Mary River Project 2016 - 2017
Lake Sedimentation Monitoring Report

Prepared for:
Baffinland Iron Mines Corporation
Oakville, Ontario

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Mary River Project 2016 - 2017
Lake Sedimentation Monitoring
Report

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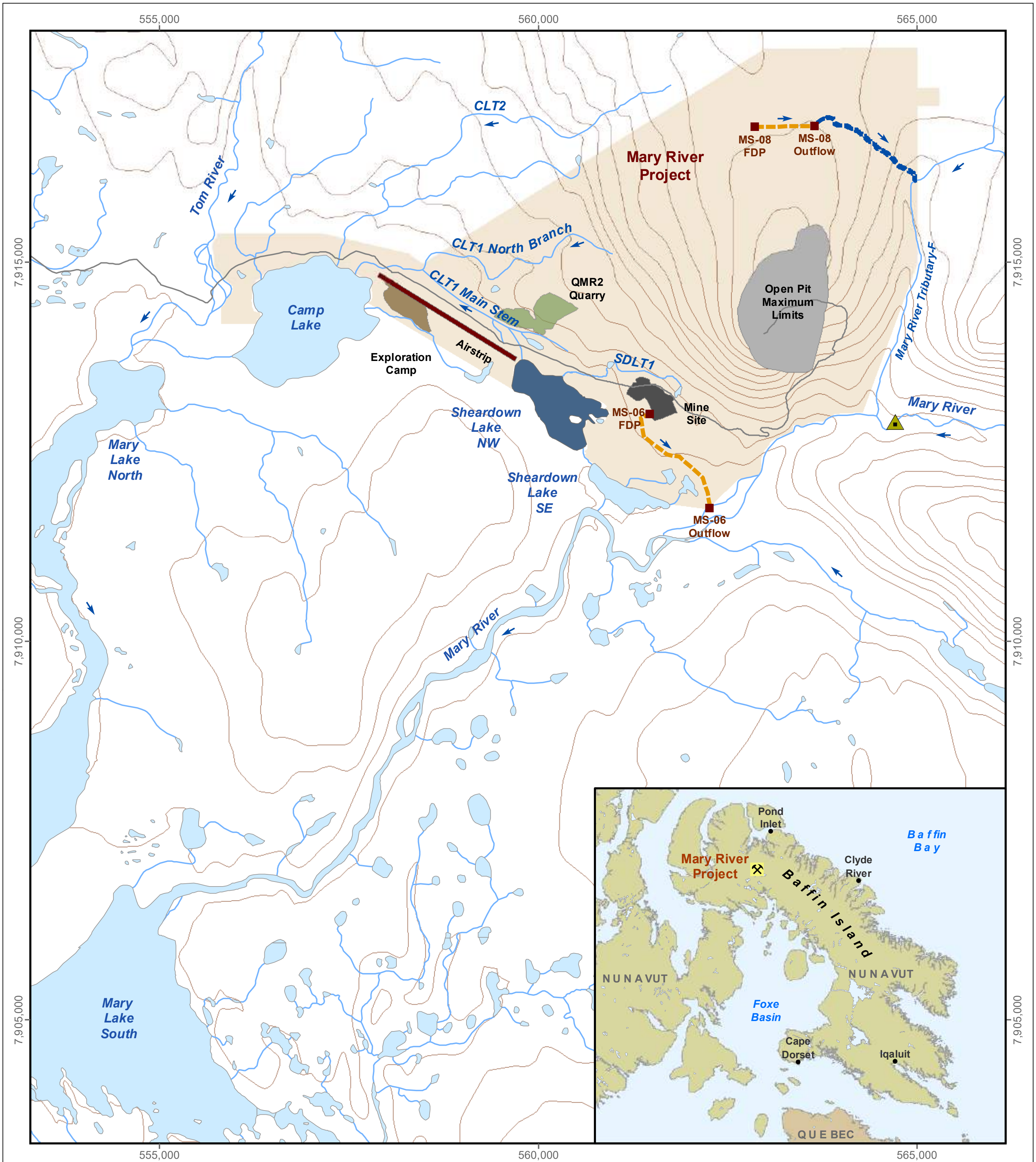
1 INTRODUCTION

The Mary River Project, owned and operated by Baffinland Iron Mines Corporation (Baffinland), is a high-grade iron ore mining operation located in the Qikiqtani Region of northern Baffin Island, Nunavut (Figure 1.1). Open pit mining, including pit bench development, ore haulage and stockpiling, and the crushing and screening of high-grade iron ore commenced at the Mary River Project in mid-September 2014. The Mary River Project has the potential to result in increased sediment deposition in mine area waterbodies through fugitive dust deposition and surface runoff/ erosion from the mine site, as well as a result of increased biological productivity (e.g., eutrophication due to treated sewage discharge). In aquatic environments, these deposits could lead to physical habitat alteration (e.g., changes in substrate composition) and/or chemical alteration (e.g., changes in metal and/or nutrient concentrations, organic content) that, in turn, could alter biotic assemblages and lead to adverse ecological effects (e.g., physical smothering of organisms residing in existing substrate, direct response or organisms to changes in substrate chemistry).

To better understand rates of sediment deposition potentially associated with the Mary River Project operation and the potential implications of this sediment deposition on aquatic biota, Lake Sedimentation Monitoring was included as a special investigation component of the mine Aquatic Effects Monitoring Plan (AEMP; Baffinland 2014; NSC 2014a). The primary issue of concern regarding greater sedimentation as a result of the Mary River Project operation is the potential effects to arctic charr (*Salvelinus alpinus*) populations at mine area lakes, which can possibly be affected by:

- Changes in benthic invertebrate community structure and/or density due to habitat alteration that, in turn, alter the arctic charr food base;
- Loss of arctic charr spawning habitat resulting from entrapment of fine material and greater embeddedness of substrate used for spawning; and,
- Limiting the amount of oxygen available in arctic charr spawning beds during the overwinter incubation period, resulting in reduced egg hatching success and/or reduced larvae survival following hatch (Berry et al. 2003).

The Mary River Project Lake Sedimentation Monitoring study is a year-round sampling program that was designed to track total dry weight sediment deposition at Sheardown Lake NW separately over ice-cover and open-water periods (Baffinland 2014; NSC 2014a,b, 2015; Minnow 2016, 2017). Sheardown Lake NW is expected to receive the highest amounts of sediment inputs through dust deposits and site runoff compared to other local waterbodies, and therefore this lake serves as the focus for the monitoring of lake sedimentation (Figure 1.1; NSC 2014b).



LEGEND

- Final Discharge Point (FDP)
- Mary River Cascade Barrier
- Discharge Line
- Overland Effluent Channel
- Sheardown Lake NW
- QMR2 Quarry
- Airstrip
- Exploration Camp
- Mine Site
- Mary River Project
- Open Pit Maximum Limits

Mary River Project Sheardown Lake NW Sedimentation Monitoring Location

0 1.25 2.5 5 km

N E S W

Map Projection: UTM Zone 17N NAD 1983

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Figure 1.1

Document Path: S:\Projects\177202\177202.0033 - Baffinland 2017\2 - Mapping\Lake Sedimentation Study Maps\17-33 Fig 1.1 Location.mxd

Sedimentation monitoring was initiated at Sheardown Lake NW in 2013, with data collected from fall 2013 to fall 2014 serving as baseline for one full ice-cover and one full open-water period for the evaluation of potential effects of active Mary River Project operations on lake sedimentation. This report presents the results of the 2016 – 2017 Lake Sedimentation Monitoring study, including the evaluation of potential Mary River Project-related influences on sedimentation at Sheardown Lake NW in the third year following the onset of commercial mine operation in 2014.

2 METHODS

2.1 Station Locations

Three sedimentation monitoring stations were established to evaluate the amount of sedimentation in Sheardown Lake NW (Figure 2.1; Table 2.1). The selection of station locations took into account dominant benthic habitat types present in the lake as well as habitat considered important for supporting the resident arctic charr population. Accordingly, lake sediment deposition was assessed using sediment traps deployed at the following representative habitats:

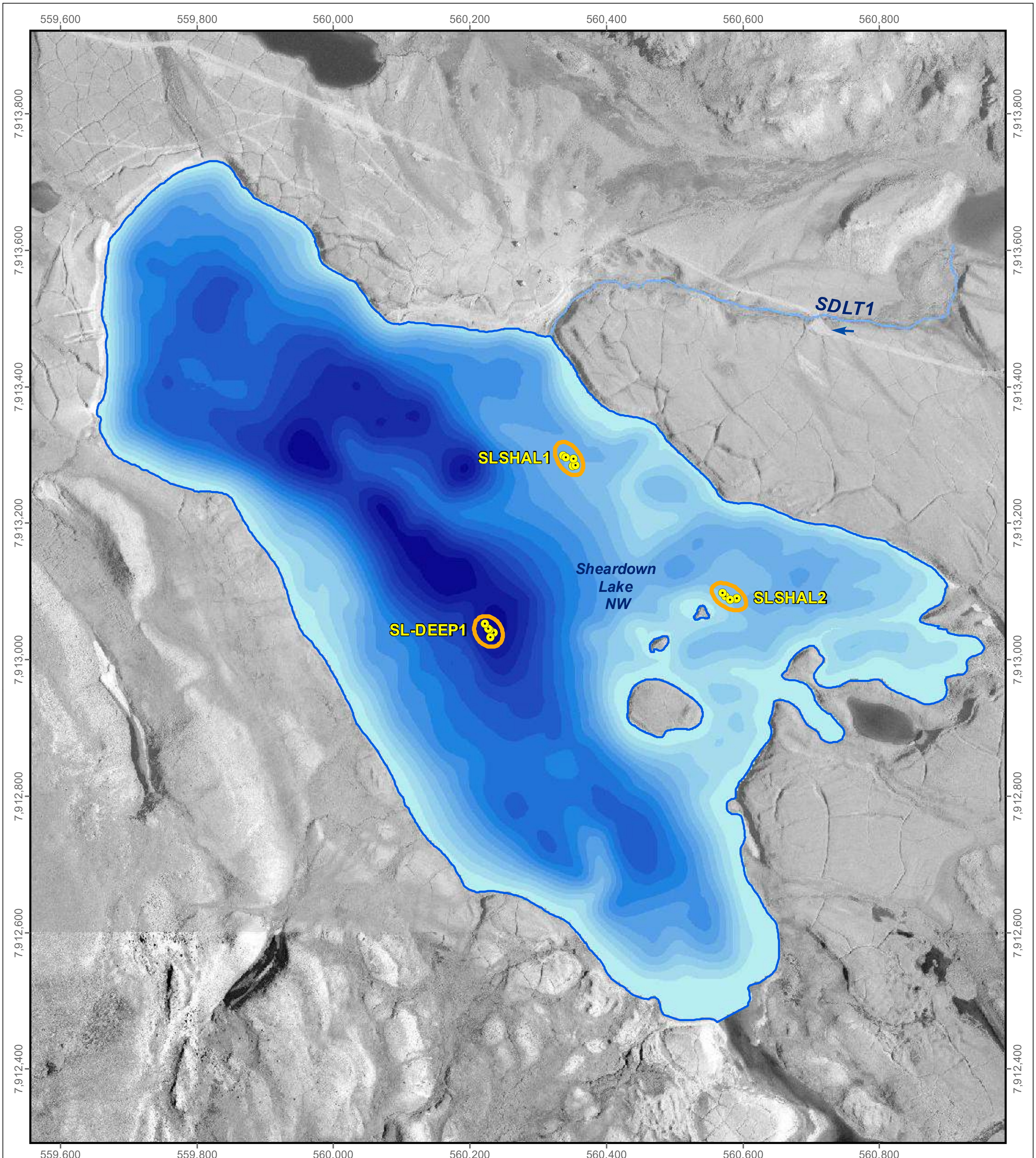
1. Shallow Depositional Station (SHAL1): Silt-loam represents the dominant substrate type in Sheardown Lake NW, and therefore increased sedimentation on habitat characterized by this substrate has the greatest potential to affect overall lake benthic invertebrate density and/or community structure. In turn, benthic invertebrate community changes in habitat of this type has a high potential to affect the arctic charr population of Sheardown Lake. Silt substrate in the lake littoral zone was targeted for placement of this station to represent a potentially high sediment deposition habitat. Because this station is located near the outlet from Sheardown Lake Tributary 1, information acquired from this station also served to evaluate the extent to which sediment releases from key lake tributaries affected sedimentation at Sheardown Lake NW.

2. Shallow Hard-Bottom Station (SHAL2): Increased sedimentation at hard-bottom areas could reduce the amount of available spawning habitat and/or reduce egg hatching/ reproductive success for arctic charr. Therefore, this station was established on coarse substrate (i.e., gravel, cobble) in the lake littoral zone at an area considered to provide suitable spawning habitat for arctic charr.

3. Deep Profundal Station (DEEP1): Because the deep profundal area is the ultimate depositional zone within lakes, the highest sediment deposition rate can be expected at the deepest point within the main basin of a lake. This station was established on silt substrate within the profundal zone of the main lake basin (30 m deep) to provide an estimate of ‘maximum’ sedimentation for Sheardown Lake NW.

2.2 Field and Laboratory Methods

Five replicate sediment traps were originally deployed at each station in 2013 to monitor lake sedimentation. The sediment traps were constructed of three 50 cm long, 5 cm inside diameter polyvinyl chloride (PVC) pipes (i.e., 58.9 cm^2 surface area) sealed at the bottom and clamped together to create a single trap ‘unit’. The sediment traps were designed to provide an aspect ratio of approximately 10:1, which meets the ≥ 5:1 aspect ratio generally recommended for



LEGEND

Sedimentation Monitoring Station

Bathymetry (m)

- 0- 2
- 2 - 4
- 4 - 6
- 6 - 8
- 8 - 10
- 10 - 12
- 12 - 14
- 14 - 16
- 16 - 18
- 18 - 20
- 20 - 22
- 22 - 24
- 24 - 26
- 26 - 28
- 28 - 30

Sheardown Lake NW Lake Sedimentation Monitoring Locations, 2016-2017

0 130 260 520 Meters

N W E S

Map Projection: UTM Zone 17N NAD 1983
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Figure 2.1

Document Path: S:\Projects\177202\177202.0033 - Baffinland 2017\2 - Mapping\Lake Sedimentation Study Maps\17-33 Fig 2.1 Sheardown Lake Bathymetry.mxd

Table 2.1: Sediment Trap Replicate Station Coordinates, Habitat Information and Deployment and Retrieval Information, Sheardown Lake NW Sedimentation Monitoring Study, 2016 - 2017

Station	Station Replicate	Location (UTM; Zone 17W)		Station Depth (m)	Substrate	Ice - Cover Period (2016 - 2017)			Open-Water Period (2017)		
		Easting	Northing			Date Deployed	Date Retrieved	Set Duration (days)	Date Deployed	Date Retrieved	Set Duration (days)
Shallow 1 (SL SHAL1)	SL-SHAL-1A	560346	7913299	9.1	silt	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-SHAL-1B	560348	7913291	9.1	silt	8-Sep-16	16-Aug-17	342	16-Aug-17	13-Sep-17	28
	SL-SHAL-1C	560349	7913289	8.9	silt	8-Sep-16	16-Aug-17	342	16-Aug-17	13-Sep-17	28
	SL-SHAL-1D	560351	7913268	8.8	silt	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-SHAL-1E	560340	7913279	8.8	silt	8-Sep-16	-	-	27-Jul-17	14-Sep-17	49
Shallow 2 (SL SHAL2)	SL-SHAL-2A	560540	7913090	6.0	cobble	8-Sep-16	23-Jul-17	318	23-Jul-17	13-Sep-17	52
	SL-SHAL-2B	560544	7913093	5.9	cobble	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-SHAL-2C	560548	7913097	6.2	cobble	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-SHAL-2D	560552	7913098	6.2	cobble	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-SHAL-2E	560570	7913097	6.3	cobble	8-Sep-16	18-Aug-17	344	18-Aug-17	13-Sep-17	26
Deep 1 (SL DEEP1)	SL-DEEP-1A	560235	7913039	29.5	silt	8-Sep-16	-	-	-	-	-
	SL-DEEP-1B	560229	7913043	29.4	silt	8-Sep-16	12-Aug-17	338	12-Aug-17	13-Sep-17	32
	SL-DEEP-1C	560227	7913045	29.5	silt	8-Sep-16	12-Aug-17	338	12-Aug-17	13-Sep-17	32
	SL-DEEP-1D	560230	7913032	29.6	silt	8-Sep-16	27-Jul-17	322	27-Jul-17	13-Sep-17	48
	SL-DEEP-1E	560222	7913052	29.5	silt	8-Sep-16	11-Aug-17	337	11-Aug-17	13-Sep-17	33

cylindrical sediment traps to effectively monitor sediment deposition (Mudroch and MacKnight 1994). The sediment trap unit was secured to a float-anchor system designed to maintain the trap in an upright position for the duration of each deployment period. Under this system, the mouth of the sediment trap unit was situated approximately 1 m above the substrate.

Sedimentation was assessed separately for applicable ice-cover and open-water periods at Sheardown Lake NW. The seasonal timing of the ice breakup and freeze-up period at Sheardown Lake NW generally corresponds to mid-July and mid-September, respectively. The 2016 – 2017 ice-cover period sediment traps were deployed on 08 September 2016 and retrieved over a period extending from 23 July – 18 August (318 – 344 day duration; Table 2.1). For the ice-cover period, each sediment trap was secured to a marker buoy deployed such that the marker buoy was submerged approximately 2 m below the water surface to attempt to avoid entrapment of the buoy by ice during winter, and a grappling tool was then required to secure the marker buoy and retrieve the sediment trap at the time of collection. The length of time required for the retrieval of ice-cover sediment traps was prolonged into summer 2017 as a result of difficulties locating the submerged marker buoys due to persistently windy conditions and commensurate influences on visibility. Open-water period sediment traps were deployed as sediment traps became available in July and August 2017, but were all retrieved 13 September 2017 (26 – 52 day duration; Table 2.1). For the open-water period, a surface marker buoy was attached to each sediment trap line to aid with trap location during retrieval. Supporting information recorded at each station during sediment trap deployment included water depth and Global Positioning System (GPS) coordinates.

One sediment trap was unable to be located at each of Station SHAL1 and Station DEEP1 following the ice-cover period in 2017, and therefore sedimentation data was acquired from the four remaining sediment traps at these study stations for the 2016-2017 period. The inability to locate sediment traps following the ice-cover period was potentially due to the entrapment of the marker buoy by ice and subsequent relocation of the sediment trap. An additional sediment trap was deployed at Station SHAL1 following the summer retrieval, but because materials were unavailable for the construction of an additional sediment trap, a full complement of sediment traps (i.e., 5) was not able to be deployed at Station DEEP1 for measurement of open-water period sedimentation (Table 2.1).

Sediment trap retrieval involved pulling the entire unit to the surface very slowly to prevent sediment re-suspension in, and/or sediment loss from, each sediment trap. The entire contents of the trap, including all water and deposited sediment, was transferred into a 20 L plastic container pre-labelled with station identification and collection date information. Ambient water was used to rinse all sediment from each sediment trap, applied as a pressurized spray where appropriate. Upon complete removal of all material within the sediment trap, the sediment traps were redeployed at approximately the same locations of retrieval. Following collection of all sediment from individual traps, the sample containers were sealed and stored upright in the dark until submission to the analytical laboratory. The lake sedimentation samples were shipped to ALS Canada Ltd. (ALS; Waterloo, ON) for analysis of sediment total dry weight. At the laboratory, the sedimentation samples were filtered through a pre-weighed 0.70 µm glass fiber filter. The filter apparatus and container were rinsed three times to ensure complete removal of all sediment. The filter and residual sample material was dried at 105°C for two hours, allowed to cool for one hour, and then weighed to the nearest milligram using an appropriate balance with draft shield. As in previous studies, low sample volumes were encountered for each sediment trap replicate, and each station, for both of the 2016 - 2017 ice-cover and open-water period samples, precluding any additional analysis of the sedimentation material (e.g., sediment metal concentrations, dry bulk density).

2.3 Data Analysis

Sedimentation (deposition) rate was calculated for each replicate sediment trap using the equation (Kemp et al. 1974):

$$\textit{Sedimentation rate}\ \left(mg/cm^{-2}day^{-1}\right) = \frac{\textit{dry weight}\ (mg)}{\textit{total area}\ (cm^{2})} \div \textit{deployment time period (day)}$$

The sedimentation data were evaluated statistically as follows: 1) spatial comparisons among the three stations for separate ice-cover and open-water periods; 2) comparisons between the ice-cover and open-water periods at each station; and, 3) temporal comparisons at each station among baseline (i.e., 2013-2014), 2014-2015, 2015-2016, and 2016-2017 data sets separately for ice-cover and open-water periods. For the statistical analysis, raw data were assessed for normality and homogeneity of variance and log-transformed as necessary to meet test assumptions prior to conducting Analysis-of-Variance (ANOVA) and *post hoc* tests, where appropriate. In instances where normality could not be achieved through data transformation, non-parametric Mann-Whitney U-test statistics were used to validate pair-wise statistical results, and Kruskal-Wallis H-tests were used to validate multiple station/year statistical results from the ANOVA using log-transformed data. Similarly, in instances in which normal data exhibited unequal variance despite log transformation, Student’s t-tests assuming unequal variance were used to validate the statistical findings of the ANOVA tests for two-group comparisons. For multiple station or year comparisons, Tukey’s Honestly Significant Difference (HSD) or Tamhane’s *post hoc* tests were conducted in cases in which normal data with equal and unequal variance, respectively, were encountered. All statistical comparisons were conducted using SPSS Version 12.0 software (SPSS Inc., Chicago, IL).

In addition to the analysis of sedimentation rates, an estimate of the uncompacted thickness (mm) of sediment accumulation was also calculated separately for each of the ice-cover and open-water periods using the equation (Kemp et al. 1974):

$$Accumulation\ thickness\ (mm \cdot yr^{-1}) = \frac{Sedimentation\ rate\ (mg \cdot cm^{-2} yr^{-1})}{Dry\ bulk\ density\ (mg \cdot cm^{-3})}$$

In lieu of sufficient sample volumes to determine bulk density of sedimentation material, bulk density information from similar sedimentation studies conducted at Canadian Shield lakes in northern Ontario (Minnow Environmental Inc. unpublished data) and from material collected from sediment interstices and/or shoreline areas of Sheardown Lake Tributary 1 (SDLT1) were used as a surrogate for the calculation of sediment accumulation. Notably, the Canadian Shield lake data were collected over the summer open-water period at temperate latitudes where aquatic biological productivity can be expected to be higher than at polar latitudes. Therefore, the calculation of annual accumulation thickness using the Canadian Shield lake sedimentation bulk density information is likely to overestimate actual accumulation thickness for sediment deposits at Sheardown Lake NW and thus provides a very conservative estimate of actual values. Silt-sized material collected from interstices of large cobble substrate instream and/or along the shoreline at five stations within SDLT1 as part of the mine's annual Core Receiving Environment Monitoring Program was subject to dry bulk density analysis at ALS (Waterloo, ON) in 2017. In contrast to the accumulation rates calculated using dry bulk density information from the Canadian Shield lakes, the use of dry bulk density values from SDLT1 material is likely to underestimate actual accumulation thickness for sediment deposits at Sheardown Lake NW given that higher density material is likely to settle within a fluvial stream environment than in a lake environment.

Adverse effects on fish egg survival have been documented for a sediment accumulation thickness exceeding approximately 1 mm during the egg incubation period (Morgan et al. 1983; Fudge and Bodaly 1984; Berry et al. 2011). Therefore, an accumulation thickness of 1 mm was used as a threshold for potential effects to arctic charr egg incubation associated with sediment deposits at the Mary River Project. On Baffin Island, arctic charr spawning occurs in autumn (September-October) and although egg hatch occurs in early April, larval emergence generally does not occur until ice breakup in mid-July (Scott and Crossman 1998). Because this period essentially mirrors the ice-cover period used in this study, accumulation thickness for the ice-cover period was used to evaluate potential effects of depositing sediment on arctic charr egg survival at Sheardown Lake NW.

3 RESULTS

3.1 Sedimentation Rates

3.1.1 2016 – 2017 Season

Spatially within Sheardown Lake NW, sedimentation rates were lower at the shallow littoral stations (i.e., SHAL1 and SHAL2) than at the deep profundal station (i.e., main basin Station DEEP1) during both the 2016 - 2017 ice-cover and 2017 open-water periods (Figure 3.1; Appendix Tables A.1 and A.2). Highest sedimentation rate at the deepest area of Sheardown Lake NW was consistent with normal lake deposition patterns (see Wetzel 2001) and previous sedimentation studies (Minnow 2016, 2017; Figure 3.1). Sedimentation rates at the shallow littoral stations were slightly, but not significantly, higher at Station SHAL1 than at Station SHAL2 (Figure 3.1; Appendix Tables A.3 and A.4), potentially reflecting slightly higher sediment inputs associated with closer proximity to the SDLT1 tributary outlet at Station SHAL1. The 2016 - 2017 sedimentation rate at Station SHAL2, which represents shallow, rocky littoral areas that potentially provide spawning habitat for arctic charr in Sheardown Lake NW, was lower than the rates at the shallow and deep depositional stations over both the ice-cover and open-water periods (Figure 3.1). This difference suggested a more erosional habitat at hard-bottomed Station SHAL2, corroborating this habitat type's potential use as spawning habitat for resident arctic charr.

Sedimentation rates were significantly higher during the open-water period compared to the ice-cover period at all three Sheardown Lake NW sedimentation monitoring stations (Appendix Table A.5). The open-water period sedimentation rates ranged from 2.4 – 3.1 times greater than during the ice-cover period, potentially reflecting a combination of greater sources of sediment generated by the mine during the summer (e.g., fugitive dust) and/or naturally greater organic (e.g., phytoplankton) productivity during the open-water period. Nevertheless, approximately 75% of the total sediment deposited at the Sheardown Lake NW stations from September 2016 to September 2017 occurred over the ice-cover period, reflecting the much longer time of the ice-cover period compared to open-water period through a typical year in the arctic.

Annual sedimentation extrapolated from the 2016 - 2017 Sheardown Lake NW data indicated approximately 33.9 and 26.9 mg/cm^2/year of sediment deposition at the SHAL1 and SHAL2 littoral stations, respectively, and 44.7 mg/cm^2/year of sediment deposition at the DEEP1 profundal station. These annual rates were within the range of those observed at other Canadian arctic lakes (e.g., 7 – 50 mg/cm^2/year; Lockhart et al. 1998) and much lower than at proglacial lakes in south-east Greenland (e.g., mean of 790 mg/cm^2/year; Hasholt et al. 2000). Therefore, the annual sedimentation rate at Sheardown Lake NW over the study period was within the range typical for Canadian arctic lakes.

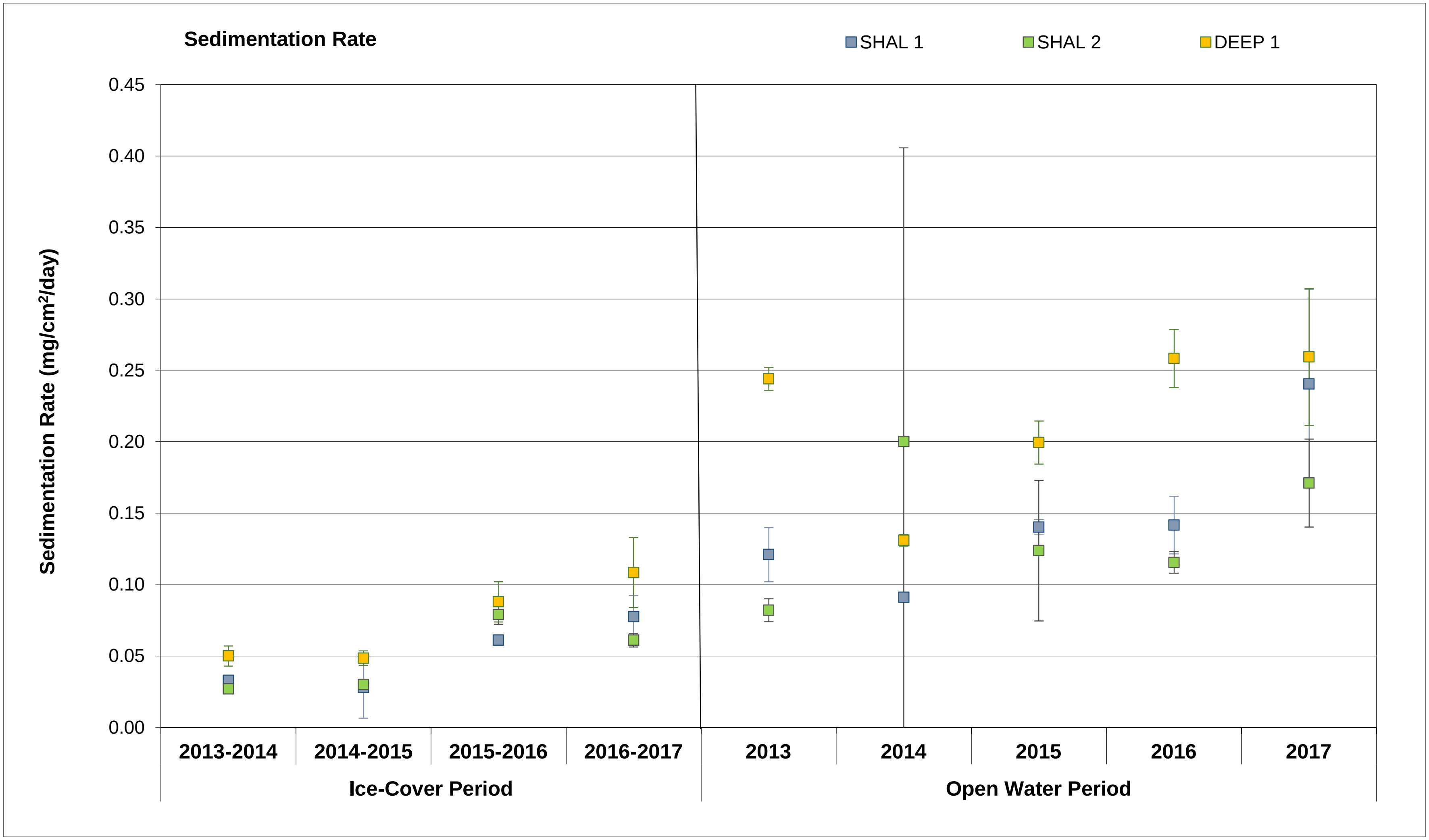


Figure 3.1: Sedimentation Rates During Ice-Cover and Open-Water Periods at Sheardown Lake NW over Mine Baseline (2013 - 2014) and Operational (2015 - 2017) Phases, Mary River Project Lake Sedimentation Monitoring Study

3.1.2 Temporal Comparisons

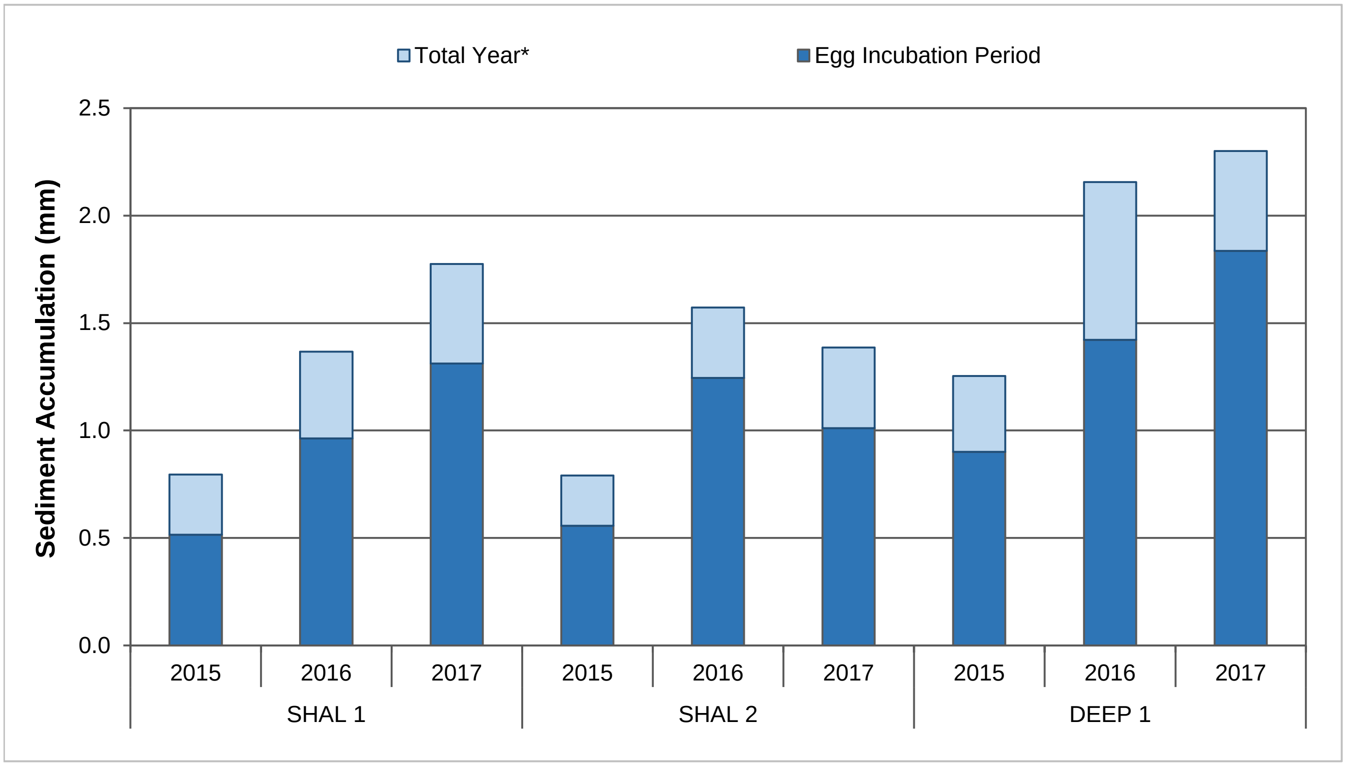
Sedimentation rates over the 2016 - 2017 ice-cover period were significantly greater than the rate determined for the mine baseline study (2013 - 2014) and the beginning year of mine operation (2014 - 2015) at all Sheardown Lake NW lake sedimentation monitoring stations (Figure 3.1; Appendix Tables A.6 to A.8). However, the 2016 - 2017 ice-cover period sedimentation rate did not differ significantly with that of the 2015 - 2016 ice-cover period at depositional stations (i.e., SHAL1 and DEEP1), and was significantly lower over the 2016 - 2017 ice-cover period than during the 2015 - 2016 ice-cover period at the erosional station (i.e., SHAL2; Appendix Tables A.6 to A.8). These data indicated higher sedimentation beginning in winter 2015 - 2016 compared to winter baseline conditions. Ice-cover period sedimentation results among stations during each study suggested a broad-scale source of sediment to the lake (e.g., deposits from fugitive dust, autochthonous organic matter) and/or wide-scale dispersal of sediment from a point source (or sources) potentially related to physical properties of the depositing sediment (e.g., particle size, shape and/or relative density). Open-water season sedimentation rates were significantly higher at stations SHAL1 and DEEP1 in 2017 compared to the 2014 baseline study (Appendix Tables A.6 – A.8). Although mean sedimentation rates over the open-water period at the DEEP1 profundal station were also considerably higher in 2017 than during the 2013 baseline study and 2016 at both littoral stations, open-water period sedimentation rates in 2017 were comparable with 2013 baseline and 2016 rates (Figure 3.1). Collectively, these data suggested that sediment deposition over the 2017 open-water season was within the natural range of baseline conditions at stations SHAL2 and DEEP1, but higher than during baseline at Station SL-SHAL1 (Figure 3.1).

Annualized sedimentation rates among the three stations were higher in 2016 - 2017 (26.9 – 44.6 mg/cm^2/year) than rates during the 2013 - 2014 baseline period (14.3 – 21.2 mg/cm^2/year; from NSC 2014a) and the 2014 - 2015 study (15.5 – 24.5 mg/cm^2/year), but comparable to the annual sedimentation rates in 2015 - 2016 (27.1 – 39.6 mg/cm^2/year)[1]. Overall, the temporal data indicated higher sedimentation rates at Sheardown Lake NW beginning in, and sustained since, winter 2015 compared to the mine baseline period.

3.2 Sediment Accumulation Estimate

Annual accumulation thickness of sediment in Sheardown Lake NW ranged from 1.39 mm/year at shallow littoral Station SHAL2 to 2.30 mm/year at the deep profundal Station DEEP1 based on calculations using sediment bulk density data from similar sedimentation studies conducted in northern Ontario (Figure 3.2). As indicated in previous studies, because these estimates of

[1] Annual sedimentation data calculated as the sum of the September to July ice-cover period data and July to September open-water period data.



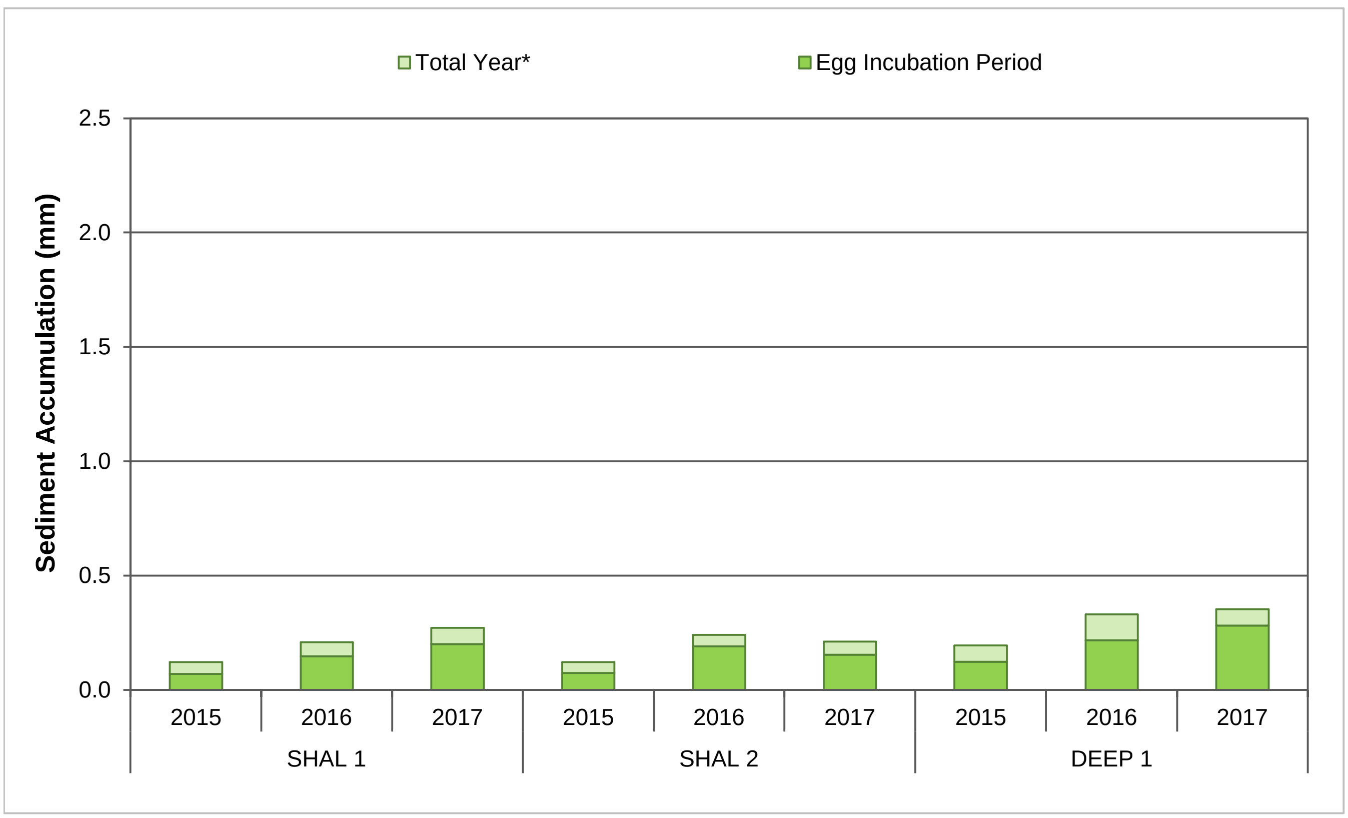


Figure 3.2: Sediment Accumulation Estimates for Arctic Charr Egg Incubation Period and Total Year Calculated using Sediment Bulk Density Collected at a) Northern Ontario Lakes and b) Sheardown Lake Tributary 1, 2015 - 2017

*Note: Year includes one full ice-cover and open-water period for each year indicated.

sediment accumulation were derived using bulk density information collected at temperate latitudes (i.e., northern Ontario) over the summer period when aquatic biological productivity can be expected to be higher than at polar latitudes, these estimates of accumulation thickness are likely conservative (over)estimates of actual values (see Minnow 2017). Annual sediment accumulation thicknesses estimated using SDLT1 sediment bulk density data collected in 2017 resulted in much lower accumulation estimates, ranging from 0.27 mm/year at shallow littoral station SHAL2 to 0.35 mm/year at the deep profundal station DEEP1 (Figure 3.2). The latter estimates of Sheardown Lake NW sediment accumulation thickness were within the lower range of sediment accumulation thicknesses observed among seven arctic lakes in western Greenland, which ranged from 0.27 ± 0.12 to 1.2 ± 0.32 mm/year and averaged 0.54 mm/yr (Sobek et al. 2014). The agreement in estimates of sediment accumulation thickness derived using the SDLT1 sediment bulk density information with published literature values was also consistent with the agreement in Sheardown Lake NW sedimentation rates to rates indicated in published literature for typical Canadian arctic lakes (Section 3.1.1). In turn, this suggested that sediment accumulation thicknesses derived using the SDLT1 sediment bulk density data provided a better estimate of actual accumulation thickness in Sheardown Lake than those derived using the northern Ontario sediment bulk density data. Notably, accurate estimates of sediment accumulation for Sheardown Lake NW require the direct collection of sediment bulk density information for each of the ice-cover and open-water periods.

Adverse effects on fish egg survival have been reported at sediment accumulation thicknesses exceeding approximately 1 mm during the egg incubation period (Morgan et al. 1983; Fudge and Bodaly 1984; Berry et al. 2011). The sediment accumulation thickness estimated for the 2016 - 2017 arctic charr egg incubation/larval pre-emergence period (i.e., approximately mid-September to mid-July; Scott and Crossman 1998) at Sheardown Lake NW varied from 1.01 ± 0.08 mm at the littoral hard-bottomed station (i.e., SHAL2) to 1.31 ± 0.27 mm at the littoral silt-bottomed station (i.e., SHAL1) based on calculations using northern Ontario sediment bulk density data. These accumulation thicknesses were near or slightly greater than 1 mm over the duration of the anticipated arctic charr egg incubation/larval pre-emergence period. However, only 0.15 ± 0.01 mm and 0.20 ± 0.04 mm was estimated to accumulate at these respective stations in Sheardown Lake NW over the 2016 - 2017 arctic charr egg incubation/larval per-emergence period based on calculations using the SDLT1 sediment bulk density data. The latter sediment accumulation estimates were well below the 1 mm sediment thicknesses reported to influence egg hatch success. As a result of the differences in sediment accumulation thickness estimates derived using sediment bulk density data from northern Ontario and SDLT1 sources, the influence of actual sediment accumulation on fish egg hatch success over the arctic charr egg incubation/ larval pre-emergence period at Sheardown Lake was uncertain.

Arctic charr population monitoring conducted as part of the Mary River Project AEMP sampling in 2017 indicated substantially higher abundance of young-of-the-year (YOY) along nearshore areas of Sheardown Lake NW than at a comparable reference lake based on electrofishing catch-per-unit-effort (CPUE; 0.63 and 0.27 YOY per electrofishing minute, respectively; Minnow 2018). Arctic charr YOY from Sheardown Lake NW were also significantly heavier and longer, indicating significantly faster growth, and did not differ significantly in condition (i.e., weight-at-length relationship) from those at the reference lake in 2017 (Minnow 2018). Collectively, these data indicated successful arctic charr hatch, emergence, and subsequent YOY growth at Sheardown Lake NW in 2017. In turn, this suggested that sediment accumulation thicknesses calculated for the arctic charr incubation period at Sheardown Lake NW that were based on bulk density information from northern Ontario lakes may have overestimated actual accumulation thicknesses at Sheardown Lake NW. Specifically, the data used to estimate sediment accumulation at Sheardown Lake NW that were based on bulk density information collected at temperate latitudes over the summer period when aquatic biological productivity can be expected to be higher than at polar latitudes. Therefore, accumulation thicknesses for Sheardown Lake NW derived using the northern Ontario sediment bulk density data can be considered conservative (over)estimates of actual values. This was supported by arctic charr YOY catch and health data, which indicated relatively high abundance of healthy YOY and suggested no adverse influences of sedimentation on egg hatch success, larval emergence and early life stage growth of arctic charr at Sheardown Lake in 2017.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Lake Sedimentation Monitoring is included as a special investigation component of the Mary River Project AEMP beginning in 2013 – 2014 to track sedimentation and evaluate the potential for adverse influences on resident arctic charr populations related to excessive sedimentation at a representative lake (Sheardown Lake NW) within the immediate area of mine influence. The principal conclusions of 2016 – 2017 lake sedimentation monitoring study are as follows:

- Sheardown Lake NW sedimentation rates were significantly higher in the 2016 - 2017 ice-cover period than during the mine baseline (2013 - 2014) and early operational (2014 - 2015) ice-cover periods. In addition, annualized sedimentation rates for the combined 2016 - 2017 ice-cover and 2017 open-water periods were higher than those during the 2013 - 2014 baseline and 2014 - 2015 mine early operational phases. However, total annual sedimentation at Sheardown Lake NW over the 2016 - 2017 ice-cover and 2017 open-water periods was within the range observed among Canadian arctic lakes uninfluenced by anthropogenic activities.
- Estimates of annual sediment accumulation thickness at Sheardown Lake NW were considerably higher using calculations based on dry bulk density data collected from northern Ontario lakes than those based on dry bulk density data collected from Sheardown Lake Tributary 1 (SDLT1). The actual sediment accumulation thickness at Sheardown Lake NW for the combined 2016 – 2017 ice-cover and 2017 open-water periods likely lied between estimates derived using each source of sediment dry bulk density, nevertheless remaining uncertain. Notably, estimates calculated using the SDLT1 dry bulk density data suggested Sheardown Lake NW sediment accumulation thickness in the lower range of representative arctic lakes which corroborated Sheardown Lake NW sedimentation rates within the range observed among typical Canadian arctic lakes.
- Sediment accumulation thickness estimated for the 2016 – 2017 arctic charr egg incubation/larval pre-emergence period at Sheardown Lake NW was well below the threshold effect level of 1 mm of sediment deposition based on estimates derived using SDLT1 dry bulk density. These results were corroborated by the continued occurrence of relatively high numbers and significantly greater size and growth of arctic charr young-of-the-year at Sheardown Lake NW than at a comparable reference lake in August 2017.

4.2 Recommendations

Adverse effects on fish egg survival have been reported at sediment accumulation thicknesses exceeding approximately 1 mm during the egg incubation period. Sediment dry bulk density information, together with sedimentation rate data, are required to provide an estimate the amount of sediment accumulation over time. *In lieu* of sufficient sample volumes collected at Sheardown Lake NW under the existing sedimentation program, sediment dry bulk density data taken from northern Ontario have been used to provide an estimate of sediment accumulation thickness at Sheardown Lake NW for the arctic charr egg incubation period. As evidenced by no effects on arctic charr YOY abundance or health at Sheardown Lake NW since 2015, the estimates of sediment accumulation derived using northern Ontario dry bulk density appeared to be very conservative. In part, this was supported by estimates of sediment accumulation derived using dry bulk density information from sediment samples collected at Sheardown Lake Tributary 1 which suggested an approximately 80% lower sediment accumulation thickness at Sheardown Lake NW than that derived using sediment dry bulk density information from Northern Ontario. Therefore, to provide a more definitive estimate of sediment accumulation thickness, it is recommended that an additional sediment trap (or traps) be deployed at Sheardown Lake NW beginning in summer (July) 2018 following the ice-cover period. In order to acquire sufficient amount of material to determine dry bulk density (i.e., approximately 10 g dry weight of material) over the open-water period, approximately 1,200 cm^2 of sediment trap surface area, equivalent to 20 of the sediment traps currently used in the sedimentation study, will be required[2].

[2] Extrapolated based on average of 0.467 g dry weight of material collected per sediment trap over the open-water period in 2015, 2016 and 2017.

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APPENDIX A

SUPPORTING SEDIMENTATION INFORMATION

Table A.1: **Sediment Trap Results for the 2016 - 2017 Ice-Cover Period at Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2016 - 2017**

Station	Station Replicate	Retrieval Location (UTM; Zone 17W)		Station Depth (m)	Date Deployed	Date Retrieved	Set Duration (days)	Total Dry Weight (g)	Sedimentation Rate ($mg/cm^2/day$)
		Easting	Northing						
Shallow 1 (SL SHAL1)	SL-SHAL-1A	560346	7913299	9.1	8-Sep-16	27-Jul-17	322	1.57	0.083
	SL-SHAL-1B	560348	7913291	9.1	8-Sep-16	16-Aug-17	342	1.92	0.095
	SL-SHAL-1C	560349	7913289	8.9	8-Sep-16	16-Aug-17	342	1.42	0.070
	SL-SHAL-1D	560351	7913268	8.8	8-Sep-16	27-Jul-17	322	1.17	0.062
	SL-SHAL-1E	560340	7913279	8.8	8-Sep-16	-	-	-	-
						Average	**332**	**1.520**	**0.078**
						Standard Deviation	**11.5**	**0.314**	**0.015**
Shallow 2 (SL SHAL2)	SL-SHAL-2A	560540	7913090	6.0	8-Sep-16	23-Jul-17	318	1.12	0.060
	SL-SHAL-2B	560544	7913093	5.9	8-Sep-16	27-Jul-17	322	1.04	0.055
	SL-SHAL-2C	560548	7913097	6.2	8-Sep-16	27-Jul-17	322	1.24	0.065
	SL-SHAL-2D	560552	7913098	6.2	8-Sep-16	27-Jul-17	322	1.26	0.066
	SL-SHAL-2E	560570	7913097	6.3	8-Sep-16	18-Aug-17	344	1.2	0.059
						Average	**326**	**1.172**	**0.061**
						Standard Deviation	**10.4**	**0.091**	**0.005**
Deep 1 (SL DEEP1)	SL-DEEP-1A	560235	7913039	29.5	8-Sep-16	-	-	-	-
	SL-DEEP-1B	560229	7913043	29.4	8-Sep-16	12-Aug-17	338	2.25	0.113
	SL-DEEP-1C	560227	7913045	29.5	8-Sep-16	12-Aug-17	338	2.50	0.126
	SL-DEEP-1D	560230	7913032	29.6	8-Sep-16	27-Jul-17	322	2.32	0.122
	SL-DEEP-1E	560222	7913052	29.5	8-Sep-16	11-Aug-17	337	1.44	0.073
						Average	**334**	**2.128**	**0.108**
						Standard Deviation	**7.8**	**0.470**	**0.024**

Table A.2: Sediment Trap Results for the 2017 Open-Water Period at Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2016 - 2017

Station	Station Replicate	Retrieval Location (UTM; Zone 17W)		Station Depth (m)	Date Deployed	Date Retrieved	Set Duration (days)	Total Dry Weight (g)	Sedimentation Rate ($mg/cm^2/day$)
		Easting	Northing						
Shallow 1 (SL SHAL1)	SL-SHAL-1A	560346	7913299	9.1	27-Jul-17	13-Sep-17	48	0.494	0.175
	SL-SHAL-1B	560348	7913291	9.1	16-Aug-17	13-Sep-17	28	0.508	0.308
	SL-SHAL-1C	560349	7913289	8.9	16-Aug-17	13-Sep-17	28	0.509	0.309
	SL-SHAL-1D	560351	7913268	8.8	27-Jul-17	13-Sep-17	48	0.502	0.178
	SL-SHAL-1E	560340	7913279	8.8	27-Jul-17	14-Sep-17	49	0.674	0.234
	Average						**40**	**0.537**	**0.240**
	Standard Deviation						**11.1**	**0.077**	**0.066**
Shallow 2 (SL SHAL2)	SL-SHAL-2A	560540	7913090	6.0	23-Jul-17	13-Sep-17	52	0.415	0.135
	SL-SHAL-2B	560544	7913093	5.9	27-Jul-17	13-Sep-17	48	0.444	0.157
	SL-SHAL-2C	560548	7913097	6.2	27-Jul-17	13-Sep-17	48	0.524	0.185
	SL-SHAL-2D	560552	7913098	6.2	27-Jul-17	13-Sep-17	48	0.457	0.162
	SL-SHAL-2E	560570	7913097	6.3	18-Aug-17	13-Sep-17	26	0.331	0.216
	Average						**44**	**0.434**	**0.171**
	Standard Deviation						**10.4**	**0.070**	**0.031**
Deep 1 (SL DEEP1)	SL-DEEP-1A	560235	7913039	29.5	-	-	-	-	-
	SL-DEEP-1B	560229	7913043	29.4	12-Aug-17	13-Sep-17	32	0.580	0.308
	SL-DEEP-1C	560227	7913045	29.5	12-Aug-17	13-Sep-17	32	0.540	0.286
	SL-DEEP-1D	560230	7913032	29.6	27-Jul-17	13-Sep-17	48	0.564	0.199
	SL-DEEP-1E	560222	7913052	29.5	11-Aug-17	13-Sep-17	33	0.474	0.244
	Average						**36**	**0.540**	**0.259**
	Standard Deviation						**7.8**	**0.047**	**0.048**

Table A.3: Sedimentation (mg/cm^2/day) Summary Statistics for Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2016 - 2017

Study Period	Station	Sample Size	Mean	Standard Deviation	Standard Error	95% Confidence Interval		Minimum	Maximum
						Lower Bound	Upper Bound		
Ice-Cover 2016 - 2017	SHAL 1	4	0.078	0.015	0.007	0.054	0.101	0.062	0.095
	SHAL 2	5	0.061	0.005	0.002	0.055	0.067	0.055	0.066
	DEEP1	4	0.108	0.024	0.012	0.069	0.147	0.073	0.126
Open-Water 2017	SHAL 1	5	0.240	0.066	0.030	0.158	0.323	0.175	0.309
	SHAL 2	5	0.171	0.031	0.014	0.133	0.209	0.135	0.216
	DEEP1	4	0.259	0.048	0.024	0.183	0.336	0.199	0.308

Table A.4: Statistical Comparison of Sedimentation among Sheardown Lake NW Stations for Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2016 - 2017

Study Period	Overall 3-group Comparison			Pair-wise, post-hoc comparisons[a]				
	Significant Difference Among Areas?	p-value	Staistical Test[b]	(I) Area	(J) Area	Significant Difference Between 2 Areas?	p-value	Statistical Test
Ice-Cover 2016 - 2017	YES	0.00425	ANOVA[c]	SHAL1	SHAL2	NO	0.3146	Tukey's HSD[c]
				SHAL1	DEEP1	YES	0.0503	
				SHAL2	DEEP1	YES	0.0033	
Open-Water 2017	YES	0.05118	ANOVA[d]	SHAL1	SHAL2	NO	0.1218	Tukey's HSD[c]
				SHAL1	DEEP1	NO	0.8455	
				SHAL2	DEEP1	YES	0.0596	

[a] Post-hoc analysis of 1-way ANOVA among all areas protected for multiple comparisons.

[b] Statistical tests include Analysis of Variance (ANOVA) and, for non-normal data sets, Kruskal Wallis H-test (KW H-test).

[c] Untransformed data were normally distributed and homogenous, and therefore no data transformation was used for the multiple-group comparison and post-hoc pair-wise comparisons.

Table A.5: Statistical Comparison of Sedimentation (mg/cm^2/day) Between the 2016-2017 Ice-Cover and 2017 Open-Water Periods at Sheardown Lake NW, Lake Sedimentation Monitoring Study, 2016 - 2017

Station	Statistical Test Results			Summary Statistics						
	Significant Difference Between Areas?	*p* -value	Statistical Analysis[a]	Period	N	Mean	Standard Deviation	Standard Error	Minimum	Maximum
SHAL1	YES	0.002	α , ε	Ice-Cover 2016-2017	4	0.078	0.015	0.007	0.062	0.095
				Open-Water 2017	5	0.240	0.066	0.030	0.175	0.309
SHAL2	YES	0.000	α , ε	Ice-Cover 2016-2017	5	0.061	0.005	0.002	0.055	0.066
				Open-Water 2017	5	0.171	0.031	0.014	0.135	0.216
DEEP1	YES	0.001	α , γ	Ice-Cover 2016-2017	4	0.108	0.024	0.012	0.073	0.126
				Open-Water 2017	4	0.259	0.048	0.024	0.199	0.308

[a] Data analysis included: α - data untransformed; β - data log transformed; γ - single factor ANOVA test conducted; δ - single-factor ANOVA test results validated using Mann-Whitney U-test; and, ε - single-factor ANOVA test results validated using t-test assuming unequal variance.

Highlighted values indicate significant difference between study areas based on ANOVA p-value less than 0.10.

Table A.6: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013, 2014) and Operational (2015, 2016, 2017) Phases at Sheardown Lake NW Shallow Station 1 (SHAL1) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 - 2017

Seasonal Period	Overall 4-group Comparison			Pair-wise, post-hoc comparisons[a]				
	Significant Difference Among Periods?	p-value	Staistical Test[b]	(I) Area	(J) Area	Significant Difference Between Periods?	p-value	Statistical Test
Ice-Cover	YES	0.00039	ANOVA[b]	2013 - 2014	2014 - 2015	NO	0.4180	Tukey's HSD[b]
				2013 - 2014	2015 - 2016	YES	0.0793	
				2013 - 2014	2016 - 2017	YES	0.0177	
				2014 - 2015	2015 - 2016	YES	0.0025	
				2014 - 2015	2016 - 2017	YES	0.0006	
				2015 - 2016	2016 - 2017	NO	0.7533	
Open-Water	YES	0.00004	ANOVA[d]	2014	2015	YES	0.0080	Tukey's HSD[b]
				2014	2016	YES	0.0119	
				2014	2017	YES	0.0000	
				2015	2016	NO	1.0000	
				2015	2017	YES	0.0206	
				2016	2017	YES	0.0311	

[a] Post-hoc analysis of 1-way ANOVA among all areas protected for multiple comparisons.

[b] Untransformed data were non-normally distributed; log-transformation resulted in normally distributed data. and thus the log-transformed data were used for statistical tests.

[c] Untransformed data were normally distributed, and thus un-transformed data used for statistical tests.

[d] Log transformed data remained non-normally distributed, and thus statistical results validated using non-parametric KW and MW tests, as appropriate.

Table A.7: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013, 2014) and Operational (2015, 2016, 2017) Phases at Sheardown Lake NW Shallow Station 2 (SHAL2) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 - 2017

Seasonal Period	Overall 4-group Comparison			Pair-wise, post-hoc comparisons[a]				
	Significant Difference Among Periods?	p-value	Staistical Test[b]	(I) Area	(J) Area	Significant Difference Between Periods?	p-value	Statistical Test
Ice-Cover	YES	0.00000	ANOVA[c]	2013 - 2014	2014 - 2015	NO	0.5180	Tamhane's [c]
				2013 - 2014	2015 - 2016	YES	0.0003	
				2013 - 2014	2016 - 2017	YES	0.0002	
				2014 - 2015	2015 - 2016	YES	0.0001	
				2014 - 2015	2016 - 2017	YES	0.0001	
				2015 - 2016	2016 - 2017	YES	0.0108	
Open-Water	NO	0.61698	ANOVA[c]	2014	2015	NO	0.9872	Tamhane's [c]
				2014	2016	NO	0.9779	
				2014	2017	NO	0.9999	
				2015	2016	NO	0.9998	
				2015	2017	NO	0.6394	
				2016	2017	NO	0.0781	

[a] Post-hoc analysis of 1-way ANOVA among all areas protected for multiple comparisons.

[b] Untransformed data were non-normally distributed; log-transformation resulted in normally distributed data. and thus the log-transformed data were used for statistical tests.

[c] Untransformed data were normally distributed, and thus un-transformed data used for statistical tests.

[d] Log transformed data remained non-normally distributed, and thus statistical results validated using non-parametric KW and MW tests, as appropriate.

Table A.8: Statistical Comparison of Sedimentation Rates Between Mine Baseline (2013, 2014) and Operational (2015, 2016, 2017) Phases at Sheardown Lake NW Deep Station (DEEP1) during Ice-Cover and Open-Water Periods, Lake Sedimentation Monitoring Study, 2013 - 2017

Seasonal Period	Overall 4-group Comparison			Pair-wise, post-hoc comparisons[a]				
	Significant Difference Among Periods?	p-value	Staistical Test[b]	(I) Area	(J) Area	Significant Difference Between Periods?	p-value	Statistical Test
Ice-Cover	YES	0.00001	ANOVA[d]	2013 - 2014	2014 - 2015	NO	0.9912	Tukey's HSD[d]
				2013 - 2014	2015 - 2016	YES	0.0018	
				2013 - 2014	2016 - 2017	YES	0.0001	
				2014 - 2015	2015 - 2016	YES	0.0007	
				2014 - 2015	2016 - 2017	YES	0.0000	
				2015 - 2016	2016 - 2017	NO	0.3796	
Open-Water	YES	0.00000	ANOVA[c]	2014	2015	YES	0.0018	Tamhane's [c]
				2014	2016	YES	0.0006	
				2014	2017	YES	0.0731	
				2015	2016	YES	0.0063	
				2015	2017	NO	0.4075	
				2016	2017	NO	1.0000	

[a] Post-hoc analysis of 1-way ANOVA among all areas protected for multiple comparisons.

[b] Untransformed data were non-normally distributed; log-transformation resulted in normally distributed data. and thus the log-transformed data were used for statistical tests.

[c] Untransformed data were normally distributed, and thus un-transformed data used for statistical tests.

[d] Log transformed data remained non-normally distributed, and thus statistical results validated using non-parametric KW and MW tests, as appropriate.

APPENDIX E.9.3

2017 HYDROMETRIC MONITORING REPORT

STORY environmental inc

MEMO

To:	William Bowden Environmental Superintendent Baffinland Iron Mines	**From:**	Andrew Rees, Ph.D. Senior Environmental Scientist
Re:	2017 AEMP Hydrometric Monitoring Program	**Date:**	16 March 2018
		Proj No:	199-04-09

1 Introduction

The 2017 Mary River Hydrometric Monitoring Program was initiated in late June around the onset of the spring melt period. Site visits were conducted by Story Environmental Inc. ("SEI") to re-install pressure transducers and conduct flow measurements at the six previously established monitoring stations and at the previously decommissioned H07 station, which was re-installed to support monitoring required under the Metal Mining Effluent Regulations ("MMER"). The hydrometric stations are a part of the streamflow monitoring program supporting the Aquatic Effects Monitoring Plan ("AEMP") and the station IDs, names, period of records, drainage areas, and locations are summarized in Table 1.1.

Table 1.1 2017 Hydrometric Monitoring Stations

Station ID	Station Name	Period of Record	Drainage Area (km^2)	Coordinates (UTM)	
				Easting	Northing
H01	Phillips Creek Tributary	2006-2008, 2011-2016	250	532831	7946247
H02	Tom River near outlet to Mary Lake	2006-2008, 2010-2016	210	555712	7915514
H04	Camp Lake Tributary (CLT-2)	2006-2008, 2010-2016	8.3	557639	7915579
H05	Camp Lake Tributary (CLT-1)	2006-2008, 2010-2016	5.3	558906	7915079
H06	Mary River	2006-2008, 2010-2016	240	563922	7912984
H07	Mary River Tributary	2006-2008 2010, 2011	14.7	564451	7913194
H11	Sheardown Lake Tributary (SDLT-1)	2011-2016	3.6	560503	7913545

During the June site visit, benchmark and water level surveys were conducted and pressure transducers were installed. Discharge was measured using the velocity-area technique and a wading current meter where lower flows permitted safe access to the channel and using dilution gauging where higher flows were present. Additional site visits were made by Baffinland Iron Mines Corporation ("Baffinland") staff and the stations were removed between 4 and 11 September prior to winter freeze-up.

2 Stage-Discharge Measurements

The stage-discharge data obtained in 2017 were compared to the existing rating curves summarized in the 2016 Hydrometric Monitoring Program Summary (SEI, 2017) for the H01, H02, H04, H05, H06, and H11 stations. The discharge data were compared to the existing rating curve for H07 presented in the Baseline Hydrology Report (KP, 2012). The rating curves for each station, inclusive of the 2017 measurements, are provided on Figures 1 to 7. A discussion and interpretation of the fit of the current data to the existing rating curves is provided in the following sections:

- **H01 (Phillip's Creek Tributary)** - A stage-discharge measurement was recorded at H01 during the June site visit using dilution gauging and is consistent with the existing rating curve (Figure 1). As such, the existing rating curve was used for the development of the 2017 streamflow record.
- **H02 (Tom River)** - A stage-discharge measurement was recorded at H02 during the June site visit using dilution gauging and is consistent with the updated rating curve presented in SEI, 2017 (Figure 2). Additional flow measurements (especially higher during higher flows) are recommended to continue to verify the updated rating curve. The updated rating curve was used for the development of the 2017 flow record.
- **H04 (Camp Lake Tributary CLT-2)** - A stage-discharge measurement was recorded at H04 during the June site visit using a wading current meter and the area-velocity technique. The measurement is consistent with the updated rating curve proposed in SEI, 2016 (Figure 3). There continues to be less confidence in the accuracy of the rating curve for flows above 0.7 m^3/s. As in previous years, additional high flow measurements are recommended to further validate the updated rating curve at H04. The updated rating curve was used for the development of the 2017 flow record.
- **H05 (Camp Lake Tributary CLT-1)** – A stage-discharge measurement was recorded at H05 during the June site visit using a wading current meter and the area-velocity technique. The measurement is consistent with the existing rating curve (Figure 4). The rating curve was used for the development of the 2017 flow record.
- **H06 (Mary River)** – A stage-discharge measurement was recorded at H06 during the June site visit using dilution gauging and is consistent with the existing rating curve (Figure 5). The existing rating curve was used for the development of the 2017 flow record.
- **H07 (Mary River Tributary)** – A stage-discharge measurement was recorded at H07 during the June site visit using dilution gauging and is consistent with the rating curve presented in KP, 2012 (Figure 6). The June measurement was during a higher flow period and helps validate the upper half of the rating curve. The lower flow portion of the rating curve was not validated in 2017 due to technical difficulties with monitoring equipment, however, there is no evidence to suggest that the downstream control has shifted. Additional flow measurements at

H07 are recommended to further validate the rating curve. The existing rating curve was used for the development of the 2017 flow record.

- **H11 (Sheardown Lake Tributary SDLT-1)** – A stage-discharge measurement was recorded at H11 during the June site visit and is consistent with the rating curve updated in 2014 (Figure 7). There remains some uncertainty around the higher stage-discharge conditions at H11 due to the lack of field measurements for validation. In future years, higher flow measurements should be obtained at H11 to validate the rating curve. The rating curve updated in 2014 was used for the development of the 2017 flow record.

3 Streamflow Hydrographs

Streamflow records were developed for each station by applying the water level records to the corresponding rating curves. The discharge hydrographs for H01, H02, H04, H05, H06, H07, and H11 are presented on Figures 8 to 14. Each water level record underwent a quality review and periods affected by channel ice or other anomalies were removed from the record.

The discharge records were converted to equivalent unit runoff (discharge per unit area) and are compared to the daily precipitation records from the climate station at the Mary River Mine Site on Figure 15. The records of unit runoff generally agree well with each other, exhibiting similar timing and magnitude of runoff events and similar patterns to previous years. As during previous years, the freshet was not captured at H11 due to an earlier melt than the stations with higher elevation catchments and there was a muted response to precipitation events later in the year. The lowest unit runoff in August was recorded at the H01 station (background station), which is likely due to differences in regional precipitation throughout the year. The data logger at H07 malfunctioned and stopped recording data at the end of July.

A strong diurnal melt pattern is evident through the end of June and first half of July, especially at the stations with higher elevation catchments (H02, H06, and H07). The snowmelt at lower elevations and the peak of freshet flows at the stations with smaller and lower elevation catchment areas occurs earlier. The 2017 freshet flow was likely not entirely captured at all of the stations, especially at the H05 and H11 stations. The estimated mean monthly discharge and unit runoff for each station in 2016 are summarized in Table 3.1.

Table 3.1 Summary of 2016 Mean Monthly Estimated Discharge and Unit Runoff

STATION	Drainage Area (km^2)	Estimated Mean Monthly Discharge (m^3/s)				Period of Record
		June	July	August	September	
H01	250	14.5	8.5	2.6	1.1	June 25 to September 4
H02	210	39.9	24.6	7.9	4.9	June 26 to September 7
H04	8.3	1.7	0.33	0.19	0.17	June 24 to September 8
H05	5.3	0.63	0.13	0.11	0.10	June 24 to September 8
H06	240	39.1	22.3	4.5	19.3	June 26 to September 7
H07	14.7	1.9	1.4			June 27 to July 30
H11	3.6	0.064	0.056	0.090	0.136	June 24 to September 5

STATION	Drainage Area (km^2)	Estimated Mean Monthly Unit Runoff ($l/s/km^2$)				Period of Record
		June	July	August	September	
H01	250	58	34	11	4	June 25 to September 4
H02	210	190	117	38	24	June 26 to September 7
H04	8.3	206	40	23	20	June 24 to September 8
H05	5.3	118	24	21	19	June 24 to September 8
H06	240	163	93	19	80	June 26 to September 7
H07	14.7	131	95			June 27 to July 30
H11	3.6	18	15	25	38	June 24 to September 5

A summary of flows at H05 from 2006 to 2017 is shown on Figure 16. The total annual runoff recorded in 2017 at the H05 station was similar to 2015 and the second lowest recorded from 2006 to 2017 for concurrent periods of record. The flow was lower than normal in June and July, likely due to the freshet occurring prior to the re-installation of the stations. There were also fewer high flow events in August than normal.

4 Summary

The 2017 Hydrometric Monitoring Program allowed for the continued monitoring of streamflow at the AEMP hydrometric stations. The data collected confirmed that the rating curves at all stations continue to be applicable. It is recommended that future hydrometric monitoring includes more frequent site visits during the season to ensure the proper operation of data loggers and to confirm or improve rating curves, especially during summer high flow events.

5 References

Knight Piésold Ltd. (KP), 2012. Mary River Project Baseline Hydrology Report. Vancouver, BC. NB102-181/30-7 Rev 1.

Story Environmental Inc. (SEI), 2017. Memorandum to Jim Millard, Baffinland Iron Mines Corporation. Re: *2016 Hydrometric Monitoring Program*. February 28. Haileybury, Ontario. Ref. No. 199-03-09.

Prepared by: Reviewed by:

Andrew Rees, Ph.D., EP
Senior Environmental Scientist

Maria Story, P.Eng.
President

Attachments:

Figure 1	H01 - Phillip's Creek Tributary Rating Curve
Figure 2	H02 - Tom River Rating Curve
Figure 3	H04 - Camp Lake Tributary (CLT-2) Rating Curve
Figure 4	H05 - Camp Lake Tributary (CLT-1) Rating Curve
Figure 5	H06 - Mary River Rating Curve
Figure 6	H07 - Mary River Tributary Rating Curve
Figure 7	H11 - Sheardown Lake Tributary (SLDT-1) Rating Curve
Figure 8	H01 – Phillip's Creek Tributary 2017 Streamflow Record
Figure 9	H02 - Tom River 2017 Streamflow Record
Figure 10	H04 - Camp Lake Tributary (CLT-2) 2017 Streamflow Record
Figure 11	H05 - Camp Lake Tributary (CLT-1) 2017 Streamflow Record
Figure 12	H06 - Mary River 2017 Streamflow Record
Figure 13	H07 – Mary River Tributary 2017 Streamflow Record
Figure 14	H11 - Sheardown Lake Tributary (SLDT-1) 2017 Streamflow Record
Figure 15	2017 Unit Runoff and Daily Precipitation
Figure 16	H05 – Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006-2016

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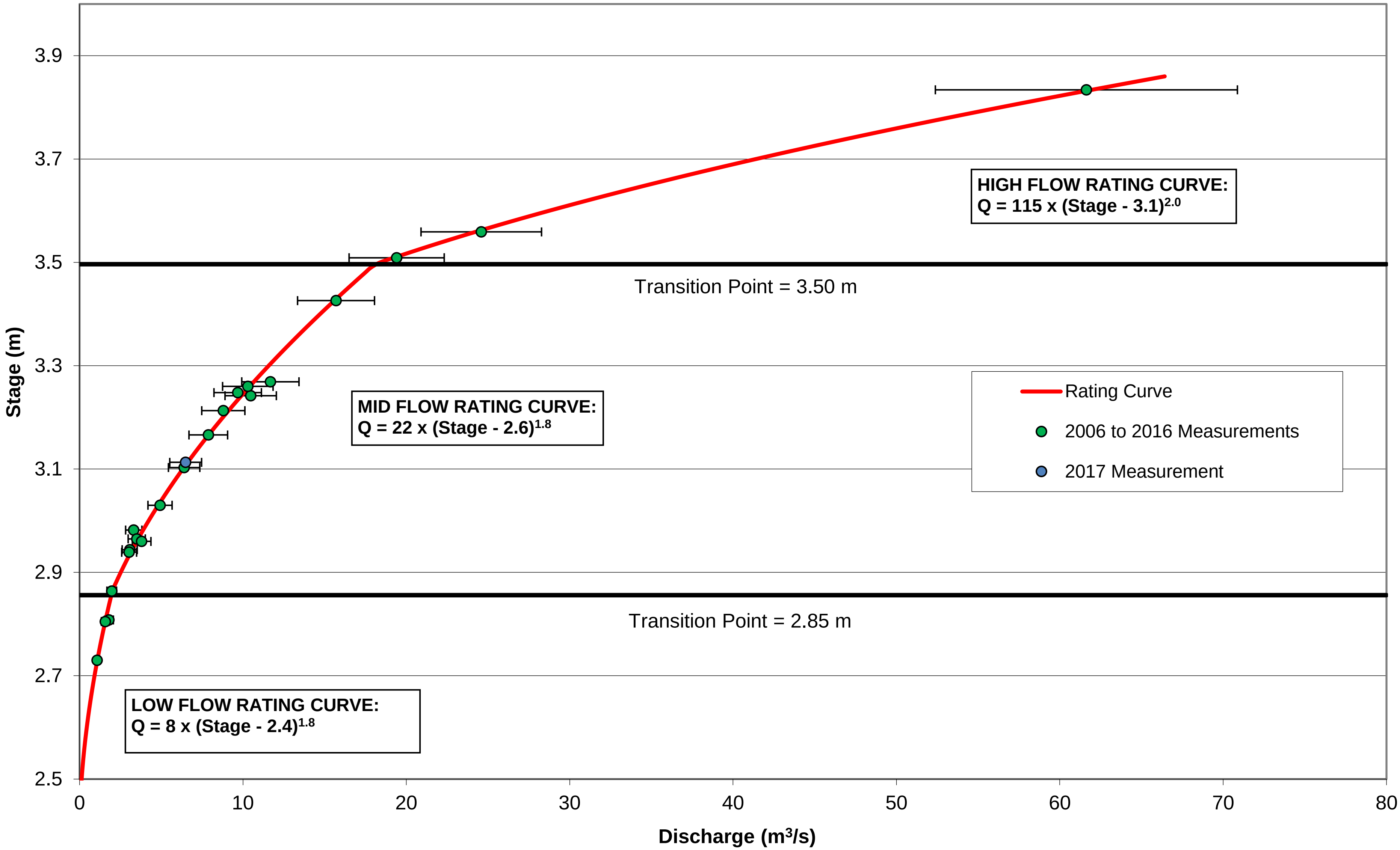
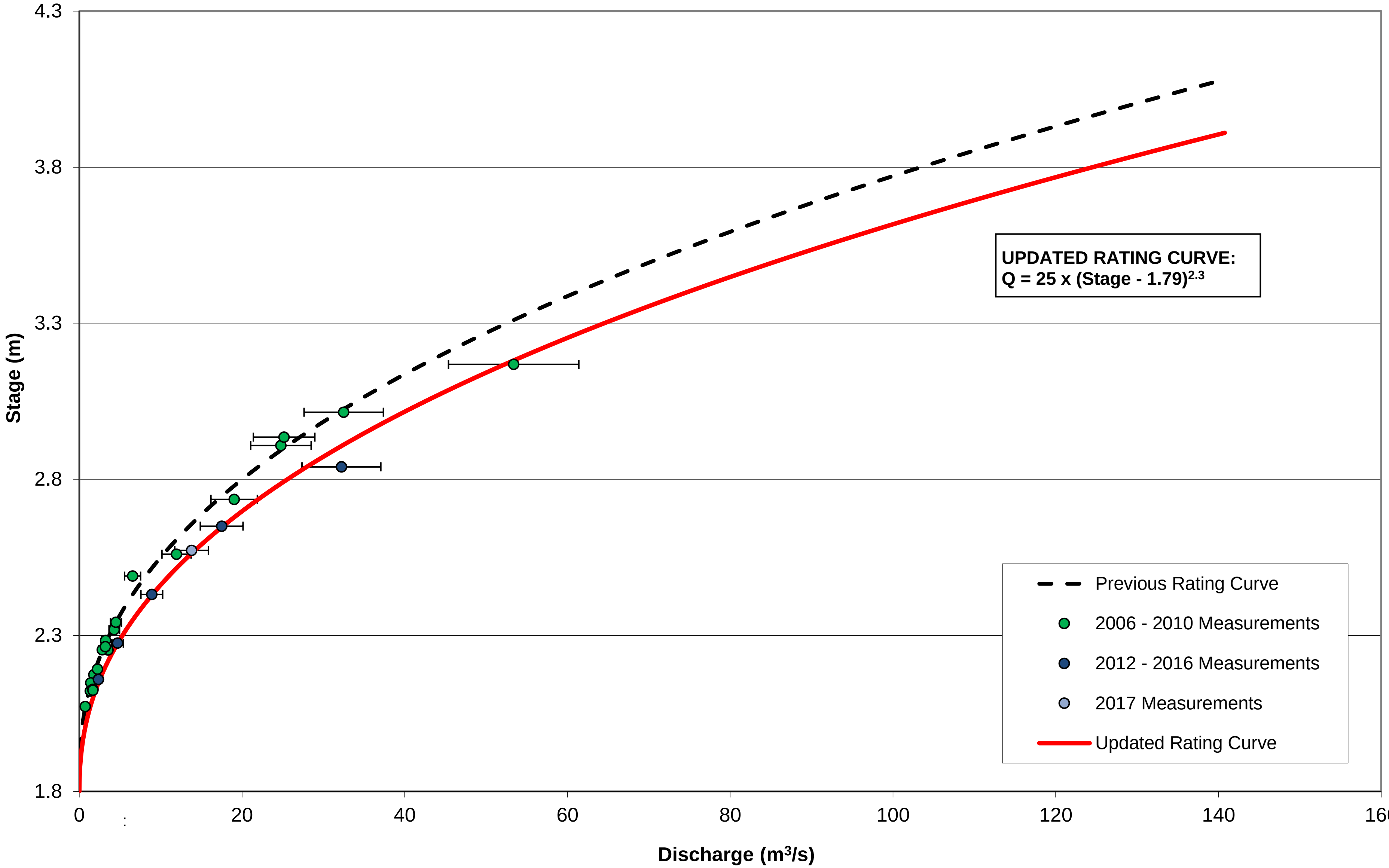
Attachments



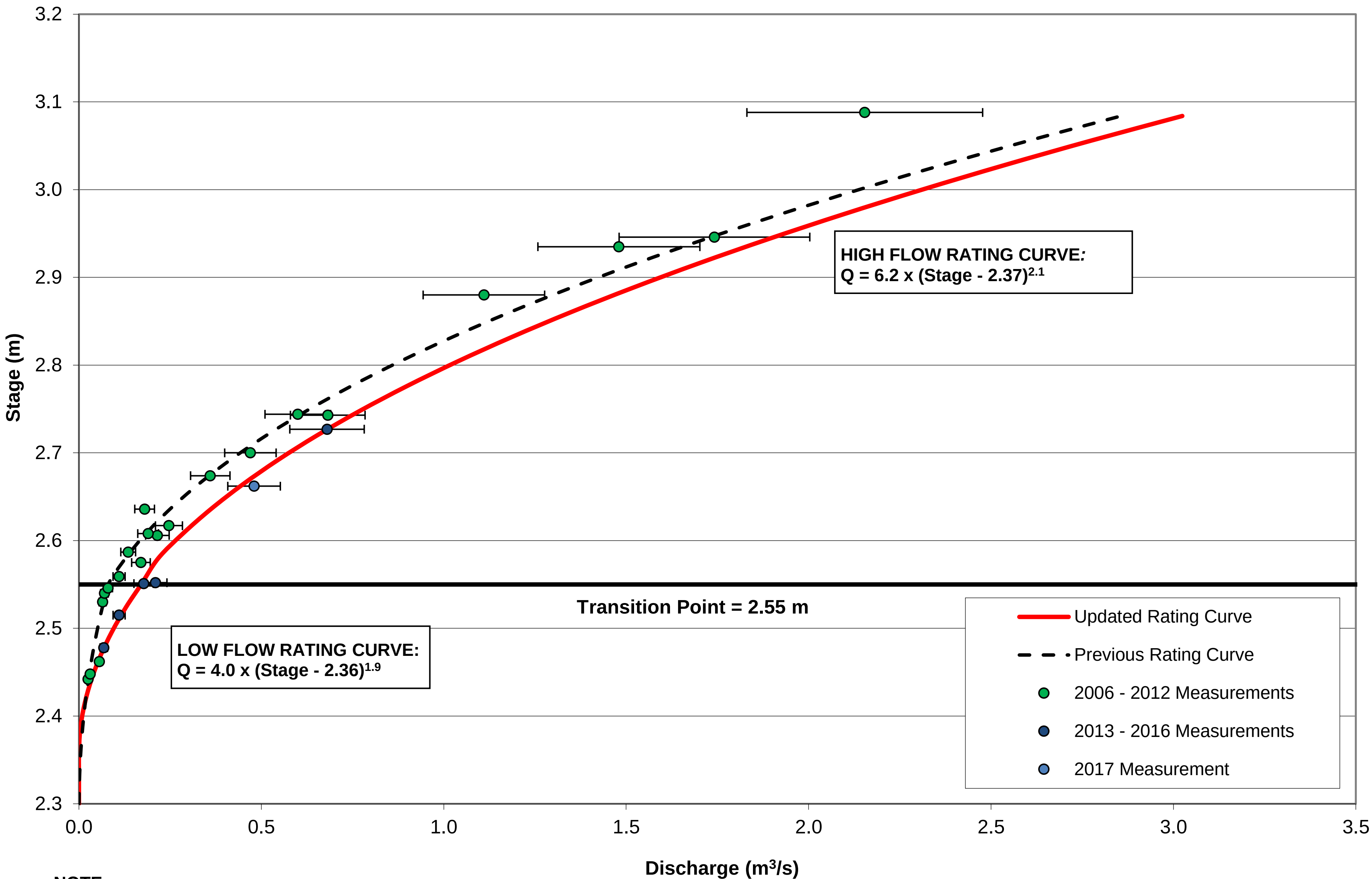
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGEIN 2017.

Figure 1 **H01 - Philips Creek Tributary Rating Curve**



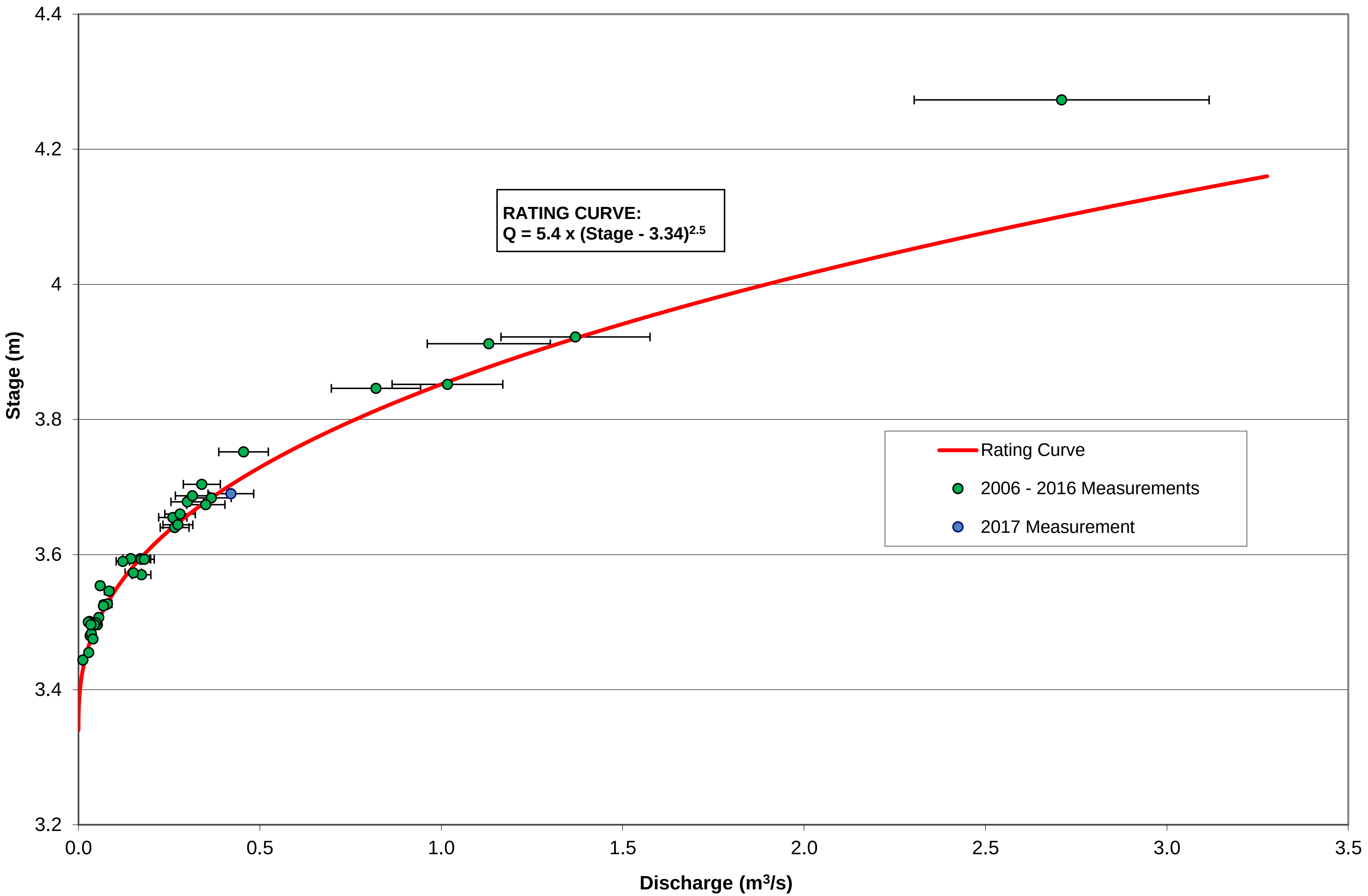
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017.

Figure 2 **H02 - Tom River Rating Curve**



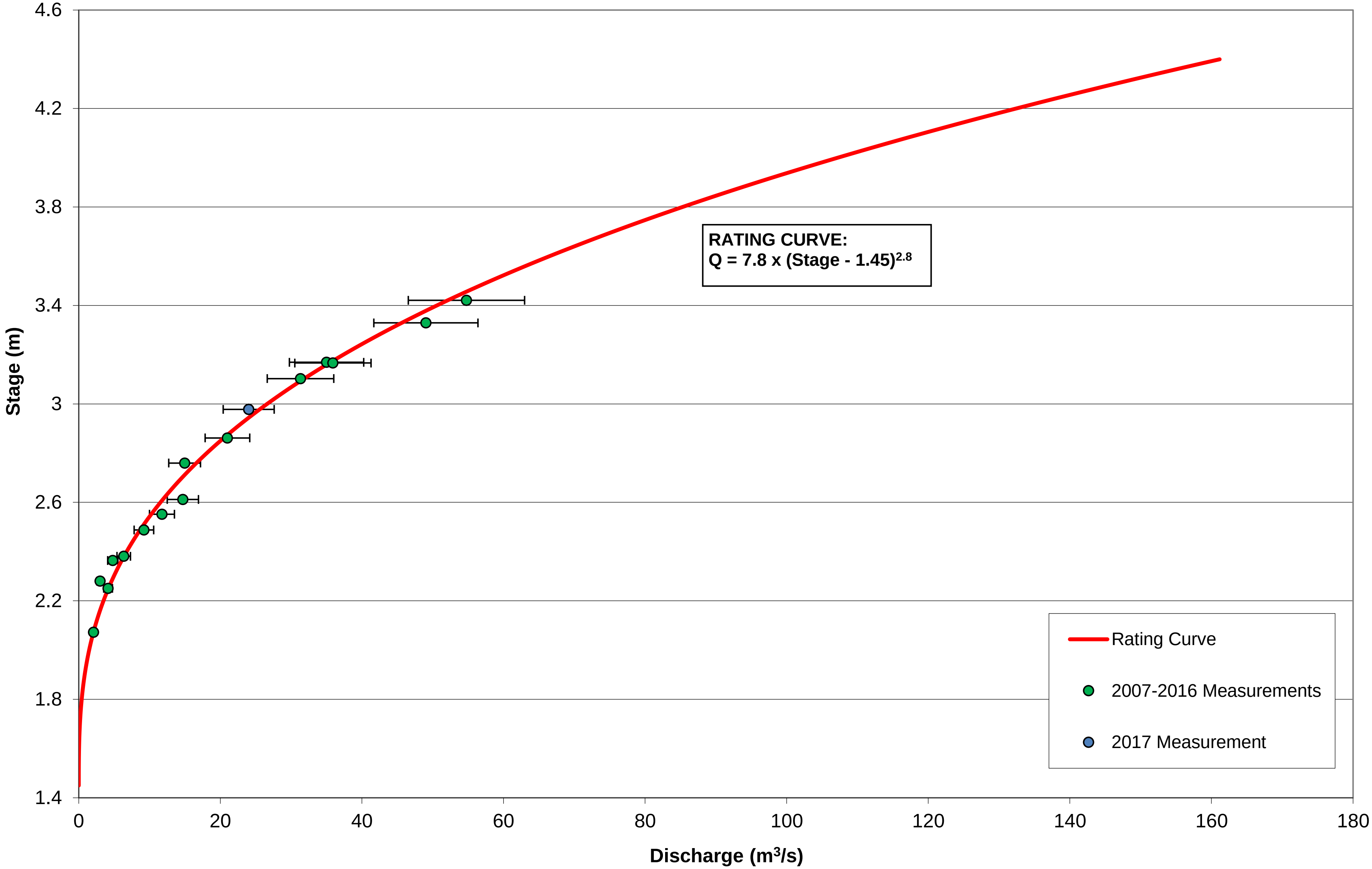
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017

Figure 3 **H04 - Camp Lake Tributary (CLT-2) Rating Curve**



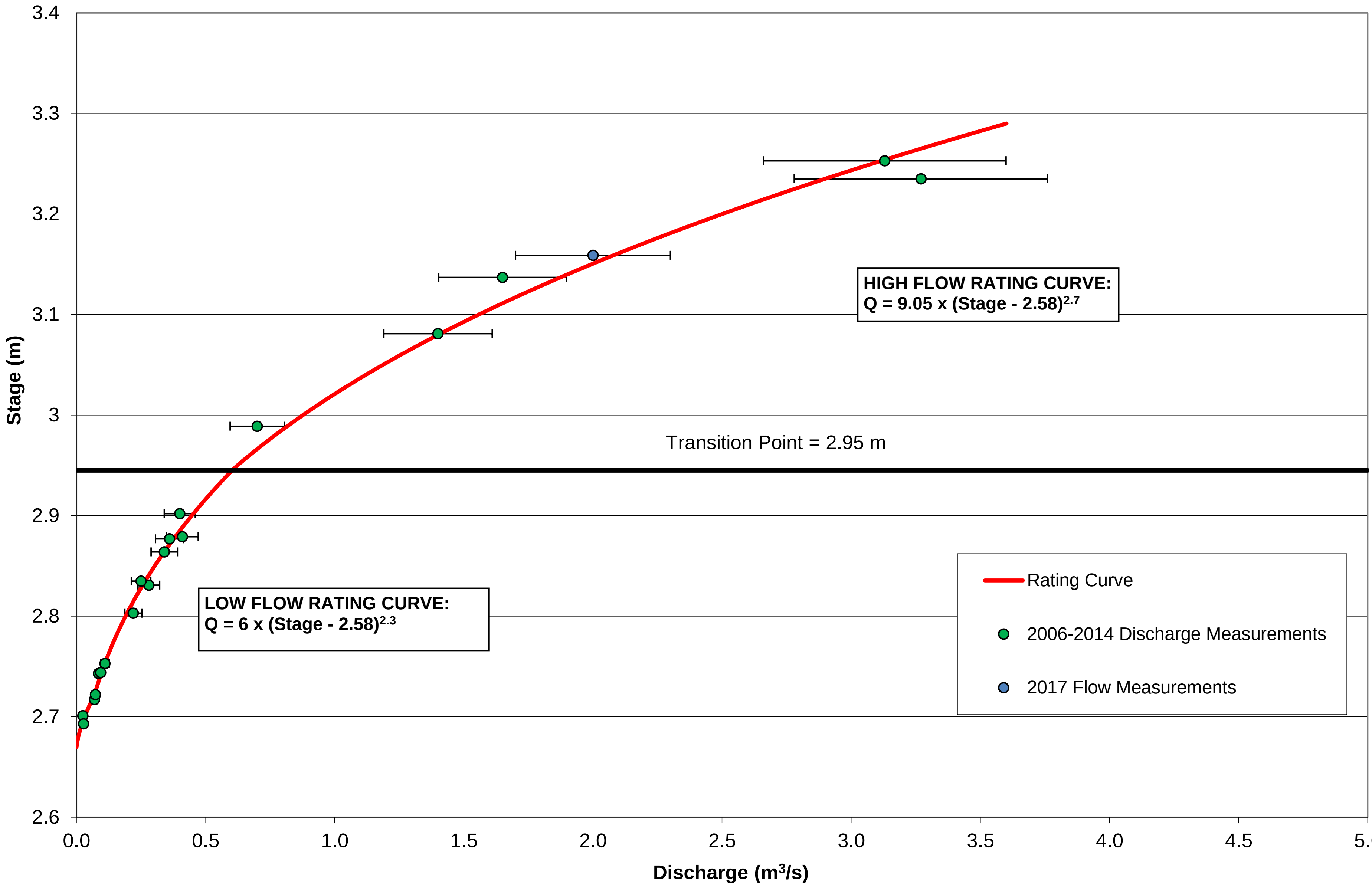
NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017

Figure 4 **H05 - Camp Lake Tributary (CLT-1) Rating Curve**



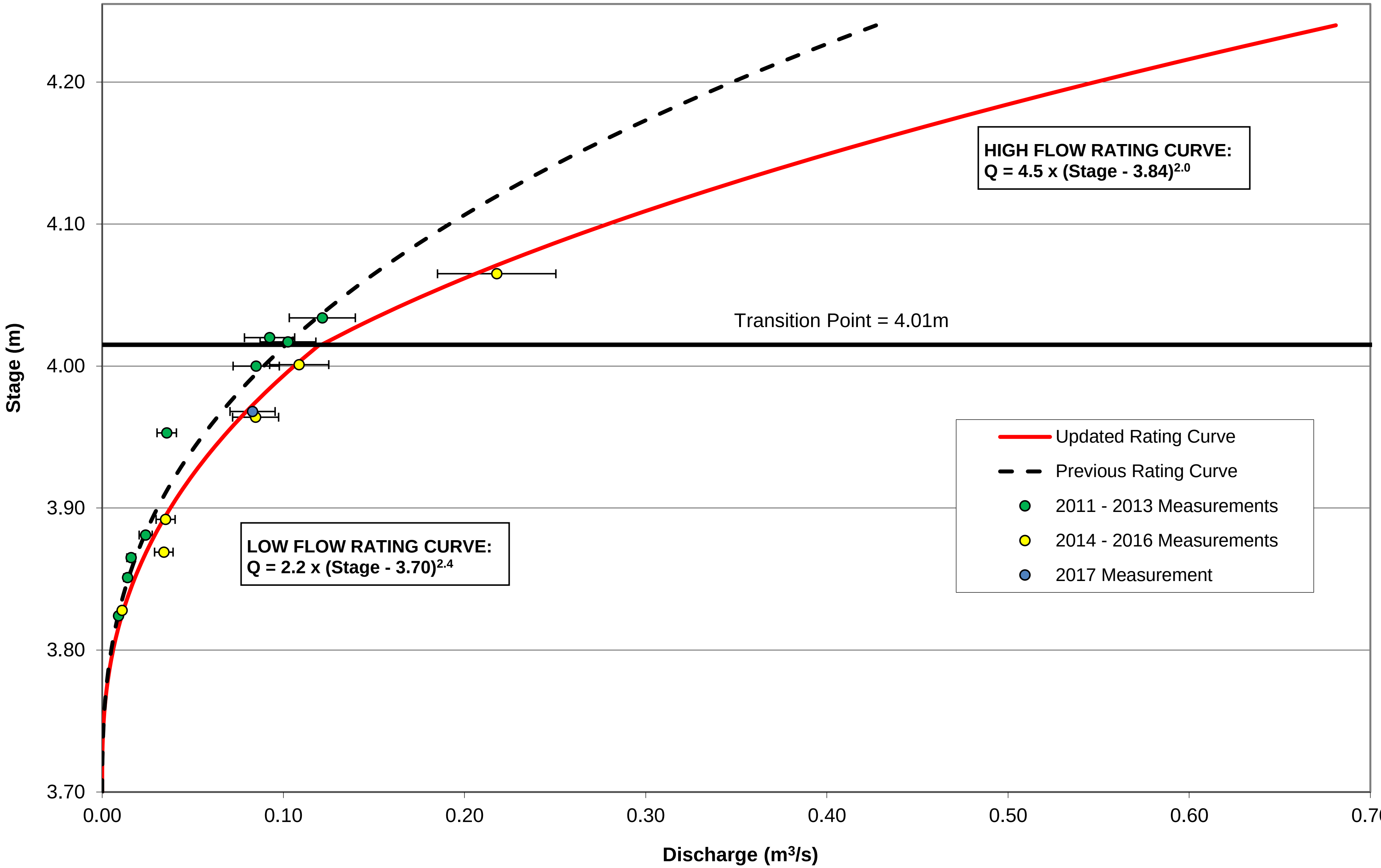
NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017

Figure 5 **H06 - Mary River Rating Curve**



NOTES:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017

Figure 6 **H07 - Mary River Tributary Rating Curve**



NOTE:
1. RATING CURVE SHOWN TO MAXIMUM RECORDED STAGE IN 2017

Figure 7 **H11 - Sheardown Lake Tributary (SDLT-1) Rating Curve**

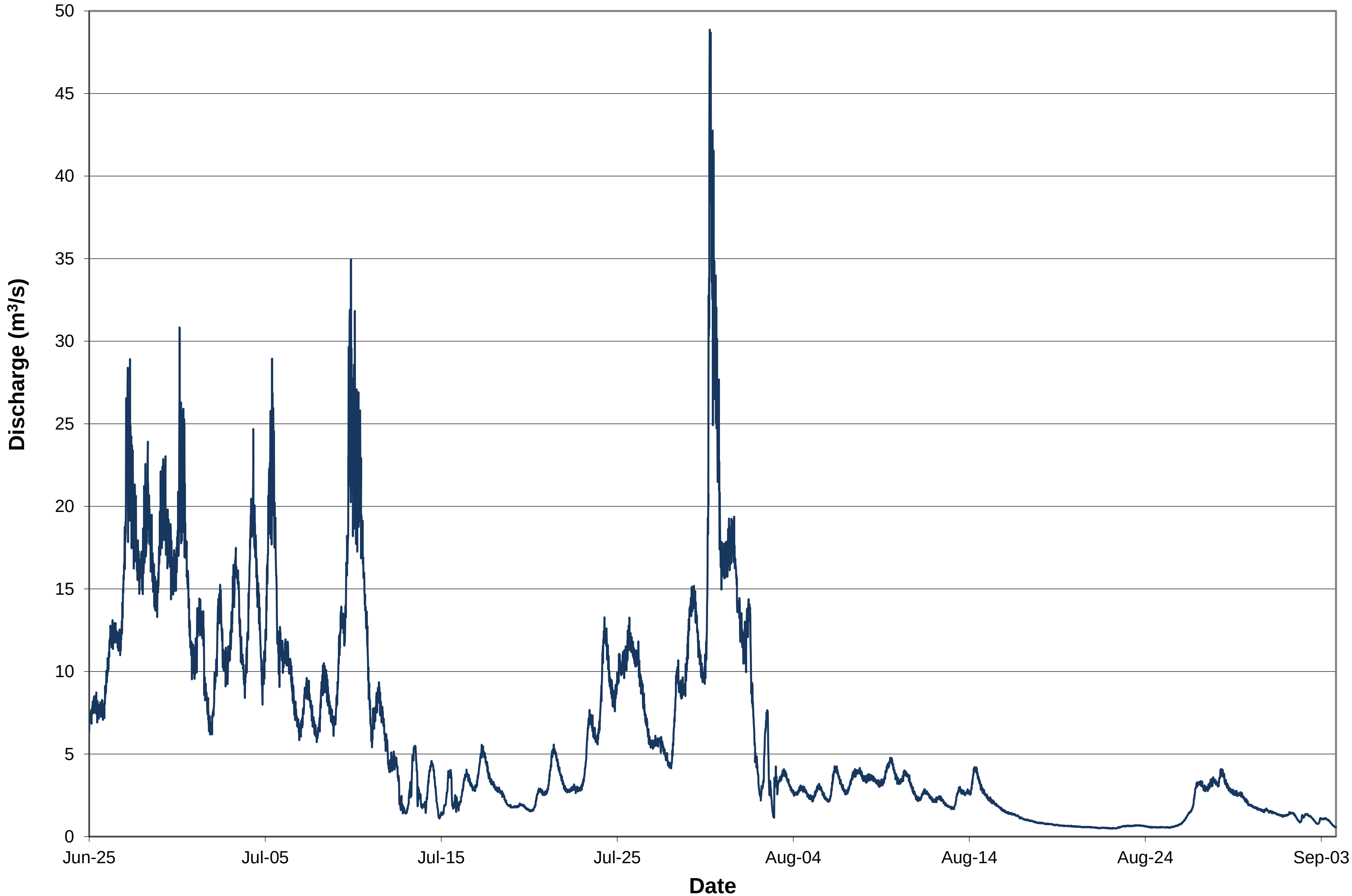


Figure 8 **H01 - Philips Creek Tributary 2017 Streamflow Record**

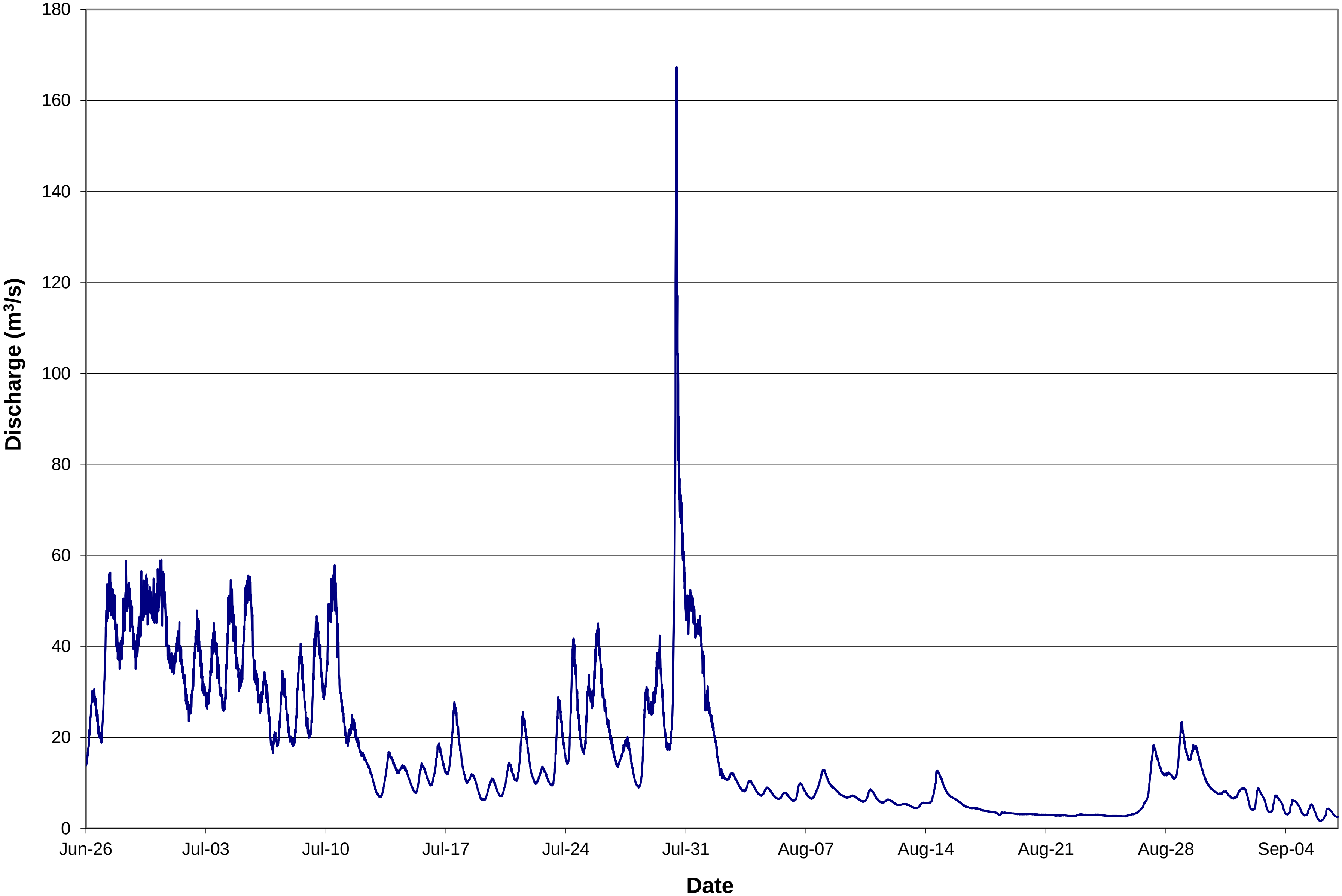


Figure 9 **H02 - Tom River 2017 Streamflow Record**

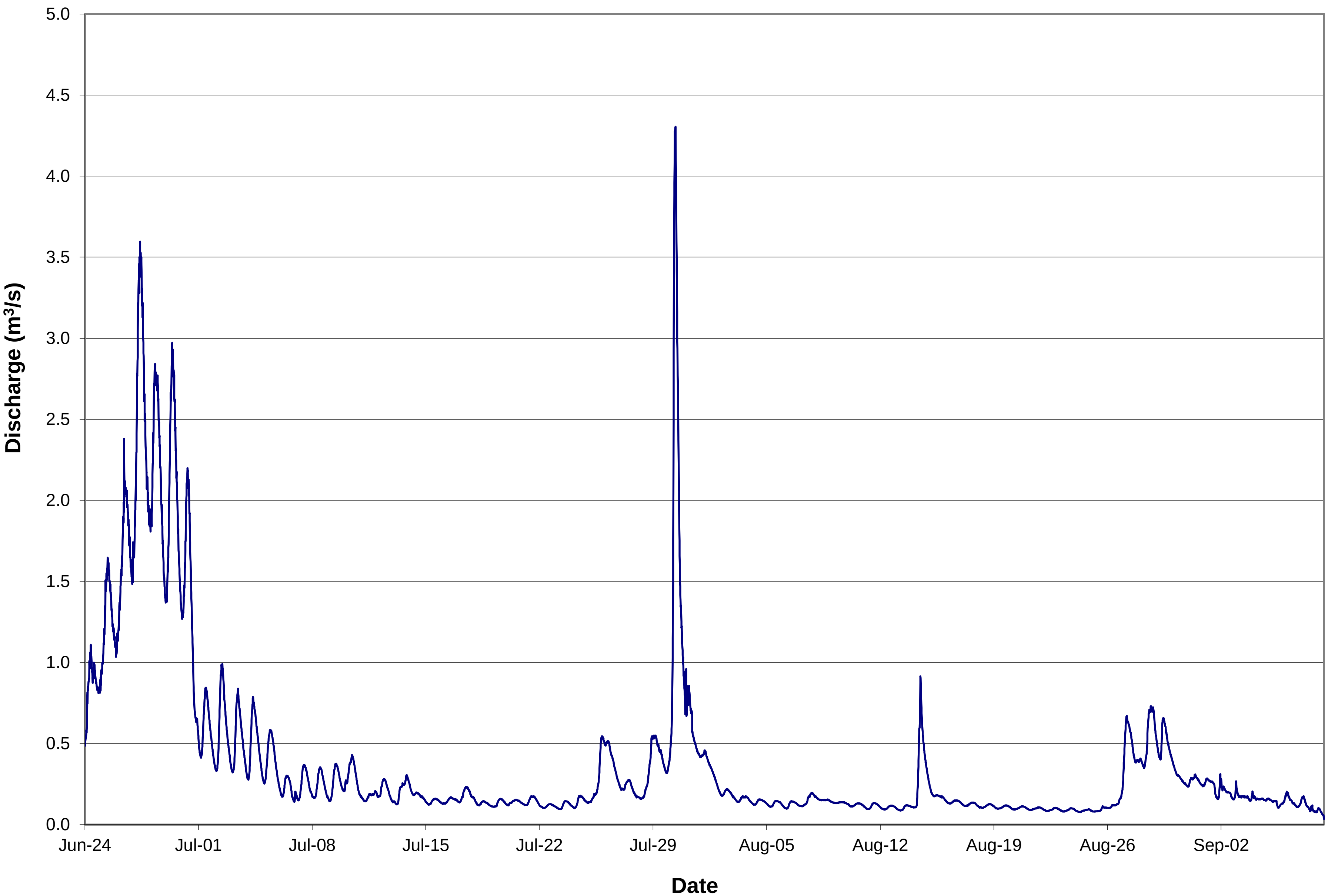


Figure 10 **H04 - Camp Lake Tributary (CLT-2) 2017 Flow Record**

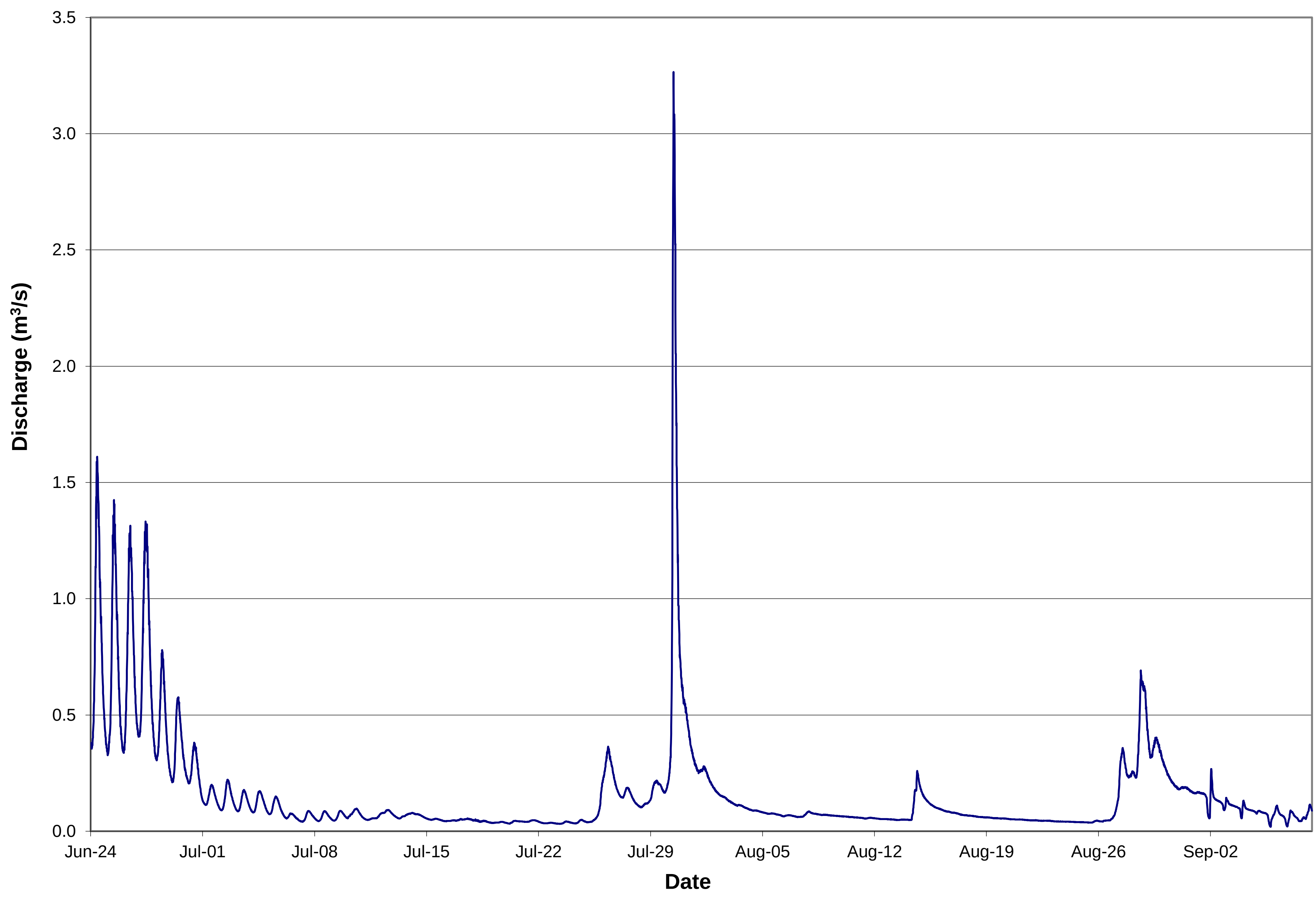


Figure 11 **H05 - Camp Lake Tributary (CLT-1) 2017 Flow Record**

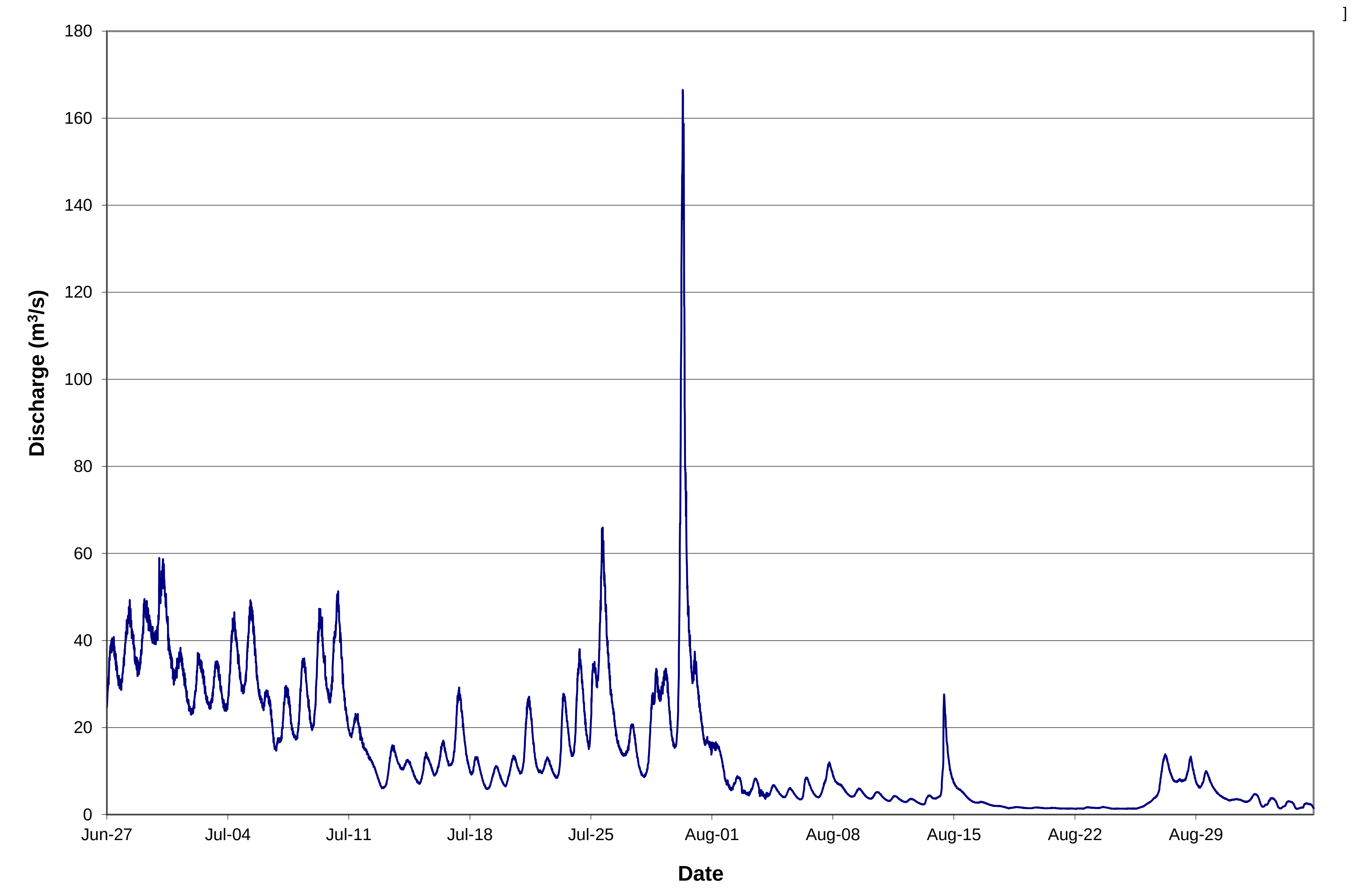


Figure 12 **H06 - Mary River 2017 Flow Record**

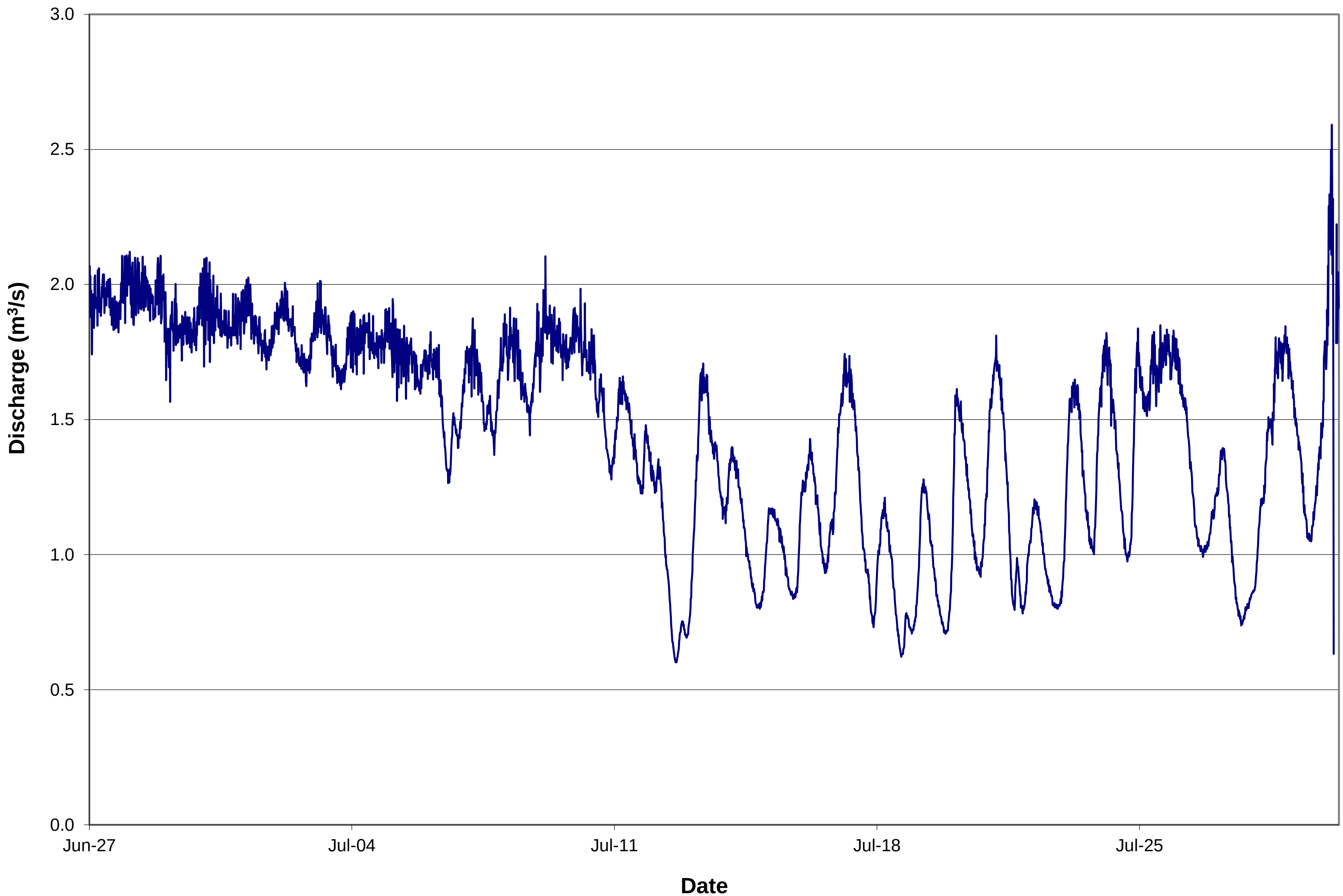


Figure 13 **H07 - Mary River Tributary 2017 Flow Record**

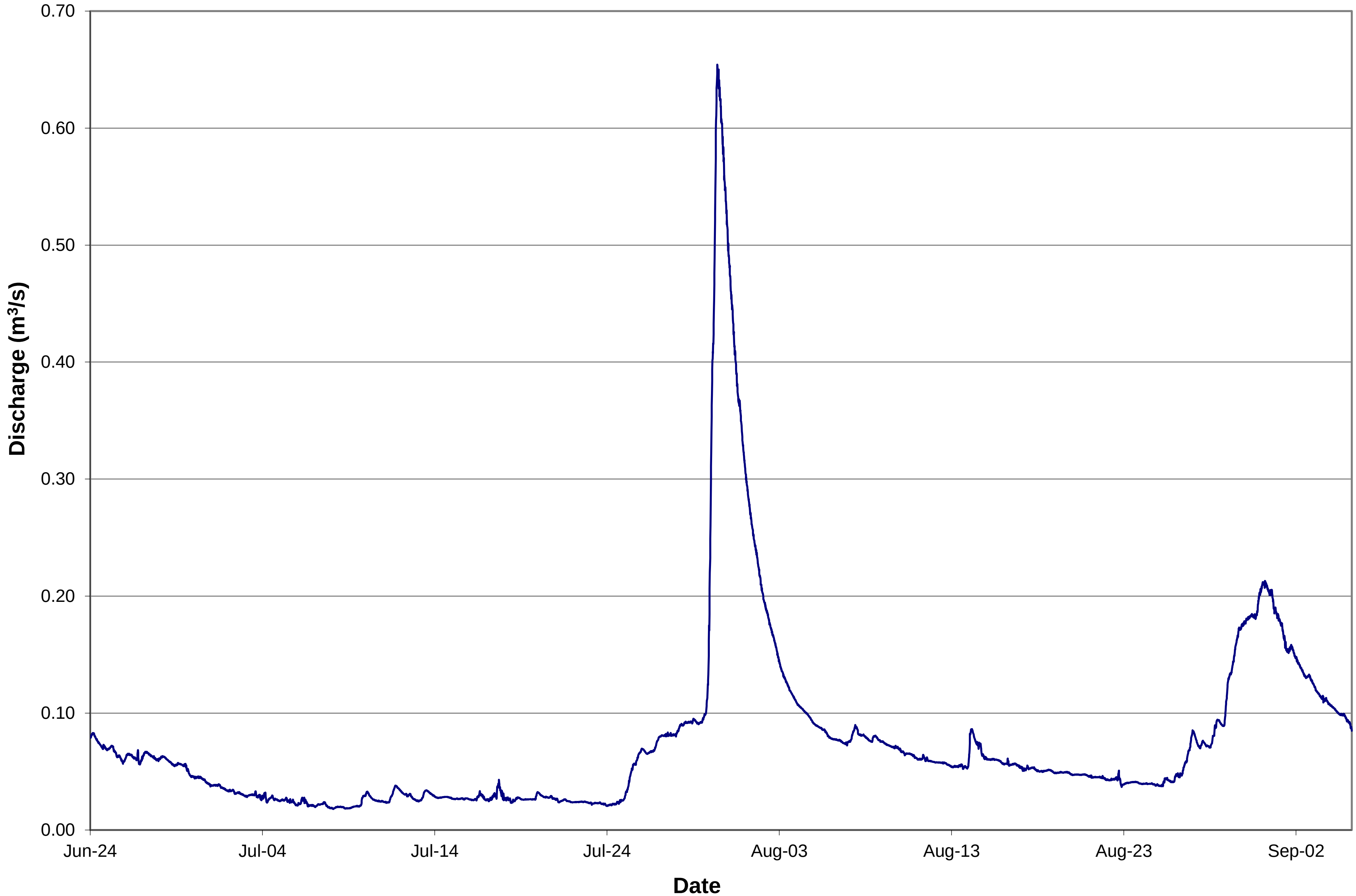
