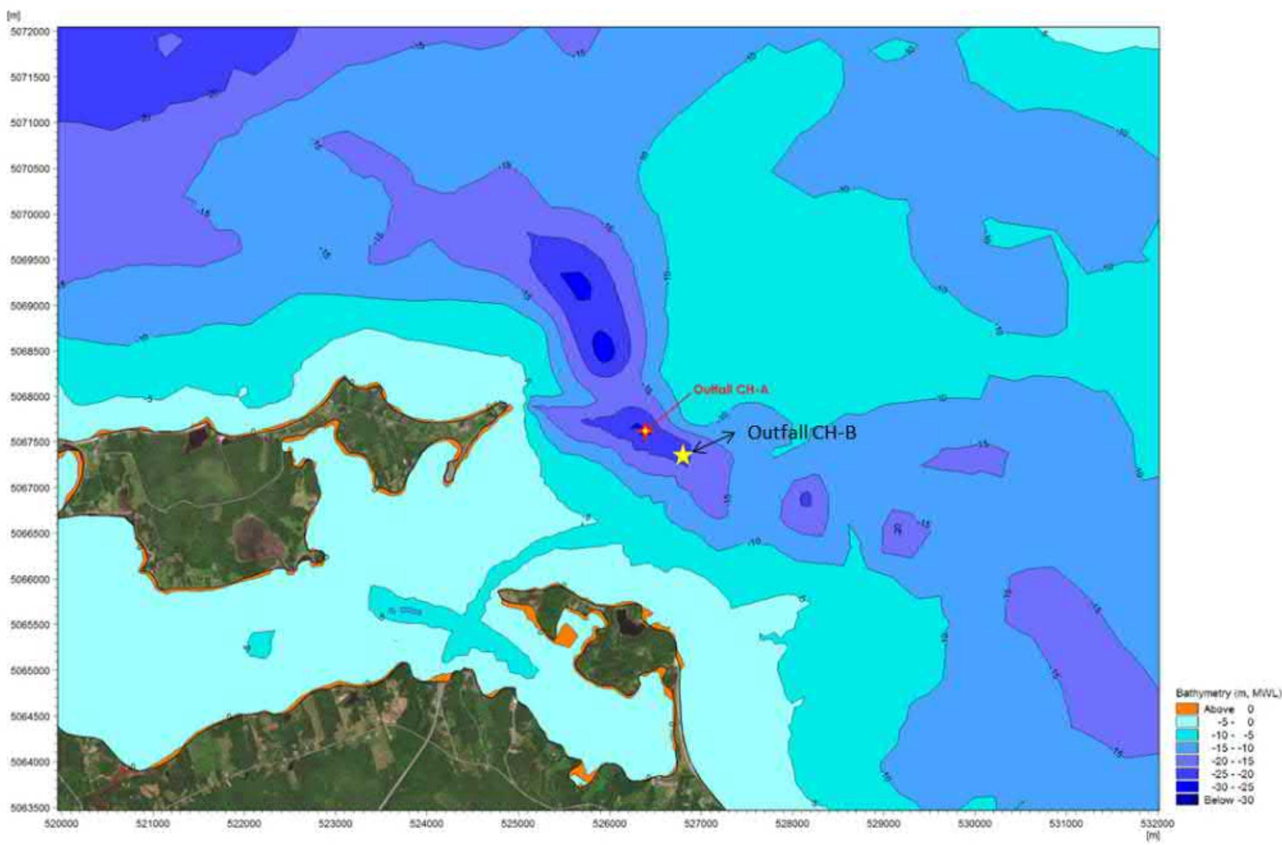



**Figure 2.4 Bathymetry and Outfall Locations CH-A and CH-B in Caribou Harbour Offshore**

**Table 2.1 Summary of Conditions and Assumptions Used in the Hydrodynamic and Particle Tracking 2D Modelling**

| Feature | Characteristics | Comments |
|---|---|---|
| **General Model Settings** | | |
| Model Domain | 13331 nodes and 24645 elements | |
| Coupled Modules | Hydrodynamic (HD), Temperature/Salinity (TS), and Particle Tracking (PT) | |
| Simulation Period | A full month from July 1 to 31, 2016 | |
| Simulation Time Step | 60 seconds | |
| Assumptions | no decay and no dispersion in the Particle Tracking module | most conservative approach |
| **Outfall Discharge Location** | | |
| Caribou Harbour A (CH-A) | Easting 526400 m, Northing 5067600 m | at a water depth 25.5 m MWL |
| Caribou Harbour B (CH-B) | Easting 526850 m, Northing 5067300 m | at a water depth 20 m MWL |
| **Effluent Properties** | | |
| Discharge Rate | 0.984 $m^3/s$ | daily maximum provided by KSH Solutions Inc. |
| Parameter | Temperature: 35°C | assumed maximum for July summer condition, based on information provided by KSH |
| | Total Dissolved Solids: 4 g/L | based on information provided by KSH a range is 1 to 4 g/L. A conservative concentration was used |
| | Concentration: 100 mg/L | assumed arbitrary concentration at discharge for calculation of dilution ratios and easy visualization of the plume |
| **Boundary and Ambient Conditions** | | |
| Predicted Tides | Tidal range 1.91 m (from -1.11 m to 0.8 m) including spring and neap tides | |
| Measured Winds | Peak and mean wind speeds in July 2016 are 10.83 m/s and 3.75 m/s respectively | based on wind records at Caribou Point (AUT), NS |
| Ambient Water | Temperature: 14 °C | based on historical DFO Ocean Data Inventory for Caribou Area |
| | Salinity: 28 g/L (equivalent to practical salinity unit) | based on DFO (2014) |

## 2.2 FAR-FIELD MODELLING RESULTS

Dispersion modelling results for effluent discharges from CH-A and CH-B outfall locations indicate that the CH-B discharge provides relatively higher dilution and less potential effluent impact on Caribou Harbour water. Although both locations provided sufficient dilution of the discharged effluent, CH-B exhibited superior dispersion characteristics and was chosen as the preferred location. Mixing and dilution at the outfall location is driven by water depth at the outfall, tides and currents. Outfall depth is often a bigger driver than exact position of the outfall (i.e., Alt-D location in comparison to CH-B).

The modelling results for CH-B discharge are presented in Figures 2.5 to 2.12 as a time series of effluent concentrations (spatial ‘snapshots’ of the effluent plume for various tidal stages and during neap and spring tides) and cumulative effects with time by the end of the one-month simulation period (Figure 2.13).

As shown in Figures 2.5 to 2.8 during a neap tide on July 13 and in Figures 2.9 to 2.12 during a spring tide on July 21 and July 22, the effluent discharged at the CH-B location is predicted to be dispersed and transported predominantly with the offshore currents in northwest and southeast directions. The effluent intrusion into Caribou Harbour is predicted to be minimum. The cumulative effects by the end of the one-month simulation period indicate that the lowest dilution factor achieved is about 35 with a limited plume extent in offshore of Caribou Harbour and where the dilution factor in most of the model domain is above 100 (Figure 2.13).

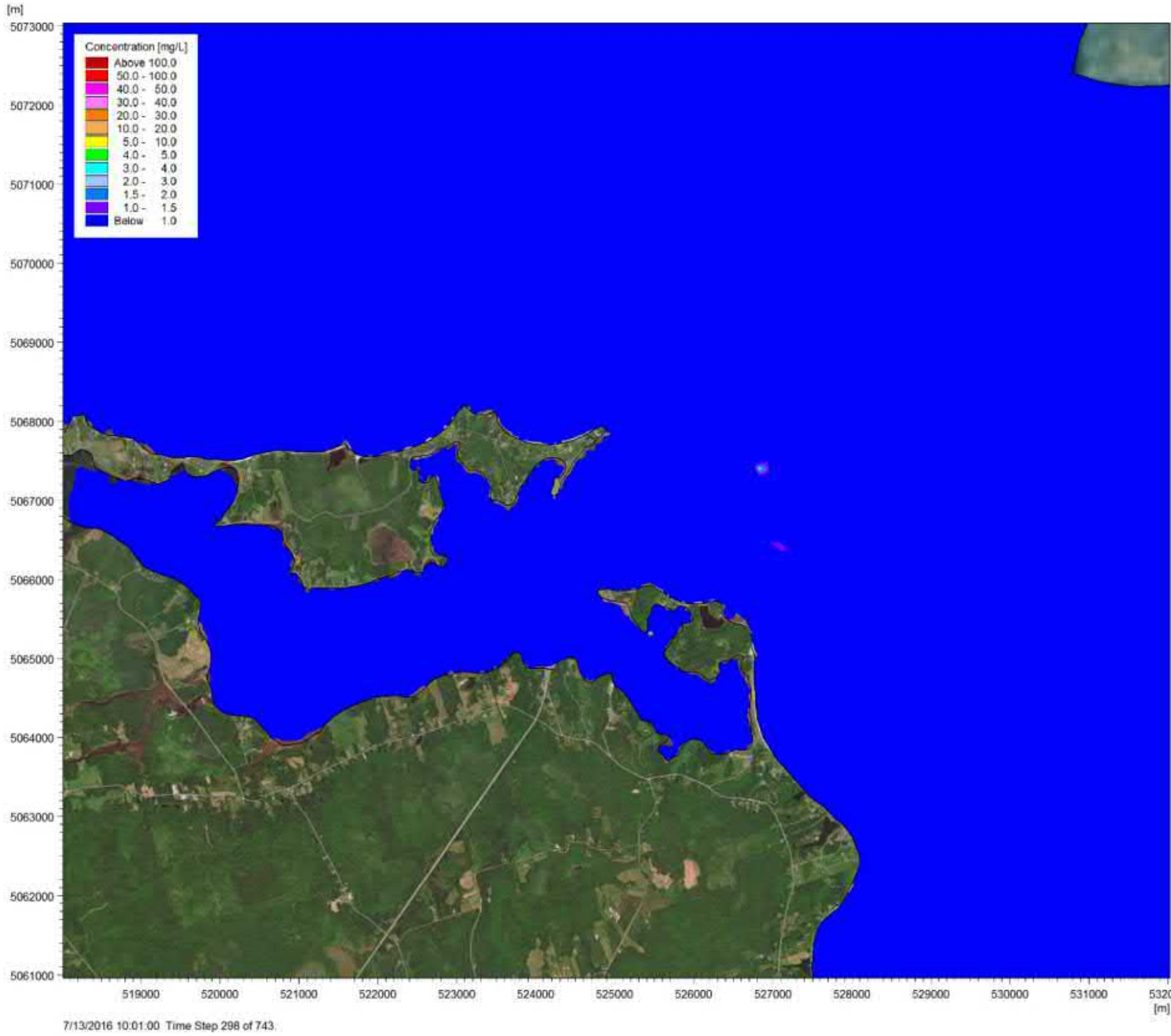



**Figure 2.5 CH-B Discharge: Simulated Effluent Concentrations for Typical Neap Tide - Slack Low Tide at 10:00 hr, July 13**

