APPENDIX H

Dilution Performance Review of As-Built Temporary Diffusers in Quesnel Lake

Golder Associates

TECHNICAL MEMORANDUM

DATE 17 October 2016 **REFERENCE No.** 1411734-174-TM-Rev0-16000

TO Dale Reimer, General Manager
Mount Polley Mining Corporation

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MOUNT POLLEY – DILUTION PERFORMANCE REVIEW OF AS-BUILT TEMPORARY DIFFUSERS IN QUESNEL LAKE

1.0 INTRODUCTION

The Mount Polley Mine (the Mine) is a copper and gold mine owned by Imperial Metals Corporation (Imperial) and operated by Mount Polley Mining Corporation (MPMC). The site is located approximately 56 km northeast of Williams Lake, British Columbia (BC). MPMC plans to submit a Technical Assessment Report to amend its Environmental Management Act Permit 11678.

In 2015, MPMC commissioned Golder Associated Ltd (Golder) to conduct a conceptual diffuser design and near field modelling in Quesnel Lake (Golder 2015a). In addition, Golder submitted to MPMC the record drawings showing the detailed design of two temporary diffusers (Golder 2015b). The diffusers were subsequently built based on the record drawings.

The locations of the constructed diffusers are shown in Figure 1 and the diffuser details are provided in Figure 2. These two figures are reproduced from the record drawings.

The dilution performance of the as-built diffusers was analyzed using the Cornell Mixing Zone Expert System (CORMIX) program (Attachment A) to estimate dilution ratios under anticipated discharge rates during Operations. This technical memorandum documents the results of the analysis. This memorandum shall be read in conjunction with the important Information and Limitations which forms an integral part of this memorandum.

