ATTACHMENT 8F1

NEAR FIELD MODELLING OF THE MISERY DISCHARGE TO LAC DU SAUVAGE

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Tables

Abbreviations

Abbreviation	Definition
2-D	Two-dimensional
3-D	Three-dimensional
CORMIX	Cornell Mixing Zone Expert System
CCME	Canadian Council of Ministers of the Environment
Diavik Mine	Diavik Diamond Mine
Dominion Diamond	Dominion Diamond Ekati Corporation
e.g.,	for example
Ekati Mine	Ekati Diamond Mine
i.e.,	that is
NWT	Northwest Territories
Project	Jay Project
SSWQO	Site-Specific Water Quality Objective
TDS	total dissolved solids
P	phosphorus
N	nitrogen

Units of Measure

Unit	Definition
%	percent
~	approximately
<	less than
>	greater than
±	plus or minus
°	Degrees (as in angle)
°C	degrees Celsius
kg/m^3	kilograms per cubic metre
km	kilometre
m	metre
m/s	metres per second
m^3/h	cubic metres per hour
m^3/s	cubic metres per second
mg/L	milligrams per litre
mg N/L	milligrams nitrogen per litre
mg P/L	milligrams phosphorus per litre

DOMINION DIAMOND

8F1-1 INTRODUCTION

Dominion Diamond Ekati Corporation (Dominion Diamond) is proposing the construction and operation of the Jay Project (Project). The Project is an open-pit diamond mine located at Lac du Sauvage, Northwest Territories (NWT) that will extend the life of the Ekati Diamond Mine (Ekati Mine). The Project is located approximately 200 kilometres (km) south of the Arctic Circle and 300 km northeast of Yellowknife, NWT.

During operations (2019 to 2029), the previously mined Misery Pit will be used as a water management facility. In the last five years of operations (2024 to 2029), water will be pumped from a pump station (PS1) located at the Misery Pit through an 8 km pipeline and discharged through a diffuser located in the main basin of Lac du Sauvage (Section 3: Project Description). An effluent diffuser is a hydraulic structure intended to promote rapid mixing of an effluent in close proximity to the structure using high discharge velocities.

This attachment describes the near-field model developed to support the diffuser design and hydrodynamic modelling. The model estimates the mixing of a discharged effluent into ambient lake water under a variety of hydrodynamic and seasonal scenarios, based on existing ambient lake data and the proposed discharge location and characteristics. Mixing was modelled using the Cornell Mixing Zone Expert System (CORMIX) (Doneker and Jirka 2007). Concentrations of water quality parameters at the edge of the mixing zone were estimated to evaluate the effectiveness of the proposed diffuser.

The design of an effluent diffuser requires the testing of several configurations (i.e., number of ports, port diameter, port angle, space between ports, port geometry) and the selection of a configuration that meets a required mixing ratio. The design basis is then selected to achieve that mixing ratio so that constituent concentrations in the effluent plume, beyond the regulatory mixing zone, meet applicable water quality standards. The main design criterion for the diffuser ports is, therefore, the definition of the mixing zone and the mixing ratio required.

The Northwest Territories Water Board provides guidance for the definition of mixing zones that is focused on wastewater effluent (NWTWB 1992). The water and effluent quality management policy of the Mackenzie Valley Land and Water Board (MVLWB 2011) further indicates that guidance on mixing zones is under development. Size and shape of the mixing zone are established on a case by case basis and maximum limits vary among regions (provinces and states).

Proposed Site-Specific Water Quality Objectives (SSWQO) for the Project are presented in Table 8F1-1-1. These threshold values are used as guidelines to evaluate near-field water quality predictions. The objective of this task was to select a diffuser port configuration that will allow plume concentrations to meet these standards within the near-field mixing zone for the Project.

Table 8F1-1-1 Site-Specific Water Quality Objectives

Parameter of Potential Concern	Units	Threshold	Rationale
Chloride	mg/L	388	Ekati SSWQO
Total dissolved solids	mg/L	1,000	Proposed SSWQO
Nitrate	mg N/L	10	SSWQO (depending on hardness) – threshold based on max hardness value (160 mg/L) for SSWQO equation
Total phosphorus	mg P/L	0.011	CCME trigger – not health related
Strontium	mg/L	11	Snap Lake SSWQO

mg/L = milligrams per litre; mg N/L = milligrams per litre as nitrogen; mg P/L = milligrams per litre as phosphorus; SSWQO = Site-Specific Water Quality Objective; CCME = Canadian Council of Ministers of the Environment.

