Additional Information Request # 19

Impacts of PSMF Discharge to Hare Lake

Related Comments:

CEAR #599 (Ministry of the Environment)

CEAR #600 (Environment Canada)

In SIR #5 the Panel requested SCI to provide a comprehensive summary of baseline conditions and function for Hare Lake, pulling together data and information collected as part of the EIS and additional data and information collected in 2013.

In its comments on SCI's response to SIR #5, the Ontario Ministry of the Environment (MOE) noted that the description of baseline conditions was adequate, and further noted that the results of the modelling undertaken by EcoMetrix included in the response to SIR #5 firmly concluded that there will be "no impact" to Hare Lake. The MOE requested further information to better understand how this conclusion was derived, to verify the accuracy of this prediction, and to evaluate the adequacy of the inputs and the corresponding outputs, leading to an assessment of the impacts of the PSMF discharge to Hare Lake.

The Panel requests that SCI:

- Provide the CORMIX input data and a sensitivity analysis that identifies the assumptions and numeric inputs that influence modeled predictions.
- Environment Canada (EC) noted that as Hare Lake is oligotrophic, increased nitrogen inputs from blasting residues could lead to eutrophication and other changes in the system. In this regard, EC found it unclear how blasting residues have been factored into the effluent quality predictions.
- To address the potential for increased nitrogen inputs to the Hare Lake system:
- Clarify how blasting residues were factored into the effluent predictions with an emphasis on the nitrogen concentrations predicted in the discharge to Hare Lake from the PSMF.

SCI Response:

Part 1

The proposed discharge of excess water from the PSMF to Hare Lake will be through an engineered, offshore, submerged, multiport diffuser, designed to maximize the mixing potential and minimize the spatial extent of the mixing zone.

A mathematical model referred to as CORMIX (Cornell Mixing Zone Expert System) was used to predict the rate of mixing of the discharge with distance downstream from the diffuser (hence, the spatial extent of the mixing zone). CORMIX was developed by Cornell University (Jirka and Akar, 1991), is supported by the United States Environmental Protection Agency, and is a widely recognized model for the analysis of mixing characteristics.

The conceptual design for the diffuser used in the assessment of potential effects consisted of a diffuser line with 10 evenly spaced nozzles with each nozzle approximately 0.051 m in diameter (approximately 2 inches). The diffuser line is located approximately 10 m offshore in approximately 3 m of water and extends parallel to the shoreline due to the steep gradient of the nearshore bottom within its vicinity.

The exact design configuration will be optimized as required during the engineering design and permitting phase to ensure optimal performance of the diffuser specific to site conditions including consideration of the use of “duck-billed” nozzles to account for variable discharge rates.

Sample model input and output files are provided in Figure 1 through Figure 4, below. The files present an example of one model scenario. The response to AIR 19 Part 2 provides results for a broader range of model runs as part of the sensitivity analysis. Table 1 and the points below summarize the parameter values for this example.

Table 1: Parameter Values for Sample Model Run

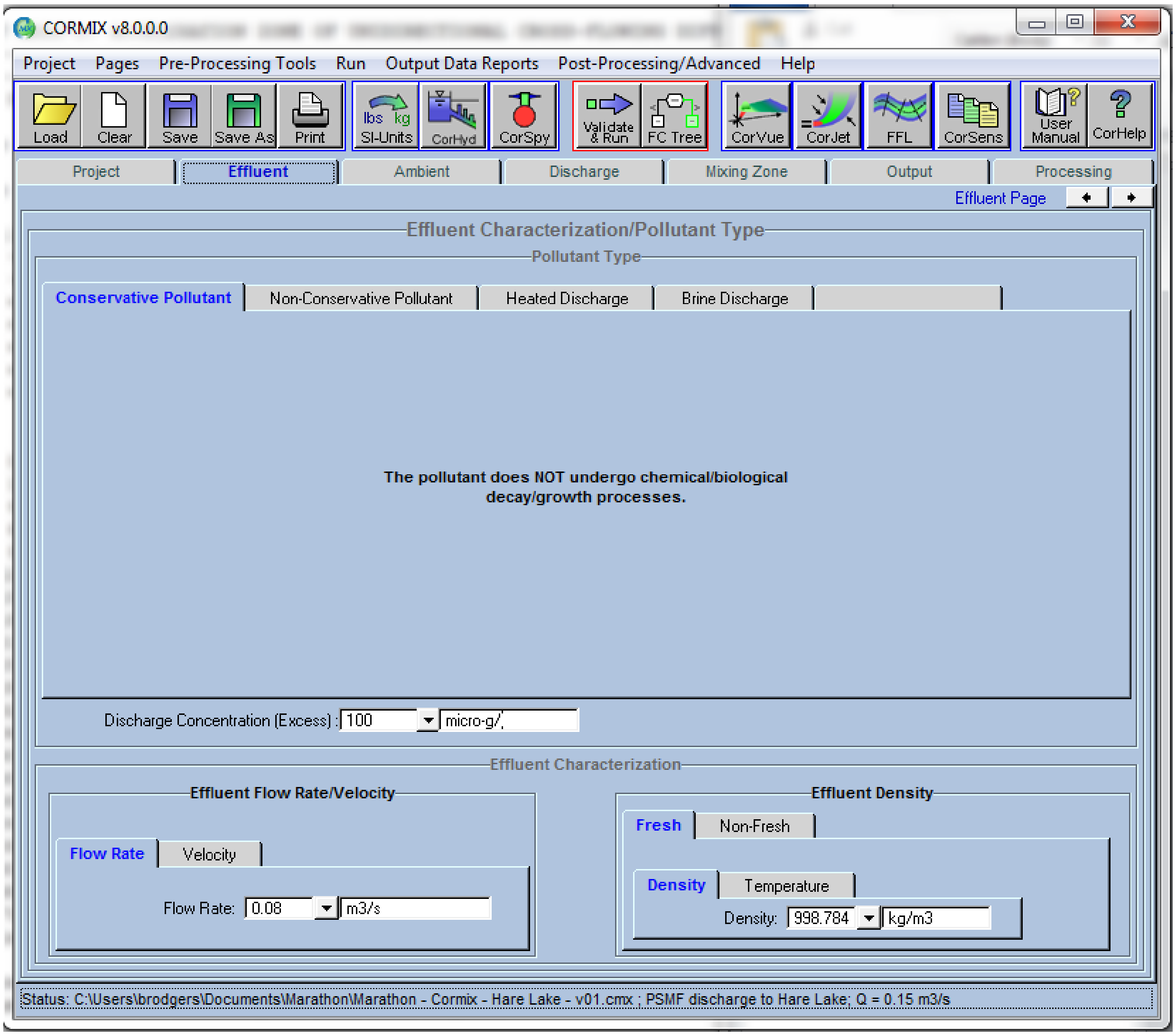
Run	Diffuser length	Exit velocity	Water depth	Current velocity	Discharge rate	Discharge density
	m	m/s	m	m/s	m^3/s	kg/m^3
Example	3	3.9	3	0.05	0.08	998.784