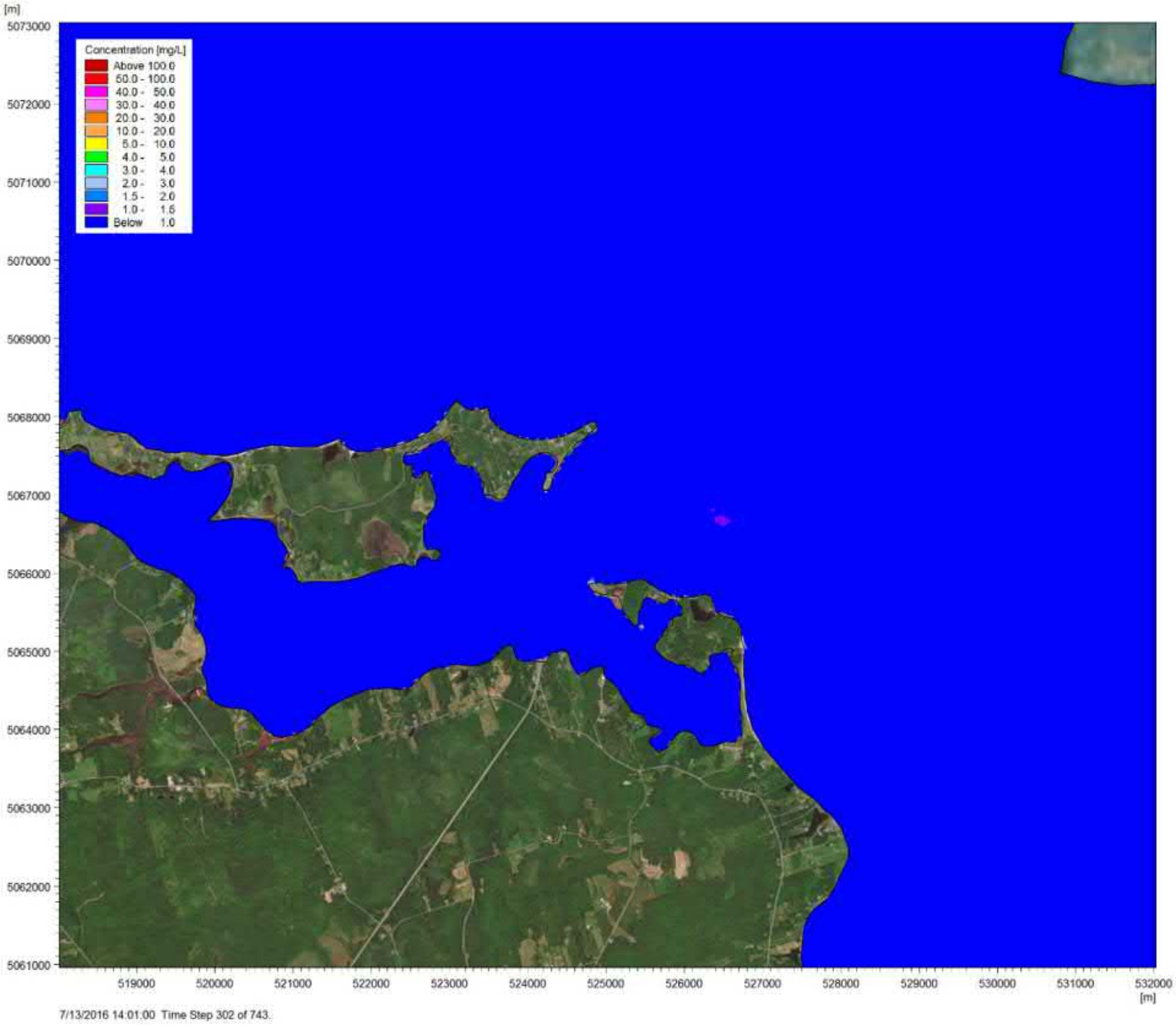



**Figure 2.6 CH-B Discharge: Simulated Effluent Concentrations for Typical Neap Tide - Flood Tide at 14:00 hr, July 13**

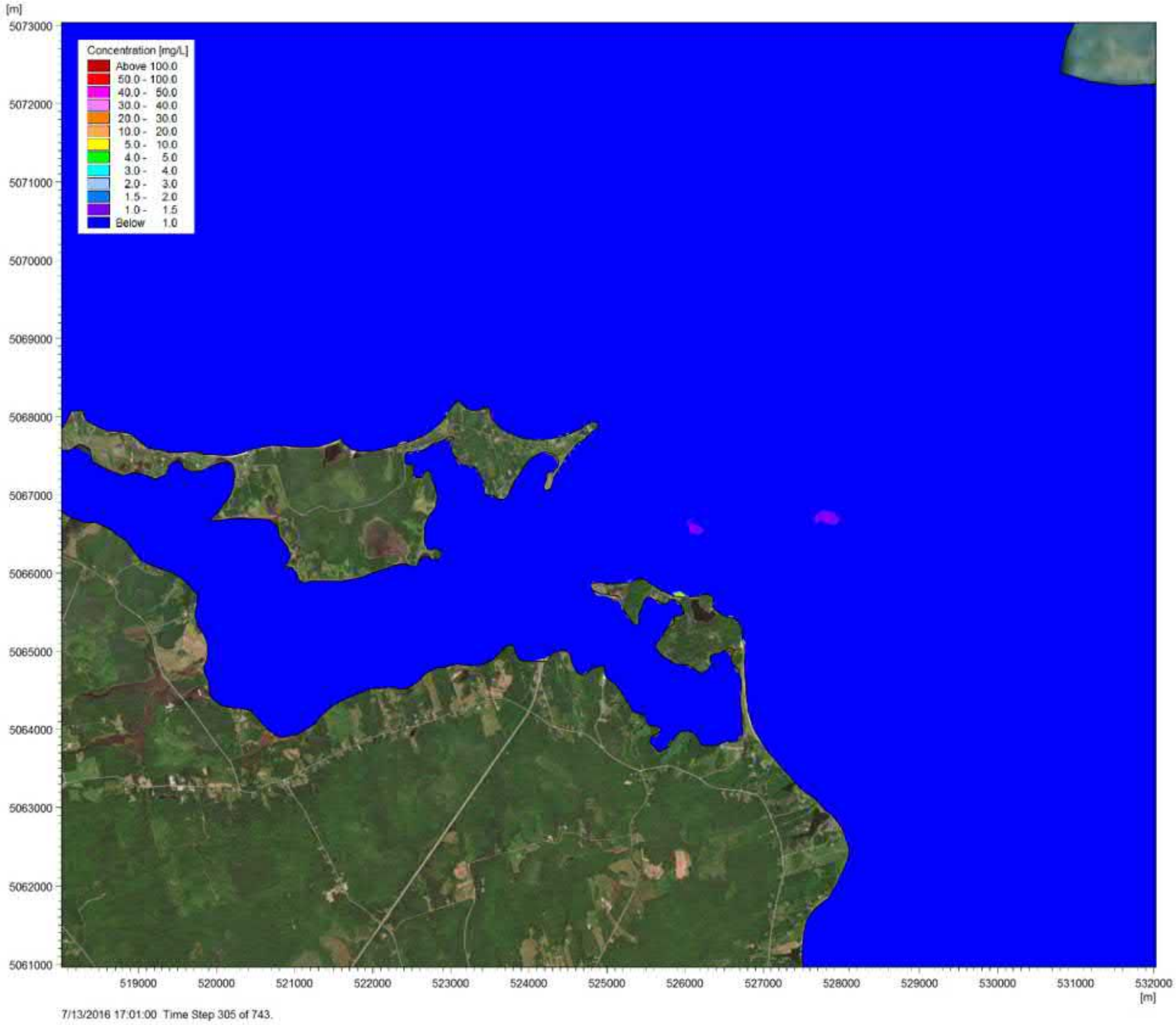



**Figure 2.7 CH-B Discharge: Simulated Effluent Concentrations for Typical Neap Tide - Slack High Tide at 17:00 hr, July 13**