8F1-2 METHODS

8F1-2.1 Model Linkages

Several interlinked hydrodynamic and water quality models were used to estimate mixing zone concentrations and extent:

- a site discharge water quality model (Appendix 8E);
- a two-dimensional (2-D) pit lake model of the Misery Pit (Appendix 8C);
- a three-dimensional (3-D) hydrodynamic model of Lac du Sauvage (Appendix 8F); and,
- a near-field plume model (this attachment).

The focus of this attachment is the near-field model of the Misery Pit discharge to Lac du Sauvage. Other models are described in their respective appendices or documentation. A brief description of each model, and how they are connected, is provided below.

Water quality, including total dissolved solids (TDS) concentrations, of the Misery Pit discharge was developed in the site water quality model, while discharge temperature was predicted by the 2-D pit lake model of the Misery Pit. These predictions were used to derive inputs to the near-field model, or used to estimate mixing zone concentrations using near-field model results. The site water quality model also predicted the flow rate of the Misery Pit discharge into Lac du Sauvage. The 3-D hydrodynamic model of Lac du Sauvage was used to establish background conditions in Lac du Sauvage as input to the near-field model. In turn, the recommended diffuser design discussed here was used to define the Misery Pit discharge in the hydrodynamic model of Lac du Sauvage (Appendix 8F).

8F1-2.2 Near-Field Model

Near-field mixing of discharge water is influenced by buoyancy and velocity of the discharge, while the shape of the resulting plume and transport within the lake (i.e., far-field) is influenced by lake characteristics including current velocity and depth. The CORMIX model (Doneker and Jirka 2007), developed in Cornell University and endorsed by the United States Environmental Protection Agency was used to estimate the near-field mixing of discharged water from the Misery Pit into Lac du Sauvage. This model is widely used for predicting near-field mixing for a variety of discharges (e.g., conservative substances, non-conservative substances, heated discharges, brine, and sediment), in a wide range of waterbodies, including lakes.

The CORMIX model assumes steady-state and generally uniform ambient conditions in receiving waterbodies. The model has specific sub-systems for analyzing plume or jet geometry and mixing characteristics of positively, neutrally, or negatively buoyant discharge from an outfall, or submerged single- or multi-port diffuser, into waterbodies that are uniform or stratified. The model determines an appropriate hydrodynamic flow pattern for each discharge based on an expert system and solves a corresponding series of simple flow patterns to obtain a complete analysis from the discharge point into the far-field. Predictions of plume geometry and mixing characteristics are based on the determination of this hydrodynamic flow pattern.

8F1-2.3 Input Data

The purpose of defining simulation conditions is to simplify the representation of discharge properties and conditions in Lac du Sauvage, and to provide the required model inputs for steady-state simulation of the resulting jets or plumes from the diffuser discharge. The required model inputs for defining the diffuser discharge conditions include lake bathymetry, ambient water temperature and TDS concentration, ambient wind speed or lake velocity, discharge rate, discharge temperature and TDS concentration, discharge velocity or flow rate, and diffuser characteristics (port diameter, number of ports, port orientation, port spacing, and port layout for a submerged diffuser). A summary of the input data used for ambient and discharge characteristics is presented in Table 8F1-2.3-1. These parameters are described in greater detail in Sections 8F1-2.3.1 and 8F1-2.3.2.

Table 8F1-2.3-1 Summary of Ambient and Discharge Characteristics Used as Input to the Near-Field Model

Description	Scenario			Comment
	Open Water, Average Wind	Open Water, Maximum Wind	Under Ice	
Ambient Characteristics				
Density (kg/m^3)	999.9		999.9	Calculated from water temperature and TDS concentration
Average depth (m)	8	8	7	From local bathymetry
Depth at discharge (m)	8	8	7	
Ambient velocity (m/s)	0.083	0.53	0.0005	3% of wind speed
Wind speed (m/s)	5.2	7.1	0	From local meteorology

Table 8F1-2.3-1 Summary of Ambient and Discharge Characteristics Used as Input to the Near-Field Model