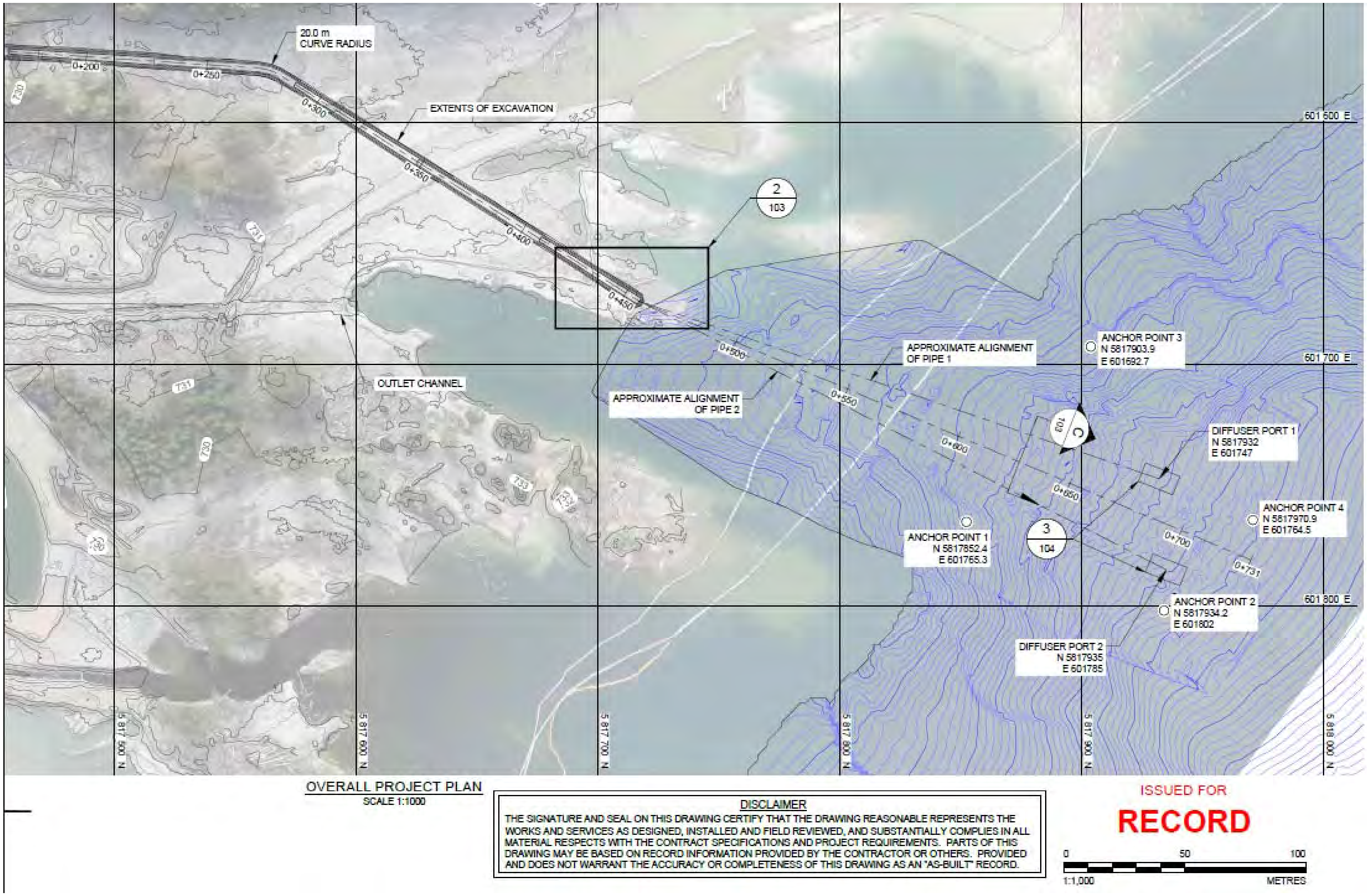

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Figure 1: Diffuser Locations