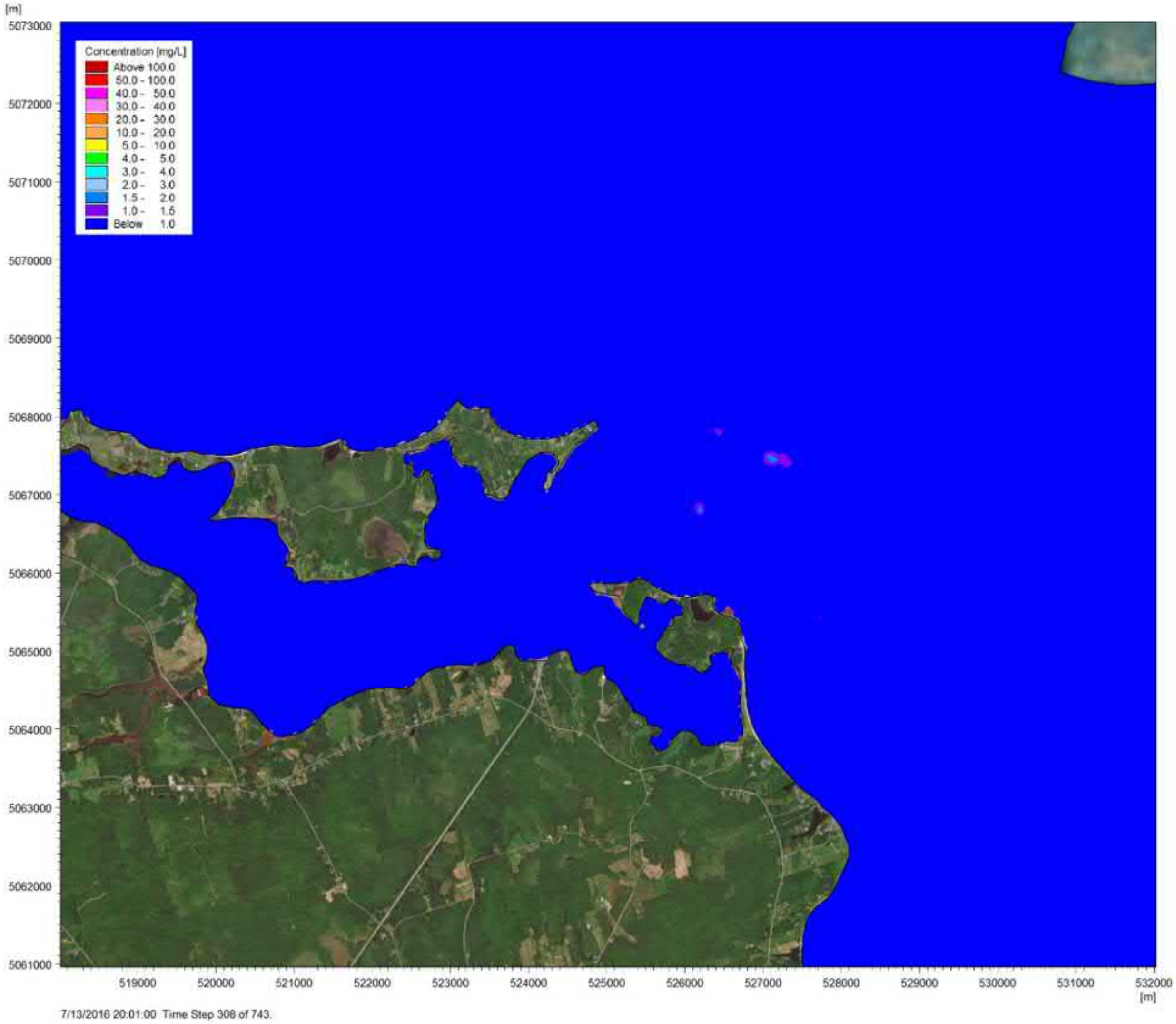



**Figure 2.8 CH-B Discharge: Simulated Effluent Concentrations for Typical Neap Tide - Ebb Tide at 20:00 hr, July 13**

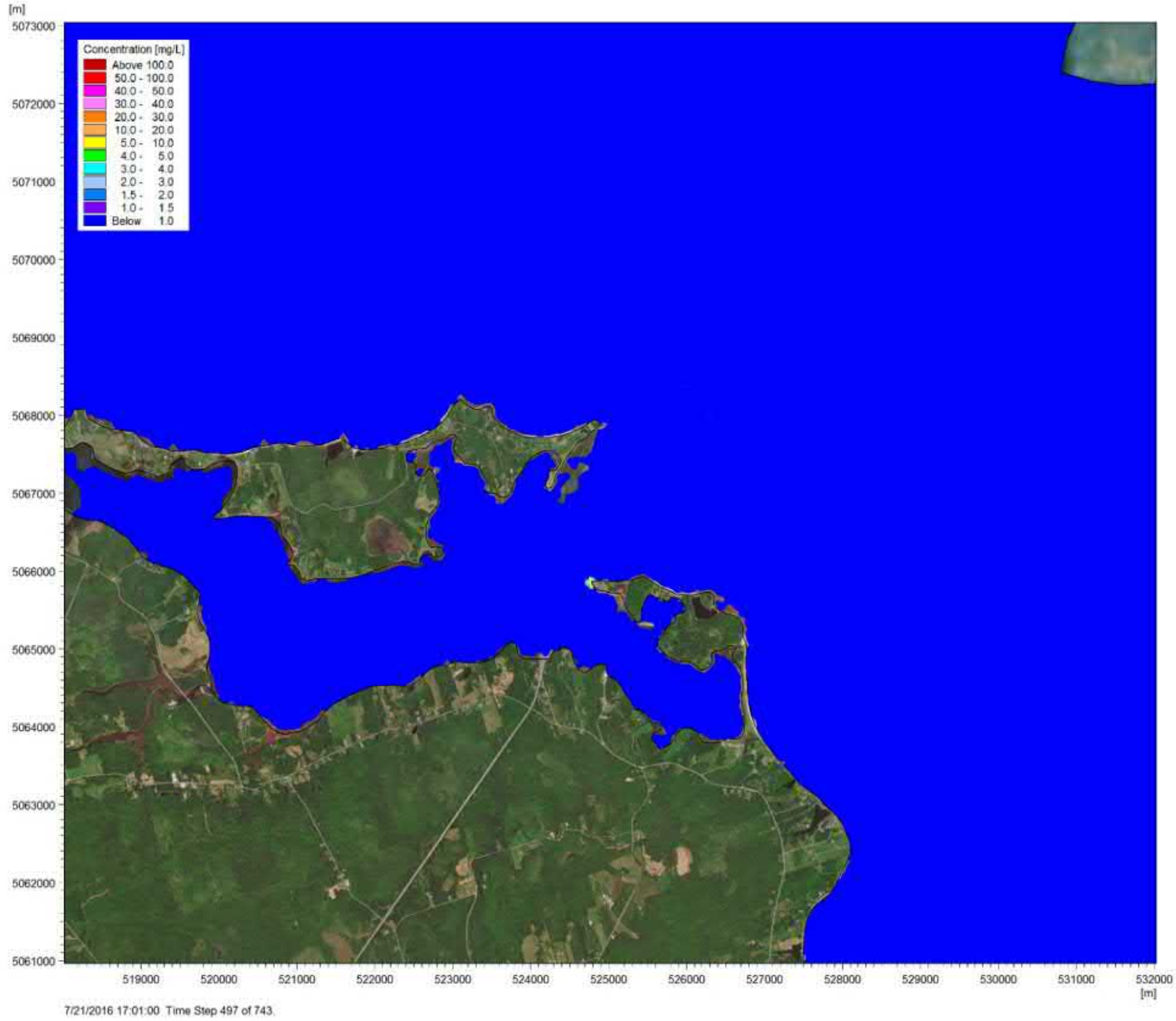



**Figure 2.9 CH-B Discharge: Simulated Effluent Concentrations for Typical Spring Tide - Slack Low Tide at 17:00 hr, July 21**

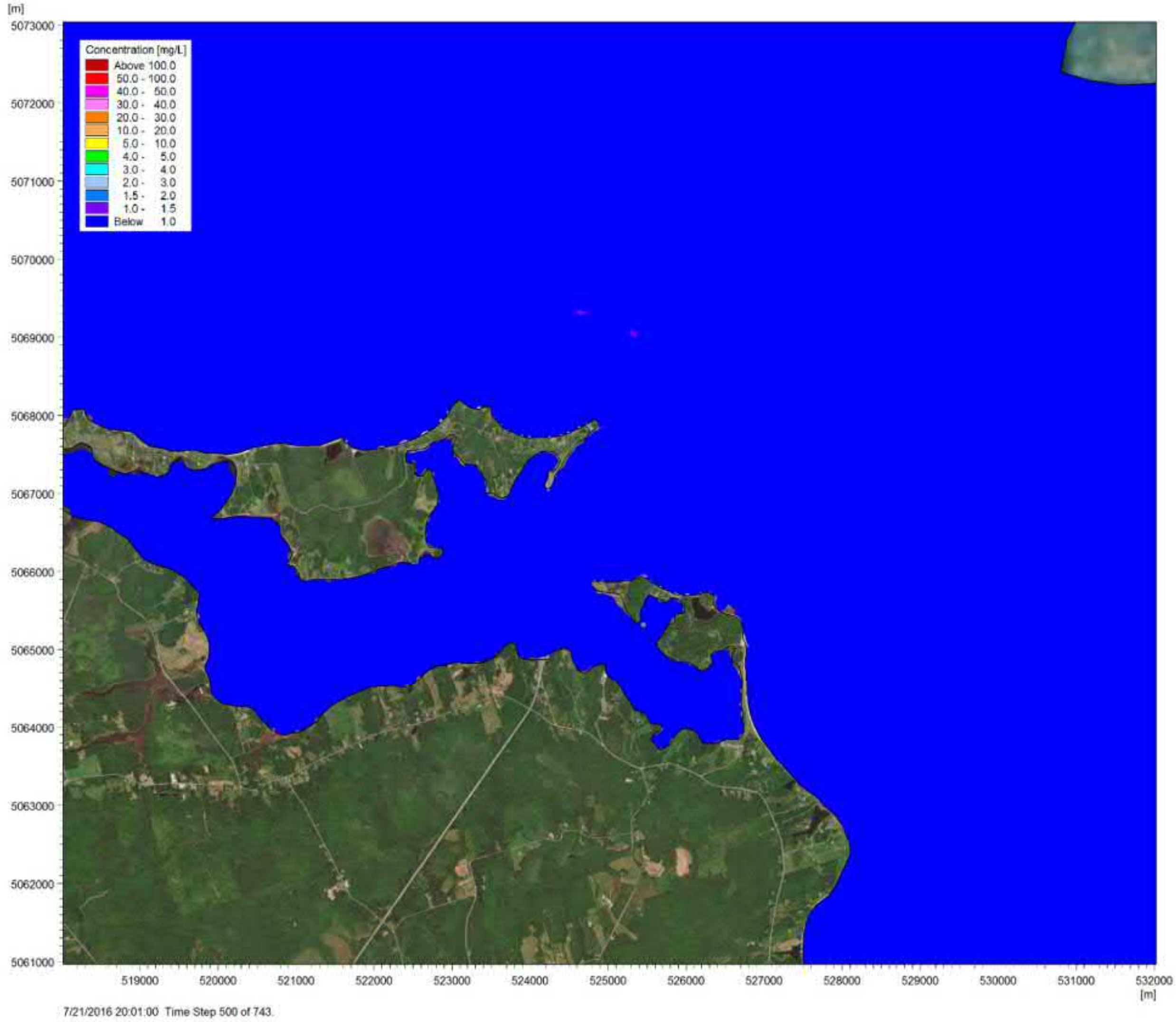



**Figure 2.10 CH-B Discharge: Simulated Effluent Concentrations for Typical Spring Tide – Flood Tide at 21:00 hr, July 21**

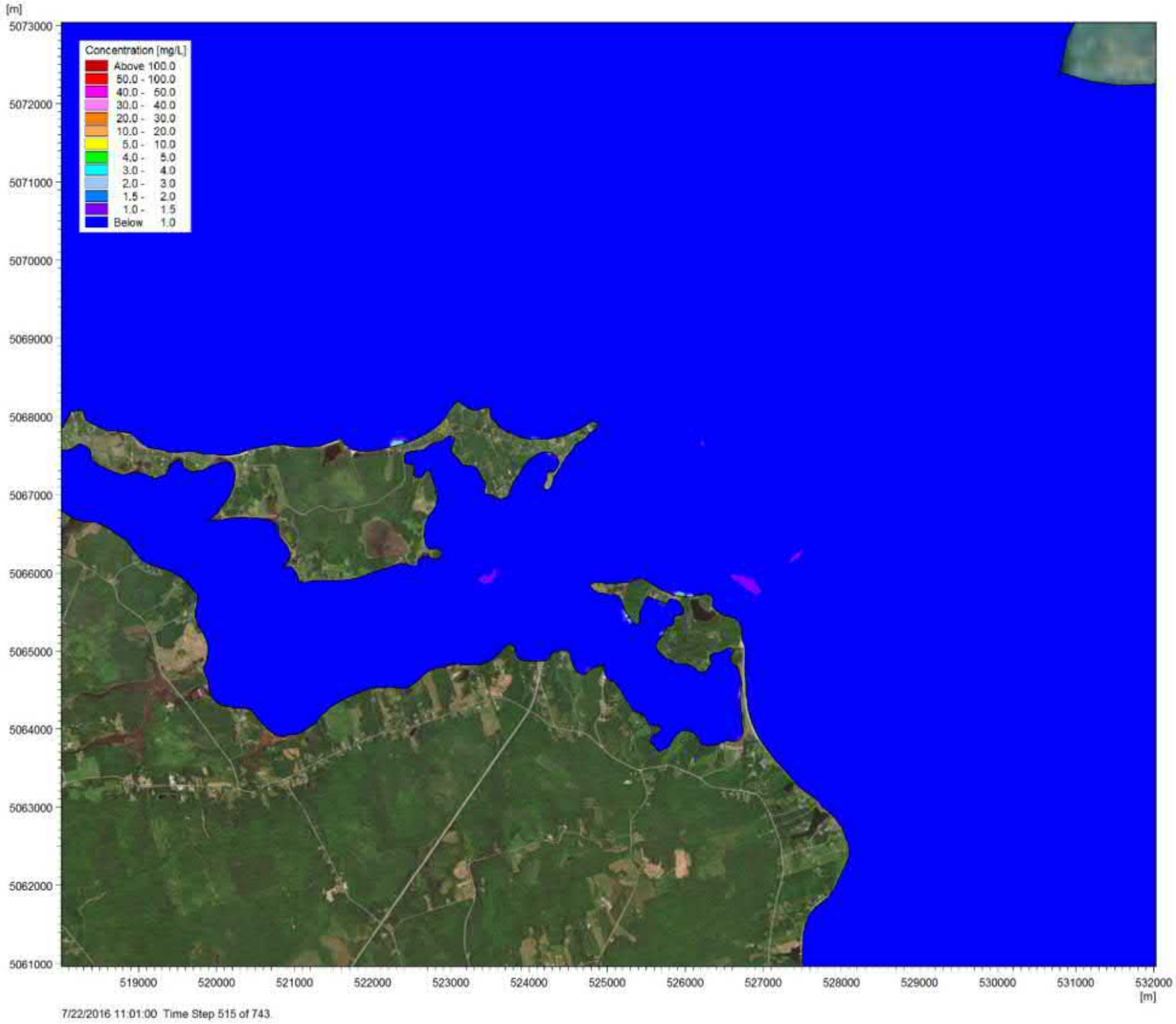



**Figure 2.11 CH-B Discharge: Simulated Effluent Concentrations for Typical Spring Tide – Slack High Tide at 11:00 hr, July 22**