- Exit velocity refers to the speed at which the discharge water exits the individual nozzles along the diffuser line. The magnitude is determined from the discharge rate, number of nozzles and diameter of the nozzles. Typical engineering design may range from 3 to 8 m/s. High velocities may lead to excessive pumping requirements, whereas low velocities (less than 0.5 m/s) may lead to undesirable sediment accumulation. The target value used in this example was 3.9 m/s corresponding to the discharge rate of 0.08 m^3/s and proposed nozzle configuration (10 nozzles each with 0.051 m diameter).
- The current velocity refers to the speed (and direction) of the ambient flow in the vicinity of the diffuser. A value of 0.05 m/s was used for this example. A broader range is provided in the sensitivity analysis. This current speed corresponds to the maximum value recorded in Hare Lake over a 3 day field program in October 2012. A total of 25 measurements were made using drogues. The measured velocities ranged from 0.001 m/s to 0.05 m/s with a median of 0.01 m/s.
- The discharge rate refers to the release of water from the PSMF to Hare Lake. A value of 0.08 m^3/s was used for this example. During the first number of years of operation as Cell 1 of the PSMF fills, the mine is not expected to discharge water to Hare Lake. During later years of operation, the mine may discharge periodically during the ice free period to manage on-site waters. During these periods, the discharge rate is expected to range from approximately 0.01 to 0.08 m^3/s, corresponding to summer and freshet.
- The density of the discharge water was 998.784 kg/m^3 for this example, corresponding to a TDS concentration of 200 mg/L and temperature of 18^{o}C. The density of the ambient water in the lake was 998.633 kg/m^3, corresponding to a TDS concentration of 0 mg/L and temperature of 18^{o}C. The sensitivity analysis considered a broader range of densities relating to hypothetical conditions to demonstrate the insensitivity of the diffuser performance to density.

Figure 1, Figure 2 and Figure 3 present the input files for the model runs, corresponding to effluent characteristics, ambient characteristics and discharge characteristics. Figure 4 presents the output files for the model run. The sub-model, CORMIX2, was used to assess mixing potential of all nozzles together.

For this scenario, the diffuser achieves a mixing potential of approximately 30:1 within approximately 40 m from the diffuser (measured in the offshore direction from the diffuser line)—referred to as the mixing zone for the purpose of this discussion. At this point, the plume is approximately 6 m wide (based on a half-width of approximately 3 m).

Figure 1: Sample Model Input File – Effluent Characteristics



The pollutant does NOT undergo chemical/biological decay/growth processes.