Description	Scenario: Open Water, Average Wind	Scenario: Open Water, Maximum Wind	Scenario: Under Ice	Comment
Manning's coefficient	0.015			Assumed coefficient, commonly used for similar systems
Discharge Characteristics				
Density (kg/m^3)	1,001.5		1,002.3	Calculated from water temperature and TDS concentration
Effluent flow rate (m^3/s)	0.56			Calculated from maximum discharge rate and port dimensions
Concentration (%)	100			Assumed
Distance to nearest bank (m)	1,000			Plume will not interact with shore
Port spacing (m)	2.5, 5, 7.5, 10, 15			Five port spacing strategies evaluated
Horizontal angle (°)	Parallel to current = 0 Perpendicular to current = 90			-
Number of ports	10			-
Port diameter (m)	0.084			Calculated to ensure discharge velocity ~10 m/s
Port height (m)	1			Ports position 1 m above lakebed

m = metre; kg/m^3 = kilograms per cubic metre; m/s = metres per second; m^3/s = cubic metres per second;% = percent; ° = degrees; TDS = total dissolved solids; ~ = approximately; “-“ = no comment.

8F1-2.3.1 Ambient Characteristics of Lac du Sauvage

Inputs required by CORMIX to define ambient characteristics include water temperature and TDS concentration, current velocity, average depth, wind speed, and Manning's Coefficient. Ambient conditions (i.e., for Lac du Sauvage) are summarized in Table 8F1-2.3-1.

Data used to detail the local bathymetry and lake characteristics in the near-field model are the same as those used with the 3-D hydrodynamic model of Lac du Sauvage (Appendix 8F). For the purposes of near-field modelling, the depth of the lake is assumed to be 8 metres (m), which is consistent with bathymetry near the discharge location. It was assumed that the ice-cover thickness will be 1 m under ice-covered conditions. This ice-cover is represented by decreasing the lake depth used in the model by 1 m in the ice-cover scenario.

Meteorological data, including temperature and wind speed, were obtained from an onsite meteorological station at the Diavik Diamond Mine (Diavik Mine). The meteorological data used in near-field modelling are consistent with those used in the 3-D hydrodynamic modelling of Lac du Sauvage and Lac de Gras (Appendix 8F). Two open water scenarios were developed: average wind speed, and maximum wind speed. Lake velocity was assumed to be equal to 3 percent (%) of wind speed. The ratio of wind speed to lake currents can vary; however, assuming lake velocities equal 3% of wind speed is considered reasonable (Wetzel 2001). This assumed velocity calibrated well with predicted lake velocities from the hydrodynamic model. During the ice-cover scenario, the ambient current velocity was estimated to be near stagnant (0.0005 metres per second [m/s]).

A water density of 999.9 kilograms per cubic metre (kg/m^3) was used for all scenarios, calculated from observed temperature and TDS concentrations. A typical Manning's Coefficient for lakes, a measure of the roughness of the lakebed, was used (0.015). This value is commonly used in modelling similar lake environments.

8F1-2.3.2 Effluent Discharge Characteristics

Inputs required by CORMIX to define discharge characteristics include effluent temperature and TDS concentration, effluent velocity or flow rate, effluent concentration, and diffuser characteristics (port diameter, number of ports, port orientation, port spacing, and port layout for a submerged diffuser). Discharge characteristics (i.e., for discharge via diffuser from the Misery Pit) are summarized in Table 8F1-2.3-1.

The diffuser was assumed to have 10 ports. Preliminary modelling indicated that 10 ports would provide sufficient mixing efficiency. Each port was assumed to be positioned 1 m above the lakebed, oriented at a 45 degree (°) angle towards the water surface. The diffuser will be approximately 1,000 m from the nearest shore. This distance makes sure that the plume from the diffuser will not interact with the bank within the near-field.

Two scenarios were developed to model different diffuser orientations under two seasonal scenarios (under-ice and open-water): parallel to lake current (coflow), and perpendicular to lake current (cross-flow). As lake current varies with wind direction, these two scenarios evaluate the changes in plume behaviour under different possible lake current orientations.