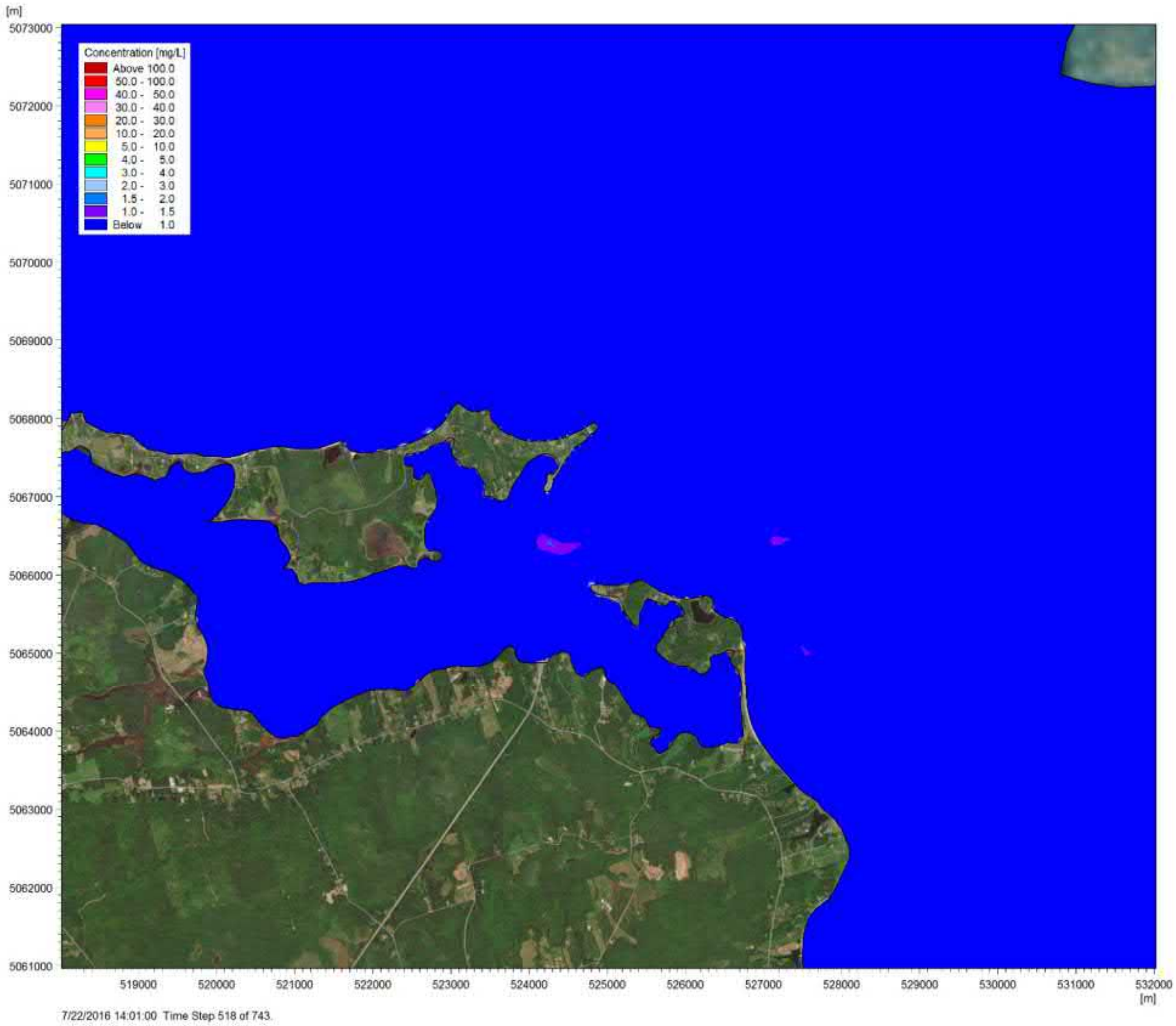



**Figure 2.12 CH-B Discharge: Simulated Effluent Concentrations for Typical Spring Tide – Ebb Tide at 14:00 hr, July 22**

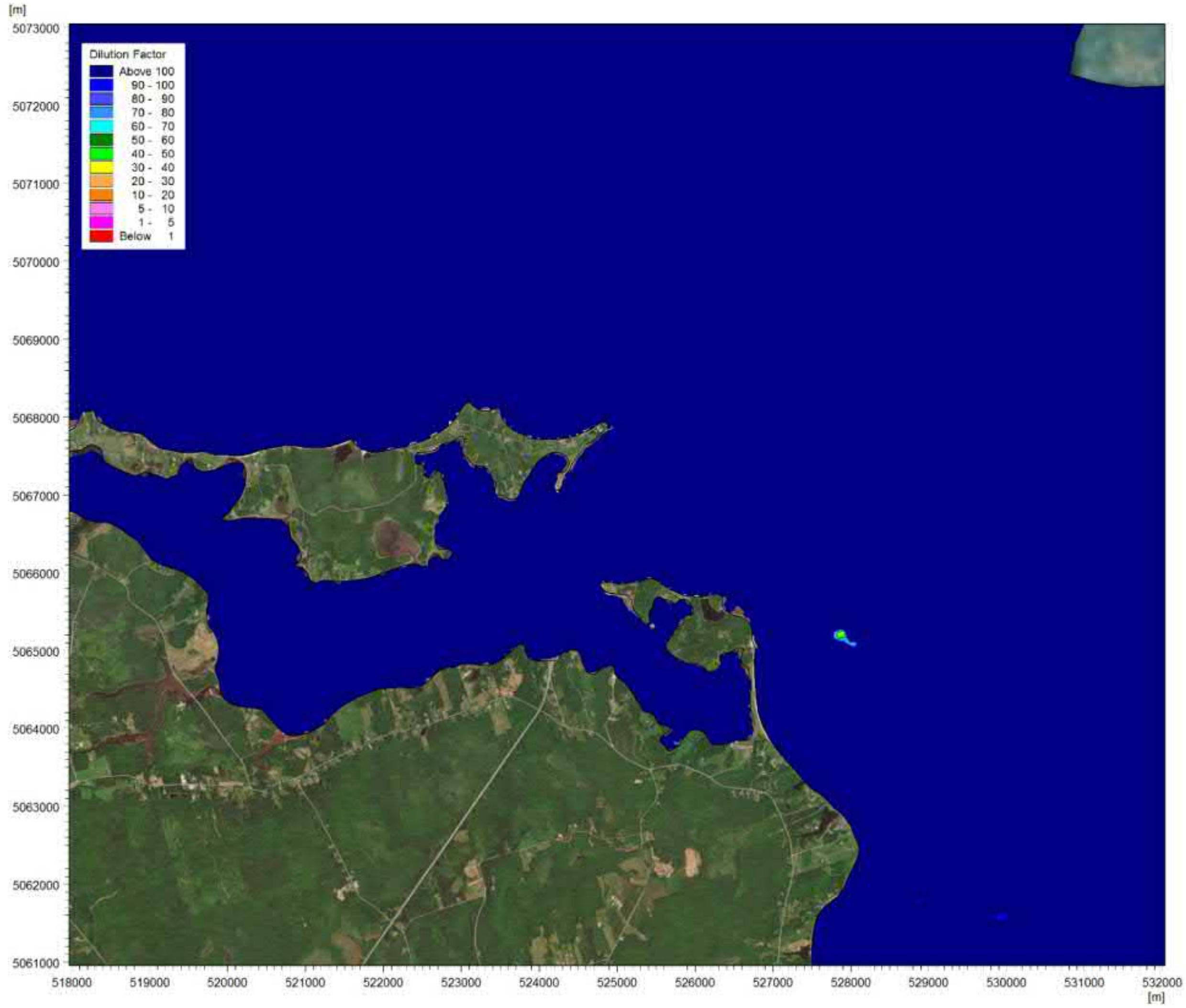



**Figure 2.13 CH-B Discharge: Spatial Distribution of Simulated Effluent Dilution Factor at the End of a One-Month Simulation Period (assuming no particle degradation over the simulation period).**

# 3.0 NEAR-FIELD MODELLING

## 3.1 NEAR-FIELD MODELLING CONDITIONS

Near-field modelling was conducted for the CH-B location, which is the proposed discharge location as determined above from the far-field results of the MIKE 21 modelling investigation. The near-field modelling was conducted using the CORMIX model (Version 11.0). The model, site-specific guidelines, and methods used for deriving water quality in the mixing zone were described in Section 3.1 of Stantec (2017).

Ambient conditions in the receiving environment are characterized by hydrodynamic factors (flows, tides, currents, etc.) and by background water quality. No historical water quality data are available for Northumberland Strait around the CH-B location. Data from neighboring Pictou Road (Stantec 2017) located about 6 km southeast were used. Water quality at Pictou Road is expected to be worse than off Caribou Point at CH-B due to higher contaminant load from Pictou Harbour and as a result of anthropogenic influences including industrial development and municipal wastewater discharges in that region. Thus, using the higher background concentrations in the model decreases the assimilative capacity of the receiving environment and, therefore, is conservative. The Pictou Road water quality used as ambient conditions in CORMIX modelling at the CH-B outfall location is summarized in Table 3.1.

**Table 3.1 Background Water Quality**

| Parameter | Unit | Number of Samples | Average Value |
|---|---|---|---|
| Adsorbable Organic Halides (AOX) | mg/L | n/a | n/a |
| Total Nitrogen (TN) | mg/L | 13 | 0.24 |
| Total Phosphorus (TP) | mg/L | 16 | 0.35 |
| Colour | TCU | 2 | 10.8 |
| Chemical Oxygen Demand (COD) | mg/L | n/a | n/a |
| Biochemical Oxygen Demand ($BOD_5$) | mg/L | n/a | n/a |
| Total Suspended Solids (TSS) | mg/L | 11 | 8.5 |
| Dissolved Oxygen (DO) | mg/L | 6 | 7.2 |
| pH | - | 13 | 8.0 |
| Temperature (summer) | °C | 6 | 17.6 |
| Temperature (winter) | °C | 2 | 0.0 |
| Salinity | g/L | 8 | 26[1] |

n/a – no data available
[1] DFO (2014) shows salinity of 28 g/L around CH-B. Therefore 28 g/L was conservatively used in CORMIX

Hydrodynamic information at the CH-B outfall location was obtained from MIKE 21. Water depth at CH-B is 20 m and the depth-averaged maximum and mean current velocities simulated by MIKE 21 are 0.27 m/s and 0.1 m/s, respectively. Based on the bathymetry in Figure 2.4, the average depth for the extent of the mixing zone was conservatively assumed to be 18 m.

Expected water quality characteristics of the treated effluent from the mill were provided by KSH and summarized in Table 3.2.