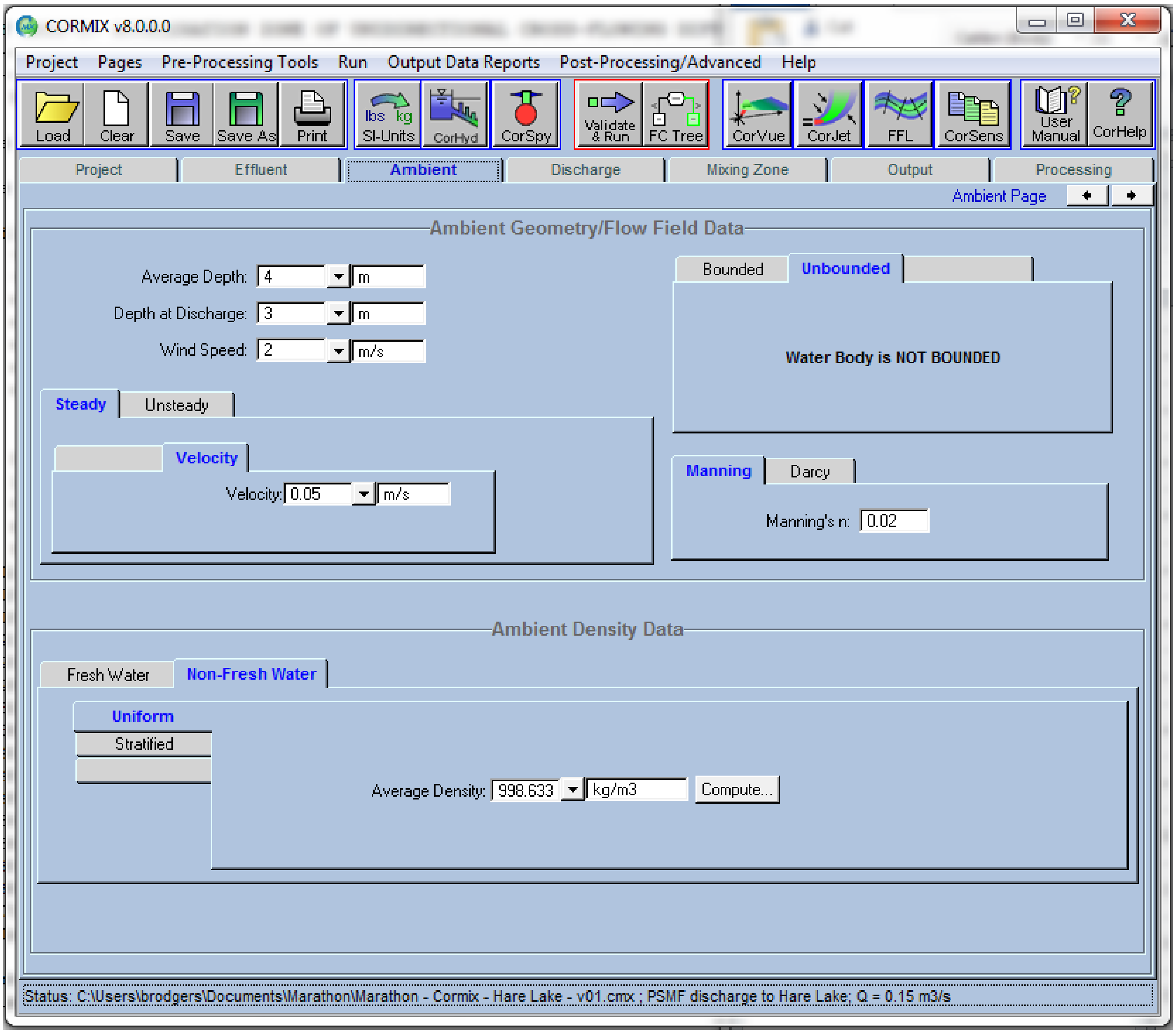
Discharge Concentration (Excess) : 100 micro-g/l

Flow Rate: 0.08 m3/s

Density: 998.784 kg/m3

Status: C:\Users\brodgers\Documents\Marathon\Marathon - Cormix - Hare Lake - v01.cmx ; PSMF discharge to Hare Lake; Q = 0.15 m3/s