Site water quality modelling developed a maximum discharge rate from the Misery Pit to Lac du Sauvage: 2,000 cubic metres per hour (m^3/h). This discharge rate was used to determine effluent flow rate from the diffuser and choosing port dimensions to establish an effluent velocity of approximately 10 m/s. Based on a 10-port diffuser layout, assuming circular ports, each port was assigned a diameter of 0.084 m.

An effluent concentration of 100% was assigned to discharge from the diffuser. This concentration was used to determine effluent mixing ratios and concentration at various distances from the diffuser. Effluent density was calculated based on the maximum TDS concentration determined in the site water quality model for each of the under-ice and open-water scenarios.

To determine the most efficient diffuser layout, five different port spacing distances were used: 2.5 m, 5.0 m, 7.5 m, 10 m, and 15 m. Calculated plume widths were used to recommend a port spacing that ensures plumes jets from each port do not interact.

8F1-2.3.3 Summary of Scenarios

In total, 30 scenarios were developed to account for variability in ambient conditions and diffuser layout:

- three scenarios of ice/wind conditions: under-ice; open-water, average wind speed; open-water, maximum wind speed;
- two scenarios of discharge orientation: perpendicular to lake current (cross-flow), and parallel to lake current (coflow); and,
- five scenarios of port spacing along the diffuser: 2.5 m, 5.0 m, 7.5 m, 10 m, and 15 m.

8F1-3 MODELLING RESULTS

Results are presented for the near-field, as predicted by the CORMIX model. In this case, the near-field is defined as within 16 m of the diffuser. This distance was set based on the depth of the diffuser, 8 m. The CORMIX predictions are considered reliable until the plume interacts with the water surface, at which point the predictions become less reliable. As the diffuser ports will be oriented at an angle of 45°, the plume will interact with the surface of the water at 8 m from the diffuser. A distance of 16 m, twice the distance to interaction with the surface, was used because results beyond this distance were not considered reasonable.

8F1-3.1 Summary of Dilution and Concentration in the Mixing Zone

A summary of the dilution and concentration of effluent at 16 m from the diffuser for each scenario modelled is presented in Table 8F1-3.1-1. This table also presents the maximum plume width over this distance. As CORMIX results are considered accurate to within plus or minus (±) 50%, the concentration at 16 m and maximum plume width have been multiplied by two, while the mixing ratio (i.e., physical dilution) has been divided by two, to ensure the most conservative results are presented.

Table 8F1-3.1-1 Summary of Near-Field Dilution and Concentration

Simulation	Port Spacing (m)	Lake Condition	Wind Speed	Flow Condition	Concentration (%) at 16 m	Mixing Ratio 16 m	Maximum Plume Half Width (m)[(a)]
1	2.5	Open-water	Average	Coflow	4.0	25	1.3
2	2.5	Open-water	Maximum	Coflow	1.1	89	1.2
3	2.5	Ice-cover	None	Coflow	6.1	17	1.6
4	2.5	Open-water	Average	Cross-flow	15	6.8	2.2
5	2.5	Open-water	Maximum	Cross-flow	**18**	**5.5**	**1.5**
6	2.5	Ice-cover	None	Cross-flow	*6.3*	*16*	*1.6*
7	5	Open-water	Average	Coflow	2.9	34	1.3
8	5	Open-water	Maximum	Coflow	0.68	146	1.2
9	5	Ice-cover	None	Coflow	5.3	19	1.6
10	5	Open-water	Average	Cross-flow	14	7.0	2.2