### Table 3.2 Daily Maximum Effluent Water Quality

| Parameter | Unit | Value |
|---|---|---|
| Adsorbable Organic Halides (AOX) | mg/L | 7.8 |
| Total Nitrogen (TN) | mg/L | 6.0 |
| Total Phosphorus (TP) | mg/L | 1.5 |
| Colour | TCU | 750 |
| Chemical Oxygen Demand (COD) | mg/L | 725 |
| Biochemical Oxygen Demand ($BOD_5$) | mg/L | 48 |
| Total Suspended Solids (TSS) | mg/L | 48 |
| Dissolved Oxygen (DO) | mg/L | > 1.5 |
| pH | - | 7.0 to 8.5 |
| Temperature | °C | 25 (winter), 37 (summer) |
| Total Dissolved Solids (TDS) or Salinity | g/L | 4 |

Two scenarios for the outfall diffuser design were modelled using CORMIX: one-port diffuser (Scenario 1) and three-port diffuser (Scenario 2). Several diffuser variables were iteratively adjusted during the design process to increase predicted dilution of the treated effluent.

The ports were assumed to be located 1.0 m above the seabed (i.e., port height). A 0.4 m port opening was used in a one-port diffuser, and a 0.3 m port opening was used in a three-port diffuser as described in Section 3.2.2 of Stantec (2017). The port diameter for each diffuser design was back-calculated using CORMIX to achieve a jet velocity in the range of 4 to 8 m/s. This velocity range provides entrainment of ambient water for mixing, fast initial mixing, and a stable plume formation.

The number of ports on the diffuser is an important characteristic as it determines the flow rate from each port, port diameter, and ultimately the resulting plume dilution. Generally, more ports provide better effluent dilution and mixing with the ambient environment. However, a large number of ports may not be technically or economically feasible to build and maintain, and a larger number of ports may create an undesirable diffuser footprint on the seabed and in the receiving environment, as well as not bringing any measurable benefits to the receiving water quality.

The horizontal angle of the diffuser was found to be optimal when it is perpendicular to the predominant flow. Statistical analysis of flow directions at CH-B revealed that 85% of the time flow is either in the southeast or northwest direction (Figures 3.1 and 3.2). Recommended horizontal direction of the three-port diffuser is shown on Figure 3.1.

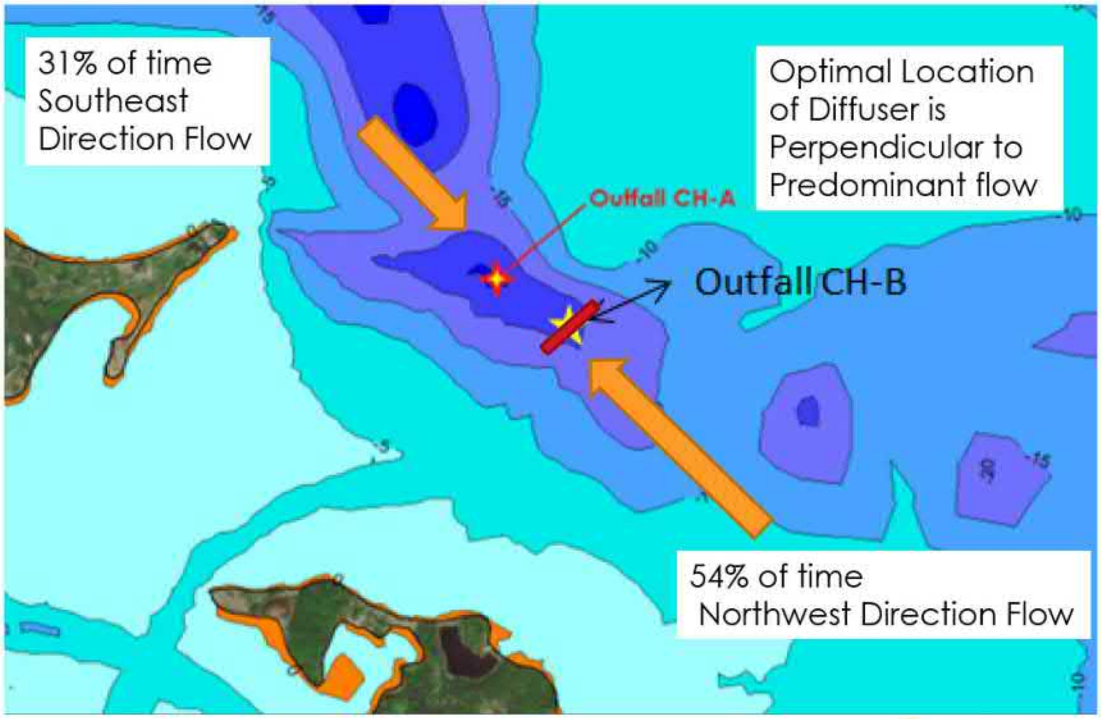



**Figure 3.1 Ambient Flow Directions at CH-B**

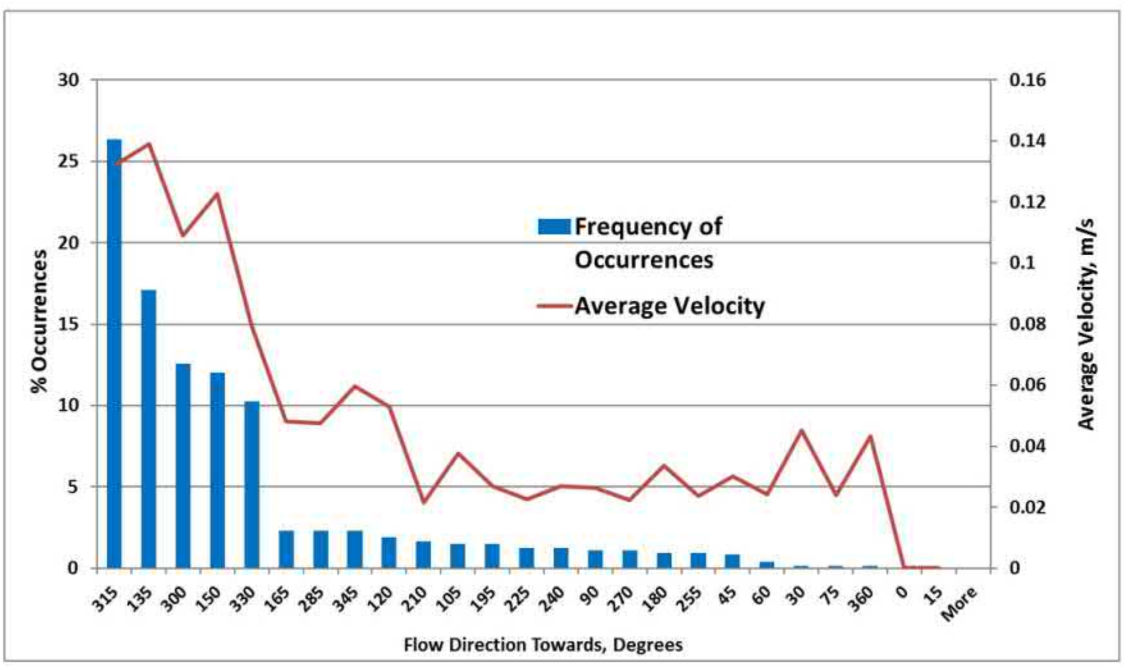



**Figure 3.2 Frequency of Ambient Flow Directions at CH-B.**

Other characteristics of the diffuser are the same as presented and discussed in Stantec (2017). Schematic representation of the three-port diffuser used in the CORMIX model is shown in Figure 3.3.

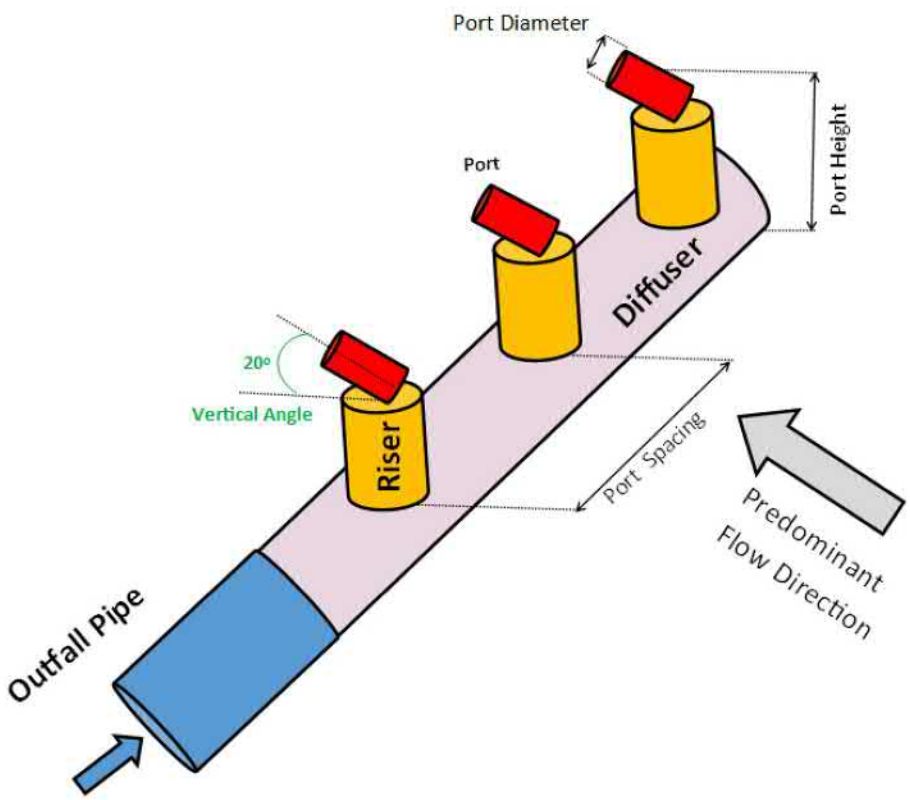



**Figure 3.3 Schematic Representation of Three-Port Diffuser**

Table 3.3 summarizes the results of the CORMIX model input data for CH-B for one and three-port diffusers.

**Table 3.3 CORMIX Input Data for the Diffuser Designs and Scenarios at the CH-B Location**

| | Scenario 1: One Port | Scenario 2: Three Ports |
|---|---|---|
| Port Opening, $m^2$ | 0.4 | 0.3 |
| Number of Ports | 1 | 3 |
| Port Spacing, m | - | 25 |
| Vertical Pipe Angle (theta)[1], degree | 20 | 20 |
| Horizontal Pipe Angle (sigma)[2], degree | 0 | 0 |
| Alignment Angle (gamma)[3], degree | - | 90 |
| Relative Orientation Angle (beta)[4], degree | - | 90 |
| Port Height Above Seabed, m | 1.0 | 1.0 |
| Wastewater Flow Rate, $m^3/s$ | 0.98 | 0.98 |
| Water Depth at Outfall, m | 20 | 20 |
| Average Depth in Mixing Zone, m | 18 | 18 |
| Ambient Velocity at Tidal Conditions, m/s | Max=0.27<br>Average=0.10 | Max=0.27<br>Average=0.10 |
| Manning's n | 0.02 | 0.02 |
| Ambient Water Density, $kg/m^3$ | 1020.06 | 1020.06 |
| Salinity, g/L | 28 | 28 |
| Effluent Density, $kg/m^3$ | 996.32 | 996.32 |
| Average Wind Speed, m/s | 3.75 | 3.75 |

Notes:
[1] Vertical Pipe Angle (Theta) – angle between port centerline and a horizontal plain
[2] Horizontal Angle (Sigma) – angle measured counterclockwise from ambient current direction to the plane projection of the port center line. Angle is 0° when the port points downstream in the ambient flow direction
[3] Alignment Angle (Gamma) – angle measured counterclockwise from the ambient flow direction to the diffuser axis.
[4] Relative Orientation Angle (Betta) – angle measured counterclockwise or clockwise from the average plan projection of the port centerline to the nearest diffuser axis.