Figure 2: Sample Model Input File – Ambient Environment



Average Depth: 4 m

Depth at Discharge: 3 m

Wind Speed: 2 m/s

Velocity: 0.05 m/s

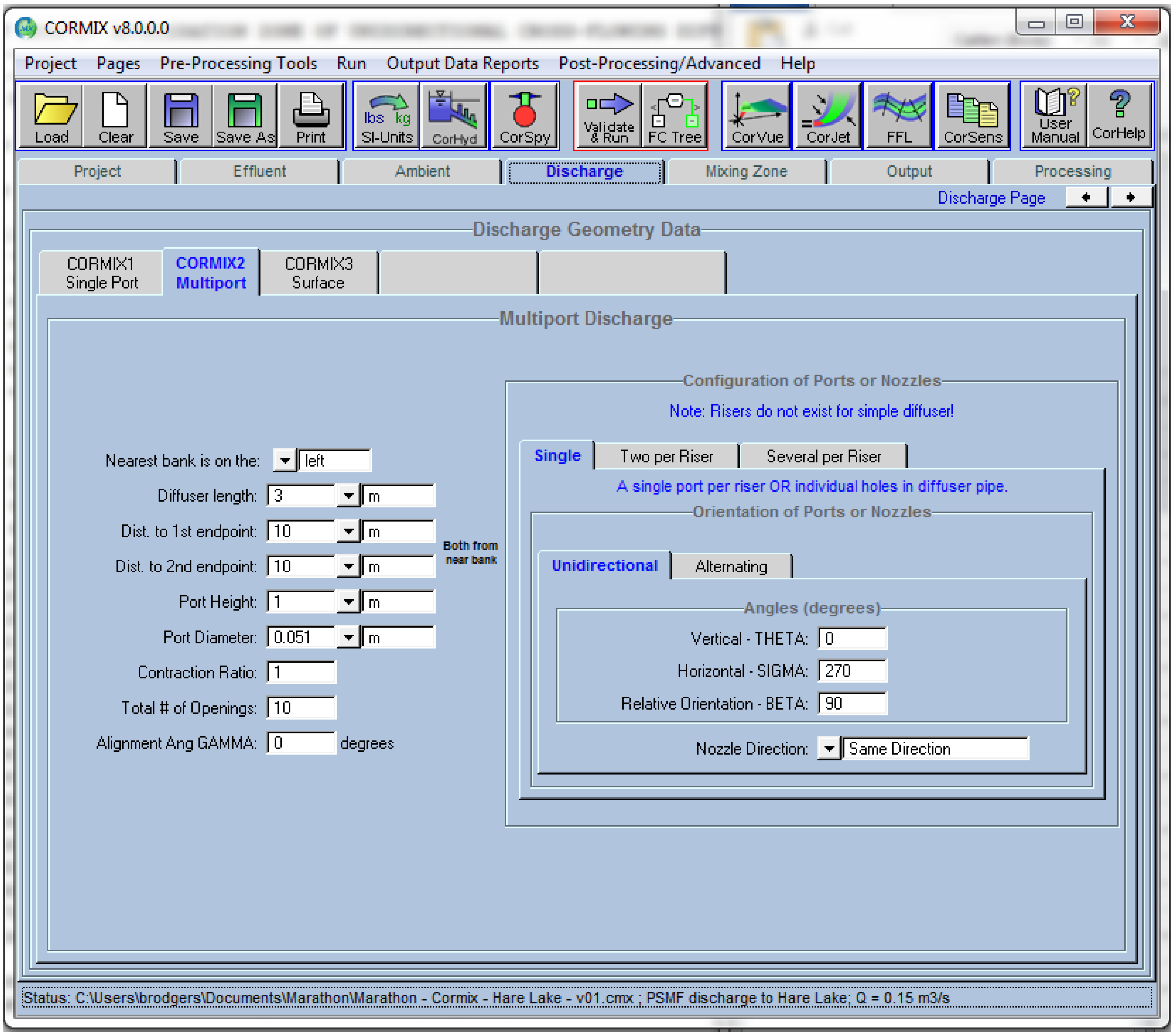
Water Body is NOT BOUNDED

Manning's n: 0.02

Average Density: 998.633 kg/m3

Status: C:\Users\brodgers\Documents\Marathon\Marathon - Cormix - Hare Lake - v01.cmx ; PSMF discharge to Hare Lake; Q = 0.15 m3/s

Figure 3: Sample Model Input File – Discharge Configuration



Discharge Geometry Data

Multiport Discharge

Nearest bank is on the: left

Diffuser length: 3 m

Dist. to 1st endpoint: 10 m

Dist. to 2nd endpoint: 10 m

Both from near bank

Port Height: 1 m

Port Diameter: 0.051 m

Contraction Ratio: 1

Total # of Openings: 10

Alignment Ang GAMMA: 0 degrees

Configuration of Ports or Nozzles

Note: Risers do not exist for simple diffuser!

A single port per riser OR individual holes in diffuser pipe.

Orientation of Ports or Nozzles

Angles (degrees)