Table 8F1-3.1-1 Summary of Near-Field Dilution and Concentration

Simulation	Port Spacing (m)	Lake Condition	Wind Speed	Flow Condition	Concentration (%) at 16 m	Mixing Ratio 16 m	Maximum Plume Half Width (m)[(a)]
11	5	Open-water	Maximum	Cross-flow	**14**	**6.9**	**1.5**
12	5	Ice-cover	None	Cross-flow	*5.3*	*19*	*1.6*
13	7.5	Open-water	Average	Coflow	2.6	38	1.3
14	7.5	Open-water	Maximum	Coflow	0.36	276	1.2
15	7.5	Ice-cover	None	Coflow	*5.2*	*19*	*1.6*
16	7.5	Open-water	Average	Cross-flow	13	7.8	2.2
17	7.5	Open-water	Maximum	Cross-flow	**13**	**7.8**	**1.5**
18	7.5	Ice-cover	None	Cross-flow	4.9	20	1.6
19	10	Open-water	Average	Coflow	2.4	42	1.3
20	10	Open-water	Maximum	Coflow	0.49	204	1.2
21	10	Ice-cover	None	Coflow	5.3	19	1.6
22	10	Open-water	Average	Cross-flow	12	8.3	2.2
23	10	Open-water	Maximum	Cross-flow	**12**	**8.3**	**1.5**
24	10	Ice-cover	None	Cross-flow	*5.3*	*19*	*1.6*
25	15	Open-water	Average	Coflow	2.1	47	1.3
26	15	Open-water	Maximum	Coflow	0.4	247	1.2
27	15	Ice-cover	None	Coflow	5.3	19	1.6
28	15	Open-water	Average	Cross-flow	11	9.0	2.2
29	15	Open-water	Maximum	Cross-flow	**11**	**9.0**	**1.5**
30	15	Ice-cover	None	Cross-flow	*5.3*	*19*	*1.6*

Note: **Bold** values indicate least dilution under open-water conditions, *italic* values indicate least dilution in under-ice conditions.
a) Calculated using single port models for each lake condition, following method of Doneker and Jirka (2007).
m = metre;% = percent

During open-water conditions when the discharge is parallel to the lake current (coflow), mixing was predicted to be the greatest and more mixing was predicted to occur with a maximum wind speed compared to an average wind speed. More mixing was predicted to occur during open-water conditions compared to under-ice conditions because the ambient lake velocity was estimated to be almost stagnant during under-ice conditions.

During open-water conditions when the discharge is perpendicular to the lake current (cross-flow), mixing was predicted to be the least, and in general, there was no difference between the mixing predicted with a maximum wind speed and an average wind speed. Mixing was predicted to be lower during open-water conditions because the lake current, which is perpendicular to the discharge, acts to deflect the discharge and reduce mixing with the lake water. More mixing was predicted to occur during under-ice conditions compared to open-water conditions because the ambient lake velocity was estimated to be almost stagnant during under-ice conditions; therefore, the discharge was not deflected.

The maximum plume half width was predicted to be 2.2 m, under the average wind speed, cross-flowing scenarios. To ensure plumes do not interact, each diffuser port would need to be at least 4.4 m apart. A closer port spacing would allow the plumes from each port to interact at their maximum widths (2.2 m each).

8F1-3.2 Water Quality at the Edge of the Mixing Zone

The lowest mixing ratio for each port spacing was used to evaluate water quality at the edge of the mixing zone against the SSWQO presented in Section 8F1-1. Summaries of calculated mixing-zone concentrations compared to these criteria are presented in Tables 8F1-3.2-1 to 8F1-3.2-5.

Table 8F1-3.2-1 Maximum Concentration During Operations Assuming 2.5 m Port Spacing

Parameter	SSWQO (mg/L)	Maximum Lake Concentration (mg/L)	Maximum Discharge Concentration (mg/L)	Mixing Ratio[(a)] (x)	End of Near-Field Concentration (mg/L)
Under Ice					
Total dissolved solids	1,000	95	1,850	16	205
Chloride	388	49	1,042	16	112
Total phosphorus (as P)	0.011	0.011	0.2	16	0.022
Nitrate (as N)	10	0.81	16	16	1.8
Strontium	11	0.34	7	16	0.7
Open Water					
Total dissolved solids	1,000	65	1,723	6	367
Chloride	388	33	964	6	202
Total phosphorus (as P)	0.011	0.0075	0.18	6	0.039
Nitrate (as N)	10	0.57	15	6	3.3
Strontium	11	0.22	6.4	6	1.35

Note:

123 Highlighted values exceed SSWQO concentrations.

a) Dilution factor at end of near-field, 16 m; assuming 10-port diffuser.

SSWQO = Site-Specific Water Quality Objective; mg/L = milligrams per litre; m = metre; P = phosphorus; N = nitrogen.