## 3.2 NEAR-FIELD MODELLING RESULTS

The results for Scenario 1 (effluent discharge from one-port diffuser) at CH-B are presented in Figure 3.4. The plume at CH-B reaches the surface at about 20 m from the diffuser. Initial discharge velocity is 7.8 m/s. The dilution ratio is five times at 10 m from the port and 69 times at the end of the mixing zone (i.e., at 100 m) for CH-B. Figure 3.4 presents the plan and side views of the effluent plume for CH-B, as well as the dilution isolines for the one-port diffuser.

The results for Scenario 2 (effluent discharge from a three-port diffuser) at CH-B are presented in Figure 3.5. The three-port diffuser scenario for the CH-B outfall location indicates improvement in near-field dilution and mixing in comparison with the preferred Alt-D location assessed in Stantec (2017). The plume at CH-B reaches the surface at about 25 m from the diffuser. Initial discharge velocity is 4.6 m/s which provides entrainment of ambient water for mixing, fast initial mixing, and a stable plume formation. The dilution ratio is 50 times at 5 m from the ports and 144 times at the end of the mixing zone (i.e., at 100 m) for CH-B, compared to a dilution ratio of 18 times at 5 m from the ports and 58 times at the end of the mixing zone for Alt-D (Stantec 2017). Figure 3.5 presents the plan and side views of the effluent plume for CH-B, as well as the dilution isolines for the three-port diffuser.

Due to port configuration and effluent buoyancy, the plume interacts with the seabed beyond 10 m from the diffuser for Scenario 2. At that distance the dilution ratios are so high that the plume is not likely to result in potential adverse effects on the benthic environment. For Scenario 1 the plume is not expected to touch the seabed within 200 m, which is the extent of the near-field model domain.

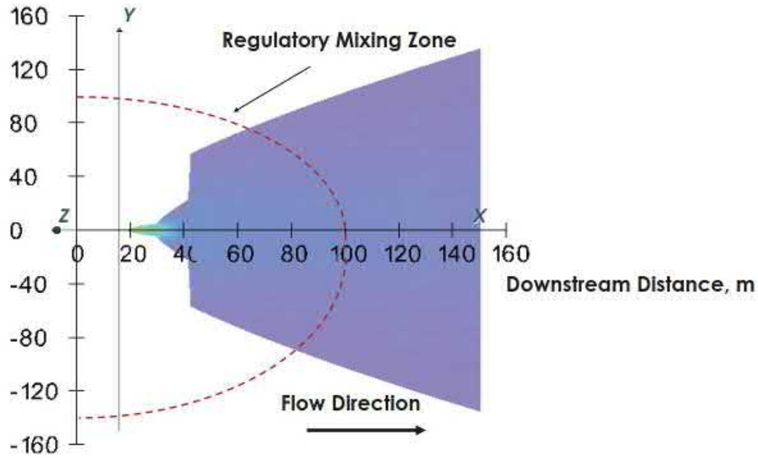
The summary of results for the effluent dilution ratios for the scenarios and diffuser designs is presented in Table 3.4.

## Table 3.4 Effluent Dilution Ratios for the CH-B Location

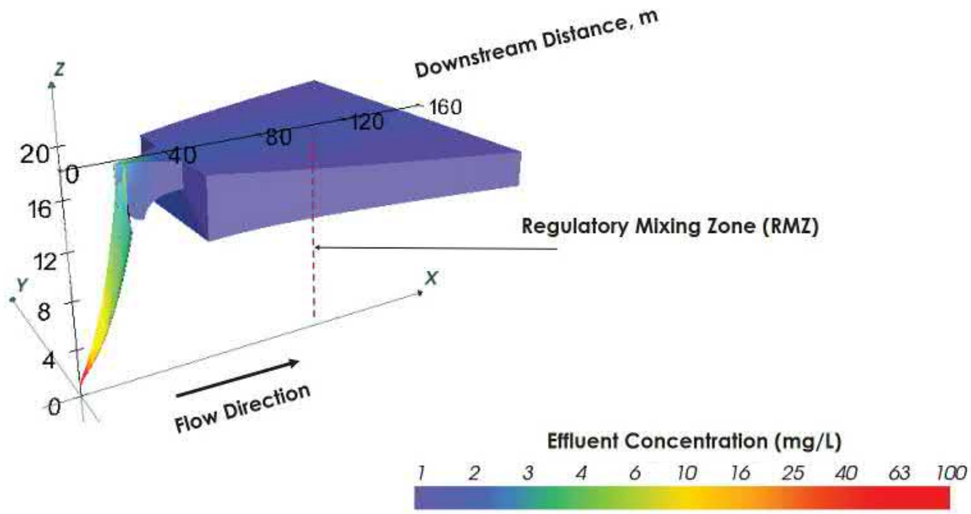
| Scenario | Distance from Diffuser and Dilution Ratio | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 m | 5 m | 10 m | 20 m | 50 m | 100 m | 200 m |
| Scenario 1: One-Port Diffuser | 1.1 | 2.6 | 5.1 | 15.6 | 61.7 | 69.3 | 77.8 |
| Scenario 2: Three-Ports Diffuser | 32.4 | 50.5 | 70.8 | 99.1 | 128.3 | 144.1 | 159.8 |