Vertical - THETA: 0

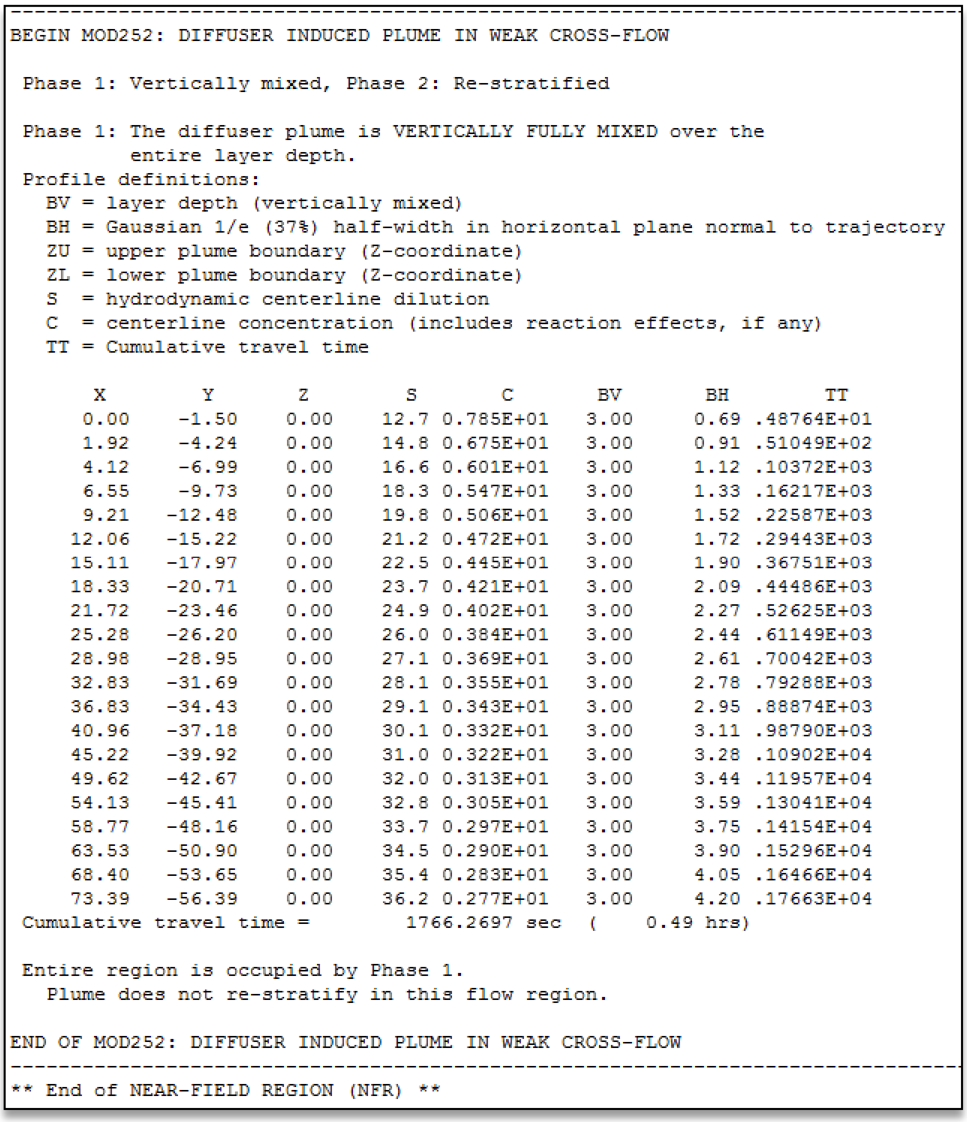
Horizontal - SIGMA: 270

Relative Orientation - BETA: 90

Nozzle Direction: Same Direction

Status: C:\Users\brodgers\Documents\Marathon\Marathon - Cormix - Hare Lake - v01.cmx ; PSMF discharge to Hare Lake; Q = 0.15 m3/s

Figure 4: Sample Model Output – Mixing Potential Predicted Using CORMIX



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BEGIN MOD252: DIFFUSER INDUCED PLUME IN WEAK CROSS-FLOW

 Phase 1: Vertically mixed, Phase 2: Re-stratified

 Phase 1: The diffuser plume is VERTICALLY FULLY MIXED over the
          entire layer depth.
 Profile definitions:
   BV = layer depth (vertically mixed)
   BH = Gaussian 1/e (37%) half-width in horizontal plane normal to trajectory
   ZU = upper plume boundary (Z-coordinate)
   ZL = lower plume boundary (Z-coordinate)
   S  = hydrodynamic centerline dilution
   C  = centerline concentration (includes reaction effects, if any)
   TT = Cumulative travel time

       X         Y        Z         S        C        BV        BH        TT
      0.00     -1.50     0.00     12.7 0.785E+01   3.00     0.69 .48764E+01
      1.92     -4.24     0.00     14.8 0.675E+01   3.00     0.91 .51049E+02
      4.12     -6.99     0.00     16.6 0.601E+01   3.00     1.12 .10372E+03
      6.55     -9.73     0.00     18.3 0.547E+01   3.00     1.33 .16217E+03
      9.21    -12.48     0.00     19.8 0.506E+01   3.00     1.52 .22587E+03
     12.06    -15.22     0.00     21.2 0.472E+01   3.00     1.72 .29443E+03
     15.11    -17.97     0.00     22.5 0.445E+01   3.00     1.90 .36751E+03
     18.33    -20.71     0.00     23.7 0.421E+01   3.00     2.09 .44486E+03
     21.72    -23.46     0.00     24.9 0.402E+01   3.00     2.27 .52625E+03
     25.28    -26.20     0.00     26.0 0.384E+01   3.00     2.44 .61149E+03
     28.98    -28.95     0.00     27.1 0.369E+01   3.00     2.61 .70042E+03
     32.83    -31.69     0.00     28.1 0.355E+01   3.00     2.78 .79288E+03
     36.83    -34.43     0.00     29.1 0.343E+01   3.00     2.95 .88874E+03
     40.96    -37.18     0.00     30.1 0.332E+01   3.00     3.11 .98790E+03
     45.22    -39.92     0.00     31.0 0.322E+01   3.00     3.28 .10902E+04
     49.62    -42.67     0.00     32.0 0.313E+01   3.00     3.44 .11957E+04
     54.13    -45.41     0.00     32.8 0.305E+01   3.00     3.59 .13041E+04
     58.77    -48.16     0.00     33.7 0.297E+01   3.00     3.75 .14154E+04
     63.53    -50.90     0.00     34.5 0.290E+01   3.00     3.90 .15296E+04
     68.40    -53.65     0.00     35.4 0.283E+01   3.00     4.05 .16466E+04
     73.39    -56.39     0.00     36.2 0.277E+01   3.00     4.20 .17663E+04
 Cumulative travel time =        1766.2697 sec  (    0.49 hrs)

 Entire region is occupied by Phase 1.
   Plume does not re-stratify in this flow region.

END OF MOD252: DIFFUSER INDUCED PLUME IN WEAK CROSS-FLOW
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** End of NEAR-FIELD REGION (NFR) **
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Part 2, CORMIX Sensitivity Analysis

The model prediction presented in Part 1 represents one scenario based on the input data shown above. The discussion below considers a broader range of conditions to help optimize the design of the diffuser and to assess the sensitivity of the model predictions to various parameter values. The sensitivity analysis considered parameters that characterize the diffuser (see Table 2) and parameters that characterize the ambient environment and discharge water (see Table 3).