Table 8F1-3.2-2 Maximum Concentration During Operations Assuming 5 m Port Spacing

Parameter	SSWQO (mg/L)	Maximum Lake Concentration (mg/L)	Maximum Discharge Concentration (mg/L)	Mixing Ratio[a] (x)	End of Near-Field Concentration (mg/L)
Under Ice					
Total dissolved solids	1,000	95	1,850	19	188
Chloride	388	49	1,042	19	102
Total phosphorus (as P)	0.011	0.011	0.2	19	0.02
Nitrate (as N)	10	0.81	16	19	1.6
Strontium	11	0.34	7	19	0.7
Open Water					
Total dissolved solids	1,000	65	1,723	7	302
Chloride	388	33	964	7	166
Total phosphorus (as P)	0.011	0.0075	0.18	7	0.032
Nitrate (as N)	10	0.57	15	7	2.7
Strontium	11	0.22	6.4	7	1.11

Note:
123 Highlighted values exceed SSWQO concentrations.
a) Dilution factor at end of near-field, 16 m; assuming 10-port diffuser.
SSWQO = Site-Specific Water Quality Objective; mg/L = milligrams per litre; m = metre.

Table 8F1-3.2-3 Maximum Concentration During Operations Assuming 7.5 m Port Spacing

Parameter	SSWQO (mg/L)	Maximum Lake Concentration (mg/L)	Maximum Discharge Concentration (mg/L)	Mixing Ratio[a] (x)	End of Near-Field Concentration (mg/L)
Under Ice					
Total dissolved solids	1,000	95	1,850	19	188
Chloride	388	49	1,042	19	102
Total phosphorus (as P)	0.011	0.011	0.2	19	0.02
Nitrate (as N)	10	0.81	16	19	1.6
Strontium	11	0.34	7	19	0.7
Open Water					
Total dissolved solids	1,000	65	1,723	8	273
Chloride	388	33	964	8	149
Total phosphorus (as P)	0.011	0.0075	0.18	8	0.029
Nitrate (as N)	10	0.57	15	8	2.4
Strontium	11	0.22	6.4	8	1.0

Note:
123 Highlighted values exceed SSWQO concentrations.
a) Dilution factor at end of near-field, 16 m; assuming 10-port diffuser.
SSWQO = Site-Specific Water Quality Objective; mg/L = milligrams per litre; m = metre.

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Table 8F1-3.2-4 Maximum Concentration During Operations Assuming 10 m Port Spacing

Parameter	SSWQO (mg/L)	Maximum Lake Concentration (mg/L)	Maximum Discharge Concentration (mg/L)	Mixing Ratio[a] (x)	End of Near-Field Concentration (mg/L)
Under Ice					
Total dissolved solids	1,000	95	1,850	19	188
Chloride	388	49	1,042	19	102
Total phosphorus (as P)	0.011	0.011	0.2	19	0.02
Nitrate (as N)	10	0.81	16	19	1.6
Strontium	11	0.34	7	19	0.7
Open Water					
Total dissolved solids	1,000	65	1,723	9	260
Chloride	388	33	964	9	142
Total phosphorus (as P)	0.011	0.0075	0.18	9	0.028
Nitrate (as N)	10	0.57	15	9	2.3
Strontium	11	0.22	6.4	9	0.95

Note:
123 Highlighted values exceed SSWQO concentrations.
a) Dilution factor at end of near-field, 16 m; assuming 10-port diffuser.
SSWQO = Site-Specific Water Quality Objective; mg/L = milligrams per litre; m = metre.

Table 8F1-3.2-5 Maximum Concentration During Operations Assuming 15 m Port Spacing

Parameter	SSWQO (mg/L)	Maximum Lake Concentration (mg/L)	Maximum Discharge Concentration (mg/L)	Mixing Ratio[a] (x)	End of Near-Field Concentration (mg/L)
Under Ice					
Total dissolved solids	1,000	95	1,850	19	188
Chloride	388	49	1,042	19	102
Total phosphorus (as P)	0.011	0.011	0.2	19	0.02
Nitrate (as N)	10	0.81	16	19	1.6
Strontium	11	0.34	7	19	0.7
Open Water					
Total dissolved solids	1,000	65	1,723	9	250
Chloride	388	33	964	9	136
Total phosphorus (as P)	0.011	0.0075	0.18	9	0.027
Nitrate (as N)	10	0.57	15	9	2.2
Strontium	11	0.22	6.4	9	0.91

Note:
123 Highlighted values exceed SSWQO concentrations.
a) Dilution factor at end of near-field, 16 m; assuming 10-port diffuser.
SSWQO = Site-Specific Water Quality Objective; mg/L = milligrams per litre; m = metre.