**Figure 3.4. CH-B Location: One Port Diffuser (Effluent Flow 0.98 m³/s)**

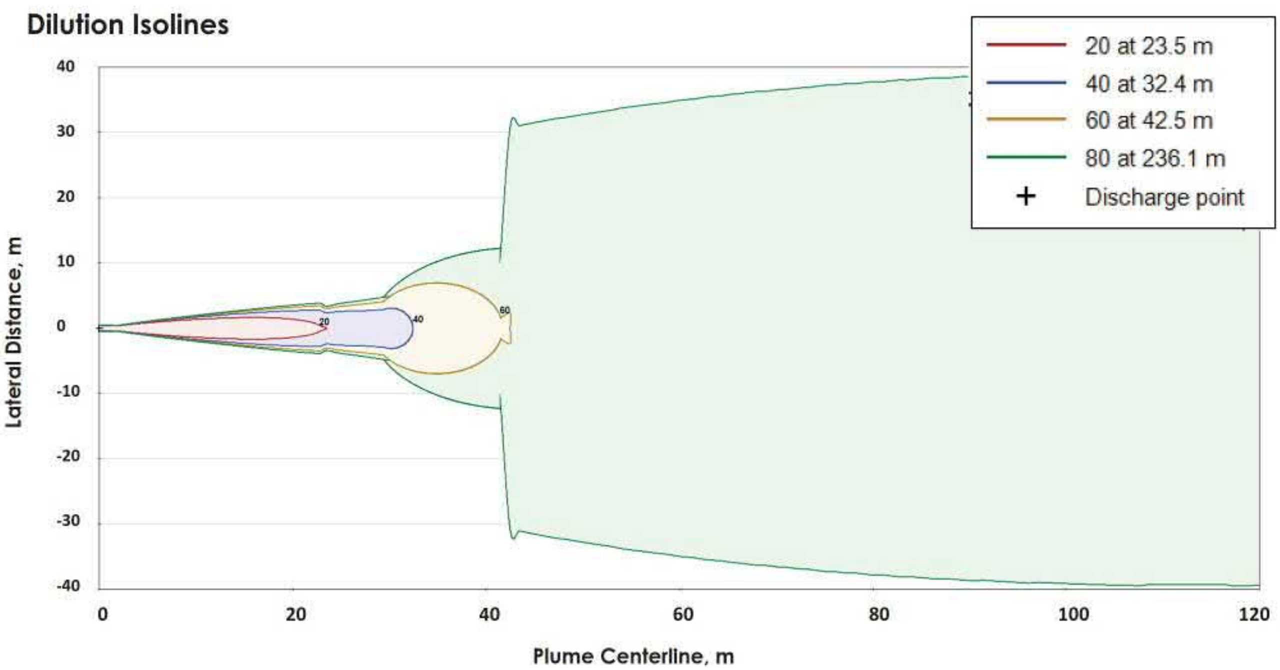
**Plan View**




**Side View**

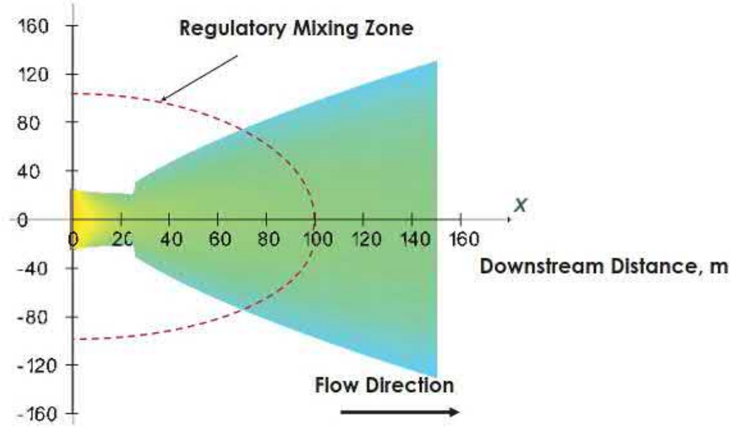



**Dilution Isolines**

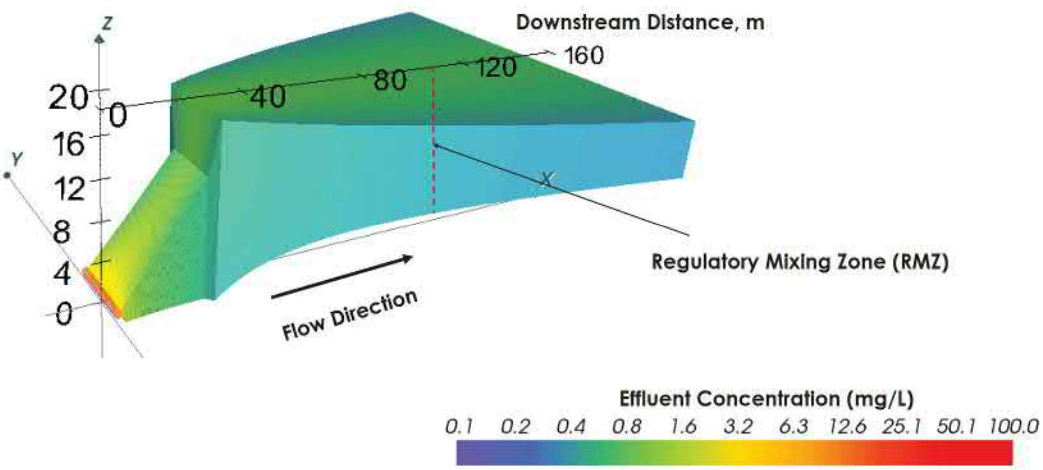


## Figure 3.5. CH-B Location: Three Port Diffuser (Effluent Flow 0.98 m³/s)

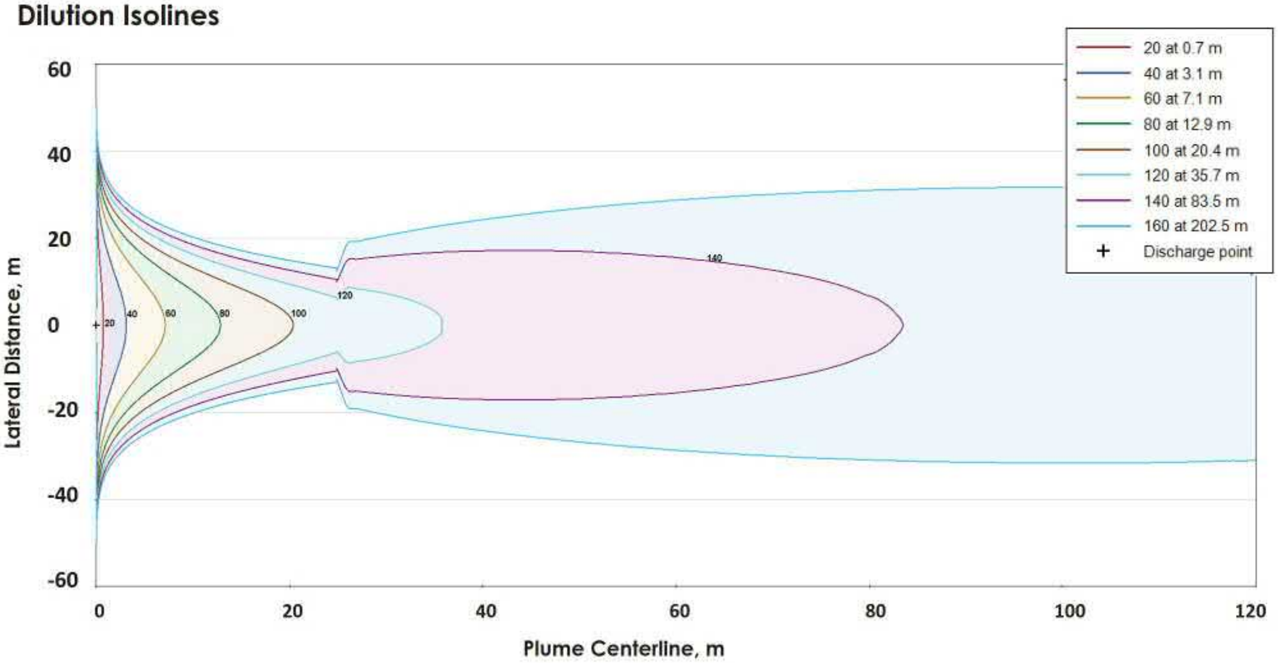
**Plan View**




**Side View**




**Dilution Isolines**



A three-port diffuser (Scenario 2) provides better dilution and mixing of the treated effluent than the one port diffuser at CH-B. Therefore, the three-port diffuser was used to characterize water quality in the mixing zone.

Water quality parameters of concern in the mill treated effluent are adsorbable organic halides (AOX), total nitrogen (TN), total phosphorus (TP), colour, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), dissolved oxygen (DO), pH, and water temperature. General descriptions and impacts of these parameters on the environment were described in Stantec (2017). Water quality at the end of the 100-m mixing zone for CH-B (three-port diffuser) scenario is presented below.

**AOX.** Data for AOX in CH-B or in Pictou Harbour are not available; however, it is expected that the AOX ambient concentrations are negligible as there are no natural sources of AOX in ocean water. Proposed daily maximum AOX concentration in the effluent is 7.8 mg/L, which is substantially less than the World Bank guideline of 40 mg/L as the maximum limit for pulp mill effluents discharging into surface waters and slightly less than the 8 mg/L limit target objective for retrofit mills (World Bank 1998). For the NPNS mill effluent discharged through a three-port diffuser at CH-B, and conservatively assuming no decay, sedimentation or any other form of transformation of organic halides in the receiving environment, the resulting AOX concentration at the edge of the 100-m mixing zone is 0.05 mg/L.

**TN.** Proposed daily maximum TN concentration in the effluent is 6.0 mg/L. At this concentration, TN is below the CCME marine guideline limit for the nitrate ion, which is a component and nitrogen form that contributes to the concentration of TN. Average background concentration of TN is 0.24 mg/L. A 1:25 (effluent: receiving environment) dilution ratio is required to reduce the effluent concentration of TN to approximately background levels. This dilution ratio is achieved in the immediate vicinity (< 2 m) of the diffuser.

**TP.** Proposed daily maximum TP concentration in the effluent is 1.5 mg/L. Average background concentration is 0.35 mg/L. A 1:4 (effluent: receiving environment) dilution ratio is required to reduce the effluent concentration to approximately background levels. This dilution ratio is achieved in the immediate vicinity (< 2 m) of the diffuser.

**Colour.** Proposed daily maximum colour concentration in the effluent is 750 true colour units (TCU). Average background concentration is 10.8 TCU. A colour of 15 TCU can be detected in a glass of water by most people and it is the aesthetic objective of the Canadian drinking water guidelines (Health Canada, 1995). A 1:50 (effluent: receiving environment) dilution ratio is adequate to reduce the effluent concentration of 750 TCU to 15 TCU. This dilution ratio is achieved within 5 m from the diffuser.

**$BOD_5$**. Proposed daily maximum $BOD_5$ concentration in the effluent is 48 mg/L. There are no CCME or provincial guidelines for BOD. Conservatively assuming no decay, sedimentation or any other form of transformation of organic matter, the resulting $BOD_5$ concentration at the edge of the 100-m mixing zone will be background or a concentration of 0.33 mg/L, whichever is higher. McNeeley et al. (1979) consider waters with $BOD_5$ less than 4 mg/L to be reasonably clean.

**COD.** Proposed daily maximum COD concentration in the effluent is 725 mg/L. Conservatively assuming no decay, sedimentation or any other form of transformation of organic matter, the resulting COD concentration at the edge of the 100-m mixing zone will be 5.0 mg/L. Natural waters with concentrations of COD less than 20 mg/L are generally considered unpolluted (UNESCO 1996).

**TSS.** Proposed daily maximum TSS concentration in the effluent is 48 mg/L. The water quality limit for a TSS concentration of 13.5 mg/L (background 8.5 mg/L plus CCME threshold of 5 mg/L) is achieved in the immediate vicinity (< 2 m) of the diffuser.

**DO.** Proposed daily maximum DO concentration in the effluent is > 1.5 mg/L. It is expected that due to the high jet velocity (4 to 8 m/s), dynamic ambient hydrodynamic conditions (agitation of water attributed to wind, tides, and waves) and substantial mass of ambient water (water depth is 20 m), the DO levels in the effluent will improve to background concentration of 7.2 mg/L within the immediate vicinity of the diffuser (< 2m).

**pH.** Proposed daily maximum pH in the effluent is in a range of 7 to 8.5. Due to substantial initial mixing after the effluent is discharged from the diffuser, the effluent pH is expected to reach ambient pH in the immediate vicinity of the diffuser (< 2 m).

**Water Temperature.** Ambient average summer temperature is 17.6°C and average winter temperature is 0.16 °C (Appendix A in Stantec 2017). Maximum effluent temperature is 37°C in summer and 25°C in winter. Potential thermal impacts of the treated effluent on the thermal regime of the receiving environment at CH-B were modelled using CORMIX. The results demonstrate that during the worst-case winter conditions, when effluent temperature is 25°C and ambient water temperature is about 0°C, the CCME guideline limits (i.e., 1°C differential) are met within approximately 2 m of the diffuser. CORMIX shows that the heated effluent quickly mixes with ambient water and the effluent temperature exponentially drops within several metres from the diffuser. After 2 m, the temperature drop decreases substantially and at 100 m the effluent plume temperature is less than 0.1 °C above background.

**Salinity**. Average salinity off Caribou Point is 28 g/L (DFO 2014). Salinity, or its freshwater equivalent TDS, of the treated effluent is 4 g/L. A dilution ratio of 7 times is required for the effluent to reach the background levels of salinity. This dilution ratio is achieved in the immediate vicinity (< 2 m) of the diffuser. Due to the differential in salinity between the effluent and ambient conditions, density of the effluent is lower which is already accommodated into the CORMIX model (Table 3.3).

Water quality at the end of the mixing zone is summarized in Table 3.5.

## Table 3.5 Water Quality at the End of the Mixing Zone for a Three-port Diffuser

| Parameter | Unit | Effluent Daily Maximum Limit | CCME, Marine Guideline | Ambient Conditions | End of Mixing Zone at 100 m from Diffuser | Distance (m) from Diffuser Ambient Condition is Reached |
|---|---|---|---|---|---|---|
| Adsorbable Organic Halides (AOX) | mg/L | 7.8 | n/a | Trace amount | 0.05 | n/a |
| Total Nitrogen (TN) | mg/L | 6.0 | 45[1] | 0.24 | 0.24 | < 2 |
| Total Phosphorus (TP) | mg/L | 1.5 | n/a | 0.35 | 0.35 | < 2 |
| Colour | TCU | 750 | n/a | 10.8 | 10.8 | < 5 |
| Chemical Oxygen Demand (COD) | mg/L | 725 | n/a | n/a | 5.0 | n/a |
| Biochemical Oxygen Demand ($BOD_5$) | mg/L | 48 | n/a | n/a | 0.33 | n/a |
| Total Suspended Solids (TSS) | mg/L | 48 | Narrative [2] | 8.5 | 8.5 | < 2 |
| Dissolved Oxygen | mg/L | > 1.5 | >8 | 7.2 | 7.2 | < 2 |
| pH | - | 7.0 - 8.5 | 7.0 - 8.7 | 8.0 | 8.0 | < 2 |
| Temperature (summer) | °C | 37 | Narrative [3] | 17.6 | 17.7 | < 2 |
| Temperature (winter) | °C | 25 | Narrative [3] | 0 | <0.1 | < 2 |
| Salinity | g/L | 4 | Narrative [4] | 28 | 28 | < 2 |

n/a – not available
[1] - CCME marine limit for $NO_3^-$ as N
[2] - Maximum average increase of 5 mg/L from background levels for longer-term exposures (e.g., inputs lasting between 24 h and 30 d)
[3] - Human activities should not cause changes in ambient temperature of marine and estuarine water to exceed ±1°C at any time, location, or depth
[4] - Human activities should not cause the salinity (parts per thousand [‰], expressed here in g/L) of marine and estuarine waters to fluctuate by more than 10% of the natural level expected at that time and depth.

# 4.0 CONCLUSIONS

Preliminary effluent dispersion analysis at the outfall location CH-B under conservative ambient conditions was undertaken using 2D far-field and 3D near-field hydrodynamic models.

Dispersion 2D modelling results using the MIKE 21 far-field model for effluent discharge at CH-B indicate that the potential effluent impact on Caribou Harbour and off Caribou Point reduces when the outfall is located towards deeper water in the Northumberland Strait. The effluent discharged at the CH-B location is predicted to be dispersed and transported predominantly with the offshore currents in the northwest and southeast directions. The effluent intrusion into Caribou Harbour is predicted to be minimum. The cumulative effects by the end of the one-month simulation period indicate that the lowest dilution factor achieved is about 35 with a limited plume extent in offshore of Caribou Harbour and Caribou Point, and the dilution factor in most of the model domain is above 100.

The CORMIX model was used for the 3D near-field hydrodynamic model at the CH-B location, with one and three-port diffuser scenarios modelled. The mixing zone was defined as the 100-m distance from the outfall pipe.