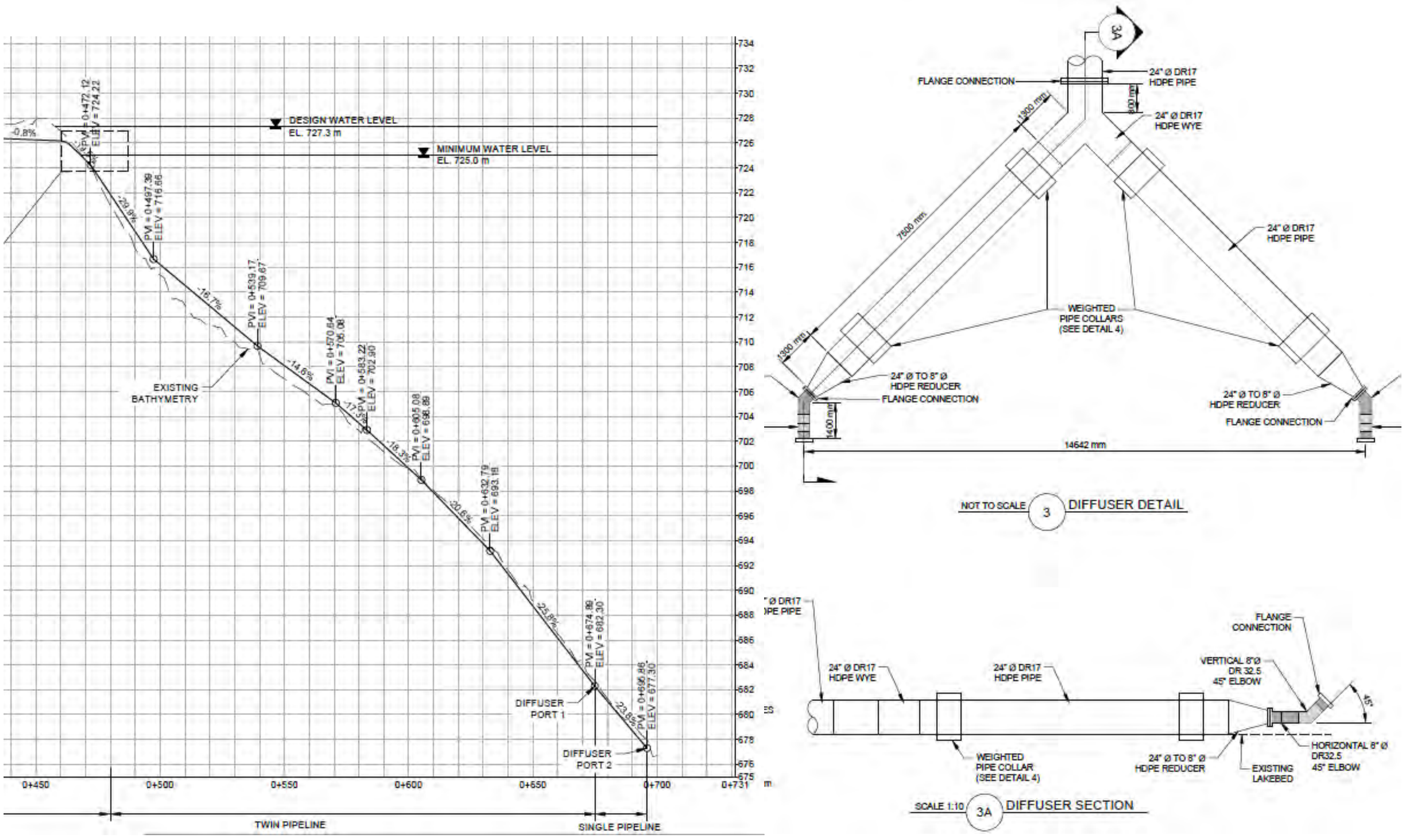

Figure 2: Diffuser Design Details

2.0 GUIDING REGULATION

Although the diffuser discharge is not a municipal wastewater effluent, the definition of the initial dilution zone (IDZ) and other specifications for the diffusers are consistent with the BC Municipal Wastewater Regulation (B.C. Reg. 87/2012; O.C. 230/2012). Specific sections of the regulation that were used as guidance for the diffuser design are listed below:

- Section 58(c): The discharge is diluted such that, at the outside boundary of the IDZ, the dilution factor exceeds 100, which was used as a target in the design but is not expected to be achievable under all operating conditions.
- Section 92: The radius of IDZ for marine waters and lakes is the lesser of 100 m and 25% of the width of water body. In the case of Quesnel Lake, the IDZ is a 100 m radius.
- Section 99(2)(c)(i): Each diffuser will provide at least 10:1 dilution at the boundary of the IDZ.
- Section 100: For additional outfall requirements for lakes, the depth of shallowest diffuser port below mean low water must be at least 10 m. The distance to the closest port of the diffuser from mean low water must be at least 30 m.

Based on the above guidelines, the following criteria were selected for the diffuser design:

- The diffuser port(s) must be at least 10 m below water surface and 30 m from shoreline.
- The dilution factor should not be less than 10 at a distance of 100 m away from the discharge location, and a dilution factor of 100 or greater is preferred.

3.0 INPUT DATA

The input data for the dilution analysis using the CORMIX program include those for the ambient water, the diffusers, and the effluent. Tables 1, 2 and 3 present the input data used for characterizing the ambient water, the diffuser design parameters, and the effluent conditions, respectively.

For the purposes of modelling, the diffusers are assumed to receive inflows from both Perimeter Embankment Till Borrow Pit (PETBP) and Springer Pit. The following should be noted:

- Other flow conditions, such as Hazeltine Creek water with no effluent, may enter the diffusers until the pipeline to Quesnel Lake is constructed by November 2017; however, these conditions are not simulated since the focus of the model was the direct discharge to Quesnel Lake.
- The water from the different sources has different total dissolved solid (TDS) concentrations. Three pairs of TDS concentrations during Operations are considered: the estimated 5th percentile, 50th percentile and 95th percentile concentrations.
- The total suspended solids (TSS) concentration of 15 mg/L is estimated by Golder (2015a).
- Two assumed effluent temperatures are evaluated: 15°C for summer discharge and 2°C for winter discharge.