In all scenarios, open-water end of near-field concentrations were predicted to be greater than under-ice concentrations because during open-water conditions, the lowest mixing ratio for each port spacing was predicted to occur when the discharge was perpendicular to the ambient lake current. As discussed in Section 8F1-3.1, mixing was predicted to be lower during open-water conditions because the lake current acts to deflect the discharge and reduce mixing with the ambient water. More mixing was predicted to occur during under-ice conditions, resulting in lower end of near-field concentrations, because the ambient lake velocity was estimated to be almost stagnant.

In all scenarios, the calculated end of near-field total phosphorus exceeded the SSWQO based on mixing ratios from near-field modelling. Calculated concentrations of all other parameters were below their respective SSWQO at the end of the near-field. During under-ice conditions, the predicted maximum lake concentration of total phosphorus (from the site water quality model) is equal to the SSWQO.

Concentrations dropped as the port spacing was increased. Most of this change occurred between the 2.5 m spacing and 10 m spacing scenarios. The 10 m and 15 m spacing scenarios resulted in similar calculated concentrations of all parameters. A space between ports of 5 m was selected to complete the geometry of the diffuser.

8F1-4 DATA GAPS AND MODEL UNCERTAINTY

Results from CORMIX are generally accurate to within ±50% with respect to dilutions, concentrations, and plume geometry (Doneker and Jirka 2007). Nevertheless, the model is considered adequate to characterize general central trends of effluent mixing in ambient aquatic environments.

The model assumes that steady-state and generally uniform ambient conditions exist in receiving waterbodies, in this case Lac du Sauvage. Since natural lake systems vary over time, various model simulations were developed to assess a range of possible ambient conditions.

Ambient lake geometry in CORMIX is limited to an assumed rectangular cross-section with constant width and depth. An adequately large width was chosen to ensure no interaction with the shore was incorporated into the model, which is an accurate representation of the Lac du Sauvage system. An average depth was chosen to represent local depth around the discharge point. The modelled geometry is considered a reasonable representation of the system.

Ultimately, even the best of models cannot compare with operational monitoring data. Site monitoring and periodic re-assessment of predictions and/or remedial measures will be required during operations.

8F1-5 SUMMARY AND RECOMMENDATIONS

A near-field mixing model was developed using CORMIX to estimate dilution, concentration, and plume geometry from a diffuser placed in Lac du Sauvage to discharge water from the back-flooded Misery Pit. Based on model predictions, near-field concentrations of key parameters were calculated and compared to the SSWQO. Modelled plume geometries are used to develop design recommendations for the diffuser. The geometry of the diffuser is as follows:

- ten ports spaced at 5 m intervals;
- port openings of 0.084 m in diameter, positioned 1 m above the lake bed;
- port openings oriented 45° upwards towards water surface; and,
- port openings orientated inline with main lake current (current fluctuates with wind direction).

Several model simulations were developed to evaluate a range of possible conditions in the lake (Table 8F1-3.1-1). The least dilution was predicted during maximum wind, cross-flow conditions for open water scenarios. During under-ice conditions, the cross-flowing simulations also had less dilution than co-flowing simulations.

Calculated near-field concentrations of total phosphorus were predicted to be above the SSWQO (Tables 8F1-3.2-1 to 8F1-3.2-5). All other parameters evaluated are predicted to be below their SSWQO. Concentration in the near-field declines as the port spacing is increased.

A port-spacing of 5 m is recommended for diffuser design. This spacing provides adequate space to prevent plumes from individual ports from interacting. A port spacing of 5 m was used to define the diffuser in the 3-D hydrodynamic model of Lac du Sauvage. The diffuser design specifications were assumed based on expert judgement and previous experience. In advance of diffuser installation, a detailed design and engineering study will be undertaken by Dominion Diamond.

For the purposes of this modelling effort, near-field concentrations, dilutions, and plume geometries are based on model results at 16 m from the diffuser. This distance is not meant as a mixing zone, but rather is based on the furthest extent of the CORMIX model where model results are considered reasonable. A larger mixing zone will be defined for the Project (e.g., 200 m radius from the diffuser).

8F1-6 REFERENCES

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