Effluent dilution ratios for the two diffuser design scenarios are presented in Table 3.4. Figures 3.4 and 3.5 present the plan and side views of the discharged plume, as well as dilution isolines for the modelled scenarios. The three-port diffuser shows substantial improvement in near-field dilution and mixing in comparison with the one-port diffuser. The plume from the diffuser with three ports reaches the surface water at about 25 m from the diffuser and not likely visible when reaching the surface based on the dilution. The dilution ratio is 50 times at 5 m from the port and 144 times at the end of the mixing zone (i.e., at 100 m). For comparison purposes, using the same three-port diffuser design and effluent flow rate, the dilution ratio at the Alt-D outfall location is lower with 18 times at 5 m from the ports and 58 times at the end of the 100-m mixing zone (Stantec 2017).

The three-port diffuser at the CH-B location off Caribou Point shows improvement in comparison with the six-port diffuser at the Alt-D outfall location outside Pictou Harbour in Pictou Road. The dilution ratio for the six-port diffuser at Alt-D is lower and 36 times at 5 m from the ports and 109 times at the end of the 100-m mixing zone (Stantec 2017). A comparison of the diffusers and dilution ratios between a three-port diffuser at CH-B off Caribou Point and a six-port diffuser at Alt-D in Pictou Road is shown in Table 4.1.

**Table 4.1 Effluent Dilution Ratios for CH-B (Caribou) and Alt-D (Pictou Road) Outfall Locations**

| Scenario | Distance from Diffuser and Dilution Ratio | | | | | |
|---|---|---|---|---|---|---|
| | 5 m | 10 m | 20 m | 50 m | 100 m | 200 m |
| CH-B Caribou: Three Ports Diffuser | 50.5 | 70.8 | 99.1 | 128.3 | 144.1 | 159.8 |
| Alt-D Pictou Road: Six Ports Diffuser | 36.3 | 41.3 | 50.9 | 76.7 | 109.3 | 135.8 |

The three-port diffuser provides much better dilution and mixing with the ambient environment than the one-port diffuser at CH-B. At the same time, the three-port diffuser has a much smaller footprint of 50 m on the seabed and potential for impact on the benthic environment than the six-port diffuser at Alt-D with a seabed footprint of 125 m. In addition, a diffuser with more than three ports at CH-B brings only marginal benefits to the receiving environment. Therefore, it was concluded that the three-port diffuser is an optimal choice for the specific conditions at CH-B. It was also found that the best mixing is occurring when the horizontal angle of the diffuser is perpendicular to the predominant flow in Northumberland Strait.

The results of the near-field modelling and water quality at the end of the 100-m mixing zone for CH-B are shown in Table 3.5, based on the expected effluent discharge quality. The proposed effluent discharge quality for AOX, TN, TP, colour, BOD, COD, TSS, water temperature, DO, pH and salinity are anticipated to meet compliance at the end of the mixing zone for applicable federal water quality guidelines.

# 5.0 REFERENCES

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# Appendix E2

*Stantec Response to Questions*

**Stantec Consulting Ltd.**
102-40 Highfield Park Drive, Dartmouth NS B3A 0A3

January 5, 2018
File: 121415079

**Attention: Terri Fraser, P.Eng.**
Technical Manager
Northern Pulp Nova Scotia Corporation
PO Box 549, Station Main
New Glasgow, NS B2H 5E8

Dear Ms. Fraser,

**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**

Stantec Consulting Ltd. (Stantec) is pleased to provide the following responses for external stakeholders with regards to the effluent discharge modelling for the proposed wastewater treatment plant replacement project.

**Question 1: Why ice in the harbour won't affect the dispersion of effluent and the 100-m mixing zone as it was modelled?**

**Quick Answer:**

**Effluent dispersion in winter will not be restricted by ice because of temperature and density. The receiving water report delves into ice differential. Warmer months are most challenging for dispersion; in fact, in winter dispersion will be better and faster due to cold temperatures and buoyancy. This is a result of the larger temperature difference with the ambient marine water in Northumberland Strait, leading to a larger density difference between effluent and receiving water. Furthermore, the ice cover would increase turbulence. Modelling results indicate that the plume from a diffuser with six ports reaches the surface at about 90 m from the outfall. Therefore, the impact of ice in the Northumberland Strait on the shape of the plume will be very limited as subsurface mixing is already complete.**

Additional technical supporting information:

When developing the mixing model for the Receiving Water Study (RWS), Stantec recommended using a more conservative case scenario when evaluating the mixing zone in the receiving environment. As detailed below, the conditions for the more conservative case are found to occur during the summer months when the temperature and density play a lessor role in effluent mixing. In winter, mixing is effectively enhanced due to the larger difference in temperature and salinity (density) conditions. The technical discussion of this aspect is described below.

**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**

Effluent plume dispersion involves a two-stage physical mixing process.

- The first stage is the initial mixing, which is dominated by the effluent jet discharge velocity and the differences in density between the effluent and the receiving water. The higher jet velocities exiting the diffuser creates turbulent mixing in the receiving water that persists until the turbulent momentum dissipates. Concurrently, the less dense effluent (compared to the receiving water in Northumberland Strait) is more buoyant, causing the effluent plume to rise upwards to the surface, further facilitating effluent mixing. It should be noted that as the difference in temperature increases between the effluent and the saline receiving environment, the mixing effectiveness increases as the plume is more buoyant (less dense). Warmer months therefore exhibit poorer initial mixing zone conditions.
- In the second stage of the physical mixing process, additional mixing is then facilitated by other factors in the receiving environment such as tidal currents, water levels, water quality, and freshwater inflows, as well as climactic conditions such as wind, waves and ice. The receiving water currents predominantly drive this latter stage of dispersion, causing the effluent plume to move horizontally.

Stantec applied a summertime scenario to the model as there would be poorer effluent plume mixing due to the smaller temperature differences (and thus buoyant mixing). Further, we minimized the potential effects of surface mixing by modelling and using smaller tidal ranges, warmer ambient waters, less wind-driven surface currents, and low freshwater inflows from rivers.

The receiving water conditions and the presence of ice during the winter season in Northumberland Strait are expected to be more favourable for effluent mixing and dispersion, compared to summer discharge conditions. This is a result of the larger temperature difference with the ambient marine water in Northumberland Strait, leading to a larger density difference between the effluent and receiving water and an increased effect of plume buoyancy on the mixing process. Therefore, it is expected a higher dilution will be achieved during the winter season compared to the summer season. Furthermore, the presence of ice cover would increase turbulence at the ice/water interface by providing resistance to the ambient water currents, resulting in a higher mixing and dilution.

In addition, results of the three-dimensional (3D) CORMIX modelling investigation (Stantec 2017) indicated that the plume from six ports at the Alt-D location reaches the surface at about 90 m from the diffuser where the effluent is fully mixed with ambient water (dilution ratio is 102 times) and vertical and horizontal velocities of the effluent are very small. Therefore, the impact of ice in Northumberland Strait on the shape of the plume will be very limited as subsurface mixing is already complete.

**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**

**Question 2: What happens to effluent in a "freak storm" with surge tides?**

**Quick Answer:**

**Surge tides generate turbulence and ultimately provide better and faster mixing conditions.**

Additional technical supporting information:

Storm surges will beneficially increase the circulation currents (including tidal currents and surface currents) and turbulence in the receiving waters, enhancing effluent mixing within the receiving environment. With storm events, a higher dilution ratio of the effluent plume in the receiving environment is expected.

**Question 3: How salinity was indirectly modelled (through density) in the report and when it will meet background salinity in the Strait?**

**Quick Answer:**

**Density is the major factor governing the vertical movements of ocean waters. The density distribution is based on temperature and salinity data. Salinity will be within 2% of background five metres away from the outfall.**

Additional technical supporting information:

Density is the major factor governing the vertical movements of ocean waters. When density is not measured directly (as for this site), standard industry practice allows it to be calculated based on salinity and temperature; these two parameters were obtained from previous studies (ENSR 1999, JWEL 1996) and were inputs to the model. The density distribution in the 3D CORMIX numerical model is calculated using the full United Nations Educational, Scientific and Cultural Organization (UNESCO) equation of state, which is based on user-provided temperature and salinity data.

As discussed below, salinity will be within 2% of background five metres away from the outfall. The salinity used for the effluent (expressed as Total Dissolved Solids (TDS)) was 4 g/L. Ambient salinity for the study area is approximately 27.5 g/L. Results for the effluent dilution ratios for various scenarios are presented in Table 3-4 of the RWS report (Stantec 2017). The CORMIX modelling results indicate that for the marine outfall at the Alt-D location with a six-port diffuser, the dilution ratio is 36.3 times within 5 m of the diffuser. The resulting effluent salinity in the plume 5 m from the outfall is calculated to be 26.9 g/L (i.e., ((36.3 L x 27.5 g/L) + 4 g)/ (36.3 L + 1 L)) which is 2 % less than background. This low difference in salinity will quickly reduce with increasing distance from the outfall.

**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**

**Question 4: A brief discussion regarding the data for the fisheries map [used in the RWS report].**

The data used to investigate the environmental sensitivities in the study area with respect to the type of fishery species that could be present and their mapping were based on commercial, recreational, and/or Aboriginal fisheries identified in existing reports. The fisheries information in Figure 2-10 of the RWS report is based on previous environmental impact assessments conducted for Boat Harbour (JWEL 1994, 2005) and environmental effects monitoring investigations that describe resources for the area (Stantec, 2004; Ecometrix 2007, 2016). The information in these reports also relied on communications with commercial fishers, First Nations, and/or the Department of Fisheries and Oceans Canada (DFO) at that time to identify the fishery species and location of fishing grounds, which was adequate for the purposes of the RWS. More recent commercial fisheries catch data that DFO can provide are fisheries landings data in grid areas 7 km by 11 km (see attached Figure 1 further below). Fisheries data at this course scale would not be practical or useful for the purposes of the RWS. Furthermore, to comply with the relatively recent Government of Canada's privacy policy, any grid cell area containing data from less than five identified vessels, licences, or fishers are labelled as privacy-screened areas where no data can be provided. To obtain more recent fisheries information and fisheries catch effort data at an appropriate spatial scale for the relatively small dimensions of the effluent plume would require consultations with commercial fishers and the engagement of Indigenous communities. These activities were beyond the scope of the RWS investigation and likely could be a component of the environmental assessment process for the project.

## CLOSING

The information contained in this letter has been prepared for the sole benefit of Northern Pulp Nova Scotia Corporation. This letter may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and Northern Pulp Nova Scotia Corporation.

Any use that a third party makes of this letter, 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 letter.

The information and conclusions contained in this letter 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 letter should not be construed as legal advice.

The conclusions presented in this letter 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 letter, we request that we be notified immediately to reassess the conclusions provided herein.

**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**

This letter was prepared by Shelton Liu (Ph.D., P.Eng.), Igor Iskra (Ph.D., P.Eng.), reviewed by Sam Salley (M.Sc.) and independently reviewed by Michael Charles (P.Eng.).

Regards,

**STANTEC CONSULTING LTD.**

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Attachment: Figure 1 – 7 km by 11 km Grid Size of DFO Commercial Fisheries Landings Data for Northumberland Strait

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**Reference: Information Request Responses, Receiving Water Study for the Northern Pulp Effluent Treatment Plant Replacement Project, Pictou Harbour, Nova Scotia**


**Figure 1 - 7 km by 11 km Grid Size of DFO Commercial Fisheries Landings Data for Northumberland Strait**