Table 4 presents the five simulation cases analyzed for each of the effluent discharge conditions listed in Table 3. The simulations are conducted using CORMIX for single port plume with port discharge equal to total discharge divided by the number of ports. When only one diffuser is used, it is assumed that the lower diffuser is used, because it has greater bottom layer depth for mixing if stratification occurs. The simulations are conducted for the worst case of lake stratification condition which has a maximum thermocline depth of 30 m.

Table 1: Ambient Water Parameters

Variable	Unit	Value
Lake bed slope	(°)	13.4
Design water depth [(a)]	(m)	45.0 (for upper diffuser); 50.0 (for lower diffuser)
Minimum water depth [(a)]	(m)	42.7 (for upper diffuser); 47.7 (for lower diffuser)
TSS concentration [(b)]	(mg/L)	67
TDS concentration [(b)]	(mg/L)	1.5
Lake current velocity [(c)]	(m/s)	0.001, 0.007, 0.009, 0.011, 0.015, 0.042 corresponding to 95%, 50%, 30%, 20%, 10%, 0% exceedance probabilities
Thermocline depth [(b)]	(m)	0 to 30 (maximum)
Water temperature [(d)]	(°C)	Open water:12.7 (top layer); 5.7 (bottom layer); Ice cover: 0 (top layer); 3.2 (bottom layer);
Density	(kg/m³)	Open water: 999.50 (top layer); 1000.03 (bottom layer); Ice cover: 999.93 (top layer); 1000.058 (bottom layer); Model used: 999.50 (top layer); 1000.03 (bottom layer);

[a] Calculated based on the design water level of 727.3 m and minimum water level of 725 m.

[b] Data source: Golder (May 2015).

[c] At water depth of 40 m, and based on the simulation results from Tetra EBA from the 2003 model run.

[d] 12.7°C and 5.7°C are the maximum water temperatures at water depths of 24.5 m and 50 m during open water season simulated by Tetra EBA from the 2003 model run.

Table 2: Diffuser Design Parameters

Parameter	Unit	Value	
		Diffuser 1	Diffuser 2
Number of ports connected to pipe	-	2	2
Pipe inside diameter	(m)	0.535	0.535
Outfall pipe length	(m)	680	701
Port inside diameter	(m)	0.205	0.205
Port vertical angle from the horizontal plane	(°)	31.6	31.6
Port angle from the sloping lake bed	(°)	45	45
Port horizontal angle from the shoreline orientation	(°)	90	90
Port height above ground	(m)	1	1
Port spacing	(m)	14.64	14.64
Port elevation	(m)	682.3	677.3

Note: These values are based on the diffuser design (Golder 2015b).

- = not applicable.