Table 2: Sensitivity Analysis – Diffuser Characteristics

Parameter	Base Case		Sensitivity Analysis	
	Value	**Rationale**	**Value**	**Rationale**
Diffuser length	10 m	First assumption	3 to 20 m	Realistic range
Exit velocity	3.9 m/s	First assumption	1.8 to 7.0 m/s	Realistic range
Water depth	3 m	Expected	2 to 5 m	Extreme range

Table 3: Sensitivity Analysis – Ambient Characteristics and Discharge Water Characteristics

Parameter	Base Case		Sensitivity Analysis	
	Value	**Rationale**	**Value**	**Rationale**
Current velocity	0.01 m/s	Median	0.001 to 0.1 m/s	Extreme range
Discharge rate	0.08 m^3/s	Expected freshet	0.01 to 0.15 m^3/s	Extreme range
Discharge density	998.784 kg/m^3	Expected summer	999.47 and 1000.16 kg/m^3	Unrealistic extreme

A total of 20 model runs are provided below. Table 4 summarizes the parameter values used in each of the runs, and Table 5 summarizes the results for each run. The first ten runs were used to further optimize the diffuser configuration, and the remaining ten runs were used to test sensitivity to parameter values.

The model results presented in Table 4 show the configuration of the mixing zone as predicted using CORMIX. The mixing zone is characterized by the alongshore and offshore distances from the diffuser to the point at which 30:1 mixing potential is achieved. The width of the plume refers to the width measured normal to the trajectory of the plume at the edge of the mixing zone. A small mixing zone is generally preferred.

Optimization of the diffuser considered the length of the diffuser line, the exit velocity of the discharge water through the nozzles, and the water depth at the point of installation. The orientation of the discharge was not assessed in this sensitivity analysis due to the physical characteristics and constraints caused by the nearshore bottom (that is, steep bed slope, and irregular and rocky substrate). The following points summarize the findings:

- The analysis considered a diffuser length ranging from 3 to 20 m. A longer diffuser often has the advantage of distributing the discharge water over a broader area, but a shorter diffuser can have the advantage of enhancing near-field mixing. The model results show that shorter diffuser optimizes mixing potential, and provides for a smaller mixing zone than a larger diffuser. As such, the diffuser length was reduced from 10 m to 3 m for all subsequent sensitivity runs.
- Exit velocity considers the speed at which the discharge water exits the nozzle (as discussed further in Part 1). It relates to the number and diameter of the nozzles, so exit velocity effectively addresses two physical characteristics of the diffuser design. As shown by the model results, a higher exit velocity achieves improved mixing potential as compared to a lower exit velocity. However, a high exit velocity is not always desired since it may lead to excessive pumping requirements. As such, the nozzles were

configured to achieve a mid-range exit velocity based on 10 nozzles with approximately 0.051 m diameter.

- The diffuser may be placed in water depths ranging from 2 to 5 m subject to site conditions and final design. The model results show greater mixing potential if placed at 5 m compared to a placement at 2 m. The target depth is 3 m.

Parameter sensitivity considered current velocity, discharge rate and discharge water density. These parameters demonstrate the potential change in mixing potential under a broad range of conditions. The following points summarize the findings:

- The recorded current measurements in Hare Lake range from 0.001 to 0.05 m/s with a median of 0.01 m/s. The model results show greater mixing potential at low currents as compared to high currents. The offshore distance to the edge of the mixing zone is relatively insensitive to the current velocity, whereas the alongshore distance is sensitive. The physical size of the mixing zone is predicted to remain within approximately 40 m distance of the diffuser under the range of recorded current velocities.
- The discharge rate from the PSMF is expected to remain within the range 0.01 to 0.08 m^3/s corresponding to summer and freshet conditions. A worst case condition of 0.15 m^3/s is assumed. The model results show potential for a larger mixing zone under low discharge rates as compared to high discharge rates due to the reduced exit velocity at the nozzles. This can be overcome through use of a “duck-billed” type nozzle.
- The density of the discharge water is estimated to be 998.784 kg/m^3 during the summer based on a predicted TDS concentration of 200 mg/L and temperature of 18^{o}C. The sensitivity analysis considered two hypothetical densities corresponding to a TDS of approximately 1,000 mg/L and approximately 2,000 mg/L (far beyond that determined through geochemical testing). The model results show the mixing potential resulting from the diffuser to be relatively insensitive to the density of the discharge water even at these hypothetical extremes.

Table 4: Sensitivity Analysis – Matrix of Model Runs

Run	Diffuser length	Exit velocity	Water depth	Current velocity	Discharge rate	Discharge density
	m	m/s	m	m/s	m^3/s	kg/m^3
(a) Optimization of the diffuser configuration						
1	20	3.9	3	0.05	0.08	998.784
2	10	3.9	3	0.05	0.08	998.784
3	5	3.9	3	0.05	0.08	998.784
4	3	3.9	3	0.05	0.08	998.784
5	3	1.8	3	0.05	0.08	998.784
6	3	3.9	3	0.05	0.08	998.784
7	3	7.0	3	0.05	0.08	998.784
8	3	3.9	2	0.01	0.08	998.784
9	3	3.9	3	0.01	0.08	998.784
10	3	3.9	5	0.01	0.08	998.784
(b) Sensitivity to Parameter Values						
11	3	3.9	3	0.001	0.08	998.784
12	3	3.9	3	0.01	0.08	998.784
13	3	3.9	3	0.05	0.08	998.784
14	3	3.9	3	0.1	0.08	998.784
15	3	0.5	3	0.01	0.01	998.784
16	3	3.9	3	0.01	0.08	998.784
17	3	7.4	3	0.01	0.15	998.784
18	3	3.9	3	0.01	0.08	998.784
19	3	3.9	3	0.01	0.08	999.47
20	3	3.9	3	0.01	0.08	1000.16

Note 1: for Runs 5, 6 and 7 the exit velocity were 1.8, 3.9 and 7.0 m/s at a discharge rate of 0.08 m^3/s corresponding to a nozzle diameter of 0.076, 0.051 and 0.038 m (approximately 3, 2 and 1.5 inches).