Table 3: Effluent Conditions for a Range of Possible Inflow Combinations

Effluent Condition No.	Inflow Rate Q (m^3/s)			Inflow TDS Concentration C_D (mg/L)			Effluent Temperature	Effluent TSS Concentration	Effluent Density
	Springer Pit	PETBP	Total	Springer Pit	PETBP	Combined	T (°C)	C_S (mg/L)	ρ (kg/m^3)
1	0.12	0.21	0.33	846 (5th percentile)	817 (5th percentile)	828	15	15	999.778
2		0.28	0.4			826		15	999.777
3		0.38	0.5			824		15	999.776
4		0.48	0.6			823		15	999.775
5		0.21	0.33			828	2	15	1000.649
6		0.28	0.4			826		15	1000.648
7		0.38	0.5			824		15	1000.646
8		0.48	0.6			823		15	1000.645
9		0.21	0.33	864 (50th percentile)	905 (50th percentile)	890	15	15	999.827
10		0.28	0.4			893		15	999.829
11		0.38	0.5			895		15	999.831
12		0.48	0.6			897		15	999.832
13		0.21	0.33			890	2	15	1000.700
14		0.28	0.4			893		15	1000.702
15		0.38	0.5			895		15	1000.704
16		0.48	0.6			897		15	1000.705
17		0.21	0.33	1062 (95th percentile)	1005 (95th percentile)	1026	15	15	999.932
18		0.28	0.4			1022		15	999.929
19		0.38	0.5			1019		15	999.926
20		0.48	0.6			1016		15	999.924
21		0.21	0.33			1026	2	15	1000.810
22		0.28	0.4			1022		15	1000.807
23		0.38	0.5			1019		15	1000.804
24		0.48	0.6			1016		15	1000.802
25	0	0.33	0.33	846 (5th percentile)	817 (5th percentile)	817	15	15	999.770
26	0.07		0.4			822		15	999.774
27	0.17		0.5			827		15	999.778
28	0.27		0.6			830		15	999.780
29	0		0.33			817	2	15	1000.641
30	0.07		0.4			822		15	1000.645
31	0.17		0.5			827		15	1000.649
32	0.27		0.6			830		15	1000.651
33	0		0.33	864 (50th percentile)	905 (50th percentile)	905	15	15	999.838
34	0.07		0.4			898		15	999.833
35	0.17		0.5			891		15	999.828
36	0.27		0.6			887		15	999.824
37	0		0.33			905	2	15	1000.712
38	0.07		0.4			898		15	1000.706
39	0.17		0.5			891		15	1000.701
40	0.27		0.6			887		15	1000.697
41	0		0.33	1062 (95th percentile)	1005 (95th percentile)	1005	15	15	999.916
42	0.07		0.4			1015		15	999.923
43	0.17		0.5			1024		15	999.930
44	0.27		0.6			1031		15	999.935
45	0		0.33			1005	2	15	1000.793
46	0.07		0.4			1015		15	1000.801
47	0.17		0.5			1024		15	1000.808
48	0.27		0.6			1031		15	1000.814

TDS = total dissolved solids; TSS = total suspended solids; PETBP = Perimeter Embankment Till Borrow Pond; C_D = inflow concentration; C_S = TSS concentration; ρ =density.

Table 4: Simulation Cases for Each Effluent Condition

Number of Diffusers Used	Single diffuser		Two diffusers		
Ambient Current Speed (m/s)	0.001 (5th percentile)	0.042 (maximum)	0.001 (5th percentile)	0.042 (maximum)	
Assumed Bottom Layer Depth[1] (m)	20	20	15	20	15
Simulation Case No.	1	2	3	4	5

Note: When lake stratification occurs under the design water level of 727.3 m, the maximum thermocline depth of 30 m corresponds to 15 m and 20 m of minimum bottom layer depths for the upper and lower diffusers, respectively.

4.0 SIMULATION RESULTS

The 48 effluent conditions combined with the five simulation cases result in a total of 240 simulation scenarios. The simulated minimum dilution factors at the IDZ boundary for the 240 simulation scenarios are summarized in Table 5.

The simulation results presented in Table 5 are highlighted and discussed below:

- The lowest dilution factors for the five simulation cases range from 37 to 64. There are 14 effluent conditions associated with simulation case 5 which have minimum dilution factor at the IDZ boundary lower than 40. Eight of those 14 scenarios occur in summer and 6 of them can happen in winter.
- The diffuser dilution performance is influenced by the thermocline depth. If the thermocline depth is no more than 29 m associated with the design water level or 26.7 m associated with the minimum lake level, the minimum dilution factor at the IDZ boundary is simulated to be 40 or higher.
- The diffuser dilution performance is influenced by the lake current velocity. Simulation cases 1 and 2 have the same ambient and effluent conditions but not the lake current velocity. The small lake current velocity in simulation case 1 results in the lowest dilution factor of 64. This compares with the large lake current velocity in simulation case 2, which results in the lowest dilution factor of 45. This is because the higher the lake current, the more ambient mixing but the less time or distance for mixing before the plumes reach the IDZ boundary.
- The diffuser dilution performance is influenced by port effluent discharge. If two ports have the same ambient and effluent conditions but different effluent discharges, the plume resulting from the lower discharge generally has better mixing. Although higher discharge plume has higher velocity and entrains more ambient water for mixing, it has less time for mixing before the plume reaches the IDZ boundary. For example, simulation cases 2 and 4 have the same effluent and ambient conditions, but the port effluent discharges in simulation case 2 are twice as large as those in simulation case 4. The dilution factors for simulation case 2 are generally lower than those for simulation case 4.

Table 5: Minimum Dilution Factors at the Initial Dilution Zone Boundary

Effluent Condition No.	Minimum Dilution Factor				
	Simulation Case 1 (Scenario 1 to 48)	**Simulation Case 2 (Scenario 49 to 96)**	**Simulation Case 3 (Scenario 97 to 144)**	**Simulation Case 4 (Scenario 145 to 192)**	**Simulation Case 5 (Scenario 193 to 240)**
1	78	53	90	84	51
2	75	49	86	72	45
3	64	>100	82	61	40
4	64	>100	79	55	37
5	79	58	>100	>100	>100
6	77	50	81	>100	>100
7	75	47	80	>100	42
8	74	45	79	68	37
9	76	52	87	84	51
10	64	>100	84	72	45
11	64	>100	80	61	39
12	64	>100	77	55	37
13	79	60	>100	>100	>100
14	78	51	81	>100	>100
15	76	47	80	>100	43
16	74	45	80	>100	37
17	64	>100	81	87	52
18	64	>100	78	72	44
19	64	>100	76	60	39
20	64	>100	64	>100	>100
21	80	64	>100	>100	>100
22	78	51	81	>100	>100
23	76	47	80	>100	45
24	75	45	80	>100	37
25	78	52	90	84	51
26	75	49	86	72	45

Effluent Condition No.	Minimum Dilution Factor				
	Simulation Case 1 (Scenario 1 to 48)	Simulation Case 2 (Scenario 49 to 96)	Simulation Case 3 (Scenario 97 to 144)	Simulation Case 4 (Scenario 145 to 192)	Simulation Case 5 (Scenario 193 to 240)
27	64	>100	82	61	40
28	64	>100	79	55	37
29	79	58	>100	>100	>100
30	77	50	81	>100	>100
31	75	47	80	>100	42
32	74	45	79	68	37
33	76	52	87	85	51
34	64	>100	83	72	45
35	64	>100	80	61	39
36	64	>100	78	55	37
37	79	60	>100	>100	>100
38	78	51	81	>100	>100
39	76	47	80	>100	43
40	74	45	80	72	37
41	64	>100	82	86	52
42	64	>100	79	72	44
43	64	>100	76	60	39
44	64	>100	64	>100	>100
45	80	63	>100	>100	>100
46	78	51	81	>100	>100
47	76	47	84	>100	45
48	75	45	80	>100	37

5.0 DIFFUSER HEAD LOSS

The design hydraulic head for the diffuser system of two diffusers is 4 m. The as-built diffuser locations are farther away from the shoreline than the design specification, and the diffuser pipe lengths are greater than the design specification. Therefore, a diffuser head loss analysis was performed to determine the required head for an effluent discharge of 0.6 m^3/s by single diffuser and two diffusers. The results of the analysis are as follows:

- the required head for the two diffusers to convey a total discharge of 0.6 m^3/s is 3.5 m
- the required head for one diffuser to discharge 0.6 m^3/s is 13.2 m

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions are made based on the results of the dilution performance analysis for the 240 scenarios:

- Sixty-one of the 240 simulation scenarios have dilution factors greater than 100 at the IDZ boundary, and 226 simulation scenarios (94%) have dilution factors greater than 40.
- The dilution factors at the IDZ boundary are greater than 40 if thermocline depth is not greater than 29 m associated with design lake water level, or not greater than 27 m associated with minimum lake water level.
- Under the conditions of the design lake water level, only 8 of the 240 simulation scenarios have the lowest dilution factor of 37.
- The estimated hydraulic head required to operate the as-built diffuser system to discharge 0.6 m^3/s is 3.5 m for two diffusers and 13.2 m for one diffuser.

6.2 Recommendations

The following recommendations are made based on the results of the dilution analysis performed in this study:

- use only one diffuser if the total effluent discharge is 0.3 m^3/s or less
- use the lower diffuser if only one diffuser is used
- use two diffusers if the effluent discharge is in the range of 0.33 to 0.6 m^3/s and if the thermocline depth is less than 27 m

7.0 CLOSURE

We trust that the above provides the information that you require at this time. Please do not hesitate to contact the undersigned if you have any questions or need clarification. Golder appreciates the opportunity to be of service on this project.

GOLDER ASSOCIATES LTD.

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Attachments: Study Limitations
Attachment A: Summary Description of the CORMIX Model System

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REFERENCES

Golder (Golder Associates Ltd.) 2015a. Conceptual Diffuser Design and Near-Field Modelling in Quesnel Lake. Report submitted to Mount Polley Mining Corporation, May 2015

Golder 2015b. Submission of Record Drawings (Rev. 2) for HDPE Pipeline – Temporary Discharge to Quesnel Lake. Reference No. 1411734-069-L-Rev2-12000. November 16, 2015.

STUDY LIMITATIONS

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ATTACHMENT A

Summary Description of the CORMIX Model System

1.0 MODEL CAPABILITIES AND ASSUMPTIONS

The Cornell Mixing Zone Expert System (CORMIX) was developed under several cooperative funding agreements between the United States Environmental Protection Agency and Cornell University during the period of 1985 to 1995. The CORMIX model system uses a rule-based system approach to data input and processing. The model system consists of three subsystems as described below:

- The CORMIX1 sub-system was designed for analyzing plume or jet geometry and dilution characteristics of positive, neutral or negative buoyant effluent from a single port diffuser, into a stagnant or flowing ambient waterbody that is uniform or stratified.
- The CORMIX2 sub-system was designed for analyzing submerged multi-port diffuser discharges under similar effluent and ambient conditions as CORMIX1. It can be used for unidirectional, staged and alternating designs of multi-port diffusers.
- The CORMIX3 sub-system was designed for analyzing positively or neutrally buoyant surface lateral discharges into a waterbody through a canal or near-surface pipe.

In addition, the CORMIX model system provides several post-processing programs to assist in analysis of the model output. These programs include the following:

- CORJET program for a detailed analysis of the near-field behaviour of buoyant jets.
- FFLOCATR program for the far-field delineation of discharge plumes in non-uniform river or estuary environments.
- CMXGRAPH graphic package used for plotting plume profiles.

The major assumptions and simplifications made in the development of the CORMIX model system include the following:

- The cross sectional profile of the waterbody is assumed to be a rectangular straight uniform channel that may be bounded laterally or unbounded. The ambient water velocity is assumed to be uniform within the cross section.
- In addition to a uniform ambient density profile, the model system allows three generic types of ambient density stratification profiles to be used for the approximation of any measured ambient density stratification profile.
- The model system assumes steady state. However, the system allows for analysis of unsteady mixing in tidal environments.
- The model system can be used to predict mixing for both conservative and first-order decay processes, and to simulate heat transfer from thermal plumes.
- The model system can be used to predict mixing for most stable processes. For unstable processes, predictions are made only for the relatively stable zone near the discharge point.