Note 2: for Runs 15, 16 and 17 the exit velocity were 0.5, 3.9 and 7.4 m/s at a nozzle diameter of 0.051 m (approximately 2 inches) corresponding to a discharge rate of 0.01, 0.08 and 0.15 m^3/s. A “duck-billed” type nozzle could be used to achieve a more consistent exit velocity under varying discharge rates.

Table 4: Sensitivity Analysis – Matrix of Results

Run	Notes	Configuration of the Mixing Zone (30:1)		
		Alongshore distance	Offshore distance	Width of plume
		m	m	M
(a) Optimization of the diffuser configuration				
1	Diffuser length = 20 m	167	21	45
2	Diffuser length = 10 m	155	21	44
3	Diffuser length = 5 m	184	21	49
4	Diffuser length = 3 m – optimum length	41	37	6
5	Exit velocity = 1.8 m/s	329	10	104
6	Exit velocity = 3.9 m/s – preferred exit velocity	41	37	6
7	Exit velocity = 7.0 m/s	9	15	4
8	Water depth = 2 m	17	59	13
9	Water depth = 3 m – target depth	8	31	7
10	Water depth = 5 m	2	10	4
(b) Sensitivity to Parameter Values				
11	Current velocity = 0.001 m/s	1	31	8
12	Current velocity = 0.01 m/s	8	31	7
13	Current velocity = 0.05 m/s – maximum recorded	41	37	6
14	Current velocity = 0.1 m/s	173	5	23
15	Discharge rate = 0.01 m^3/s	70	10	87
16	Discharge rate = 0.08 m^3/s	8	31	7
17	Discharge rate = 0.15 m^3/s – worst case	16	58	13
18	Discharge density = 998.784 kg/m^3 – expected	8	31	7
19	Discharge density = 999.47 kg/m^3	5	26	6
20	Discharge density = 1000.16 kg/m^3	10	35	20

Note 1: Run numbers correspond to the parameter values in Table 3.

Note 2: Configuration of the Mixing Zone refers to the alongshore and offshore distances from the diffuser at which 30:1 mixing potential is achieved. The width of the plume refers to the width measured normal to the trajectory of the plume at the edge of the mixing zone.

Part 3, Nitrogen Compounds in Treated Effluent

Explosives Best Management Practices

Most explosives contain ammonium nitrate (NH_4NO_3) commonly abbreviated as AN, that is soluble and residual explosives can enter water in the open pit and mine rock storage areas. Ammonia can occur as unionized (NH3) or ionized (NH4+; ammonium ion) species. Total ammonia is a measure of both unionized and ammonium ion species. The unionized species is more toxic to aquatic life than the ionized species. The relative proportions of unionized and ionized ammonia depend on, primarily, water pH and temperature (see: Water Management Policies, Guidelines, Water Objectives of the Ministry of Environment and Energy. July 1994. Table 2 – Table of PWQOs and Interim PWQOs – Ammonia (un-ionized)).

Experience at mines has shown that the use of best practices during explosives preparation, handling, and blasting can reduce the effects of nitrogen residuals on water quality (Wiber, et al, 1991; Forsyth et al, 1995; Revey, 1996; Golder 2006). SCI will be implementing an explosives management plan to minimize the quantities of nitrogen compounds in mine water from explosives use.

When explosives are efficiently detonated, the ammonia and nitrate are consumed and generally not available to dissolve in water in the mine. There are several potential ways in which undetonated explosives are exposed to water during a mining operation (Revey, 1996). These include:

- poor choice of explosives
- inappropriate storage and handling methods,
- inappropriate techniques for loading of blast holes, and
- incomplete detonation.

Best management practices will be followed for explosives handling and blasting during mining of the Marathon deposit. These will include:

1. Use of an emulsion explosive formula - Emulsions are water resistant and therefore do not readily dissolve when in contact with water. A mixture of emulsion (70%) to AN (30%) will be water resistant. Use of the emulsion type explosives will greatly reduce nitrogen compounds in pit water compared to the use of typical and lower cost ANFO products alone with no emulsion. Therefore a water-resistant emulsion will be mixed with ANFO to decrease ammonium nitrate solubility.
2. Specialized training of Staff - Appropriate training of staff on methods to handle and properly load explosives into holes is key to explosives and nitrogen management (Forsyth et al, 1995). Practical methods to control explosives losses and to reduce nitrogen levels in mine water are provided in Revey (1996) and these methods will be incorporated into the company's standard operating procedures (SOP) for training and implementation of best practices. Training will include:
    - proper loading techniques to maximize detonation efficiency,
    - blast designs to maximize detonation efficiency, and
    - appropriate detonation methods,
    - spill avoidance, and
    - clean working procedures.
3. Standard Operating Procedure - A standard operating procedure (SOP) will be developed and maintained for explosives management.
4. Monitoring - Pit water and mine rock runoff quality will be monitored to assess the nitrogen (NH_4 and NO_3) loadings from explosives use. The monitoring data will be used to forecast effluent quality and to

provide feedback for explosives management. A threshold value will be developed to provide early warning of any future effects on mine water quality and will allow mitigation measures to be implemented, if required.

Explosive management plans are common in the industry and much experience has been gained over the number of years to provide guidance on best practices and for nitrogen management in mine waters. Best practices will maintain low levels of nitrogen compounds in mine water at Marathon during the operation.

Part 4, Nitrogen Compounds in Discharge to Hare Lake

As discussed in the response to AIR 19, Part 3, the primary source of nitrogen compounds in mine waters is explosives used to blast rock during mining. Experience at mines has shown that the use of best practices during explosives preparation, handling, and blasting can reduce the effects of residuals on water quality. SCI will be implementing an explosives management plan to minimize the quantities of nitrogen compounds in mine water from explosives use.

Receiving-water based discharge quality criteria will be established for the PSMF to protect water quality within Hare Lake. The approach taken follows MOE's Procedure B-1-5 (1994b). Table 5 presents the background and benchmark water qualities used in the assessment. The parameter list includes nitrogen compounds and phosphorus. Supporting Information Document No. 6 (EcoMetrix, 2012) provides a more comprehensive list of all parameters included in the assessment.

Table 5: Surface Water Quality Benchmarks for Hare Lake

Parameter	Units	Background	PWQO	CWQG	Benchmark
Ammonia (total)	mg/L	0.031	1.3	1.2	1.2
Nitrite as N	mg/L	0.16	-	0.06	0.16
Nitrate as N	mg/L	0.11	-	2.9	2.9
TKN	mg/L	0.43	-	-	-
Phosphorus (total)	mg/L	0.011	0.02	0.02	0.02

Note 1: From Table 3-4, Supporting Information Document No. 6, EcoMetrix 2012.

Note 2: Background refers to the background water quality in Stream 5 and Stream 6, used to characterize the inflows within the Hare Lake and Hare Creek drainage.

The quality criteria for the PSMF discharge will ensure that the concentration of nitrogen compounds do not exceed the benchmark concentrations set out in Table 5. This will ensure that the objectives for surface water quality protection are achieved. The same is true for phosphorus, although the PSMF is not expected to discharge elevated phosphorus to Hare Lake since there is no identified source—sewage is treated in the septic beds; all detergents used on site are phosphate free; and the site does not have laundry facilities.

The background water quality within Hare Lake complies with the surface water quality benchmarks for nitrogen components and phosphorus, as indicated in Table 6. The data summary in Table 6 includes all monitoring data collected by SCI and its consultants over the period July 2008 to October 2011. Of the 24 samples collected, 17 reported non-detectable concentrations of ammonia and 15 reported non-detectable concentrations of total phosphorus.

The concentration of total phosphorus within Hare Lake is typically below the detection limit of 0.005 mg/L and far below the PWQO of 0.020 mg/L (set to avoid nuisance concentration of algae in lakes). The lake is classified as oligotrophic given the low levels of phosphorus.

Table 6: Summary of Surface Water Quality – Hare Lake

Parameter	Units	Count	Minimum	Median	75th Percentile	Maximum
Ammonia (total)	mg/L	24	<0.02	<0.02	<0.02	0.036
Nitrite as N	mg/L	-	-	-	-	-
Nitrate as N	mg/L	24	0.034	0.104	0.160	0.191
TKN	mg/L	24	0.207	0.250	0.263	0.343
Phosphorus (total)	mg/L	23	<0.005	<0.005	0.0054	0.0081

Note 1: Surface water quality monitoring data for Hare Lake, July 2008 to October 2011.

Algae require both phosphorus and nitrogen for growth. If one nutrient is limited, algal growth will be controlled regardless of the availability of the other nutrient. For Hare Lake, the growth of algae is controlled by phosphorus. This is evident by the low levels of phosphorus in the lake. It is also evident by the ratio of nitrogen to phosphorus, which far exceeds the relative nutrient requirements of plants (typically taken as a 10:1 ratio of nitrogen to phosphorus). The same is true of the nearby streams that characterize the natural inflows to the lake (see Table 7).

Table 7: Summary of Surface Water Quality – Stream 5 and Stream 6

Parameter	Units	Count	Minimum	Median	75th Percentile	Maximum
Ammonia (total)	mg/L	137	<0.021	0.021	0.031	0.14
Nitrite as N	mg/L	8	<0.10	0.11	0.16	0.48
Nitrate as N	mg/L	117	<0.030	0.079	0.11	0.31
TKN	mg/L	137	<0.005	0.29	0.43	0.81
Phosphorus (total)	mg/L	117	<0.005	0.0077	0.011	0.40

Note 1: From Table 3-4, Supporting Information Document No. 6, EcoMetrix 2012.

References

Forsyth, B., A. Cameron and S. Miller. 1995. Explosives and Water Quality. Proc. IN Sudbury ’95 Mining and the Environment, p. 795-800.

Golder (Golder Associates), 2006 Final Report on the AN Loss Mechanism Investigation Report on Diavik Diamond Mines Ltd.

Revey, G.F. 1996 Practical Methods to Control Explosives Losses and Reduce Ammonia and Nitrate Levels in Mine Water, Mining Engineering, July, p. 61-64.

Wiber, M. R. Connel, B. Michelutti, B. Bell, D.K. Joyce and W. Luinstra, 1991. Environmental Aspects of Explosives Use, Northwest Mining Association Short Course, Spokane.