2.0 MODELLING METHODOLOGY

The prediction of plume and jet geometry and dilution characteristics by the CORMIX model system is typically based on the solutions of several simple flow patterns to obtain a complete analysis from the discharge point into the far field. The CORMIX model system is based on a flow classification system.

The flow classification system provides a complete and robust expert knowledge base that carefully distinguishes among the many hydrodynamic flow patterns that a discharge may exhibit. The classification system is based on length scales, which represent the influence of different hydrodynamic processes present in a particular situation. In addition, empirical knowledge and laboratory and field data were used in developing the flow classification system. The model system developers have verified the flow classification system through repeated testing and data comparison. For the three sub-systems, a total of 80 generic flow configurations or classes were identified.

Once a flow class has been selected based on the input data, the CORMIX model system executes a sequence of appropriate hydrodynamic simulation modules for the flow processes in the flow class without exceeding their associated spatial regions. The simulation modules are based on buoyant jet similarity theory, buoyant jet integral models, ambient diffusion theory, stratified flow theory and simple dimensional analysis. Each of the simulation modules uses the final values of the previous module as the “initial conditions”. The simulation modules, upon execution, jointly predict the trajectory and dilution characteristics of a complex discharge condition.

3.0 MODEL INPUT

The version of the CORMIX model used in this study is V8.0 which is a Windows version with seven input pages, including Project, Effluent, Ambient, Discharge, Mixing Zone, Output, and Processing. Input data to the CORMIX model system are entered to the input cells in these input pages. The required model input data are summarized below:

- The Project page has the site/case identifier data. The model system requests information on the name of the site and the file name for the case to be simulated.
- The Effluent page has discharge characteristic data. The amount of input data requested by the model system depends on the following four types of effluents: conservative effluent, non-conservative effluent, heated discharge, and brine discharge. The requested inputs are discharge rate, discharge density, and discharge concentration or temperature. For heated discharge, the surface heat exchange coefficient is required. For diffusers under deep water, the surface heat exchange can be neglected. For non-conservative effluent, the decay rate is required.
- The Ambient page has the ambient condition data. The model system requests all ambient data including water density (stratification), water current, waterbody depth and width, wind speed, channel roughness coefficient and tidal conditions.

- The Discharge page has the diffuser layout data including the following:
  - i) The geometry of the effluent at the point of discharge.
  - ii) The location and orientation of the discharge port(s) with respect to the nearest bank and the direction of the water.
- The Mixing Zone page has the data for spatial region of interest. The model system requests information on the spatial region of interest, ambient water quality standard and the definitions of the toxic dilution zone and the regulatory mixing zone.
- The Output page has various options for outputs and displays.
- The Processing page has buttons for running step simulations (validate inputs; calculate parameters; and classify flows) or running an entire simulation.

4.0 MODEL OUTPUT

The CORMIX model system output is presented by qualitative descriptions, detailed quantitative numerical predictions, and graphical output showing the predicted effluent jets or plumes.

Qualitative descriptions provided by the output file include descriptive messages addressing the case study and the logic employed by the model system. In addition, the length scales, which represent the influence of different hydrodynamic processes in the simulation run, are computed and compared to determine the dominant hydrodynamic process. These length scales are subsequently used to determine the flow class for the simulation run.

Detailed quantitative predictions of the jet or plume geometry and dilution characteristics are provided in the output file presenting the coordinates of the jet or plume centreline, the bulk or the centreline dilution and concentration, and the jet or plume width. In addition, information is provided on the different types of simulation modules used and the reasons for using them, the cumulative travel time at the end of each simulation module, location of plume attachment to the bed and bank and possible model limitations.

The graphics package can be used to show the plan and side views of the predicted plume geometry. In addition, the graphics package can generate plots of the jet or plume centreline concentration against downstream distance and distance along the jet or plume trajectory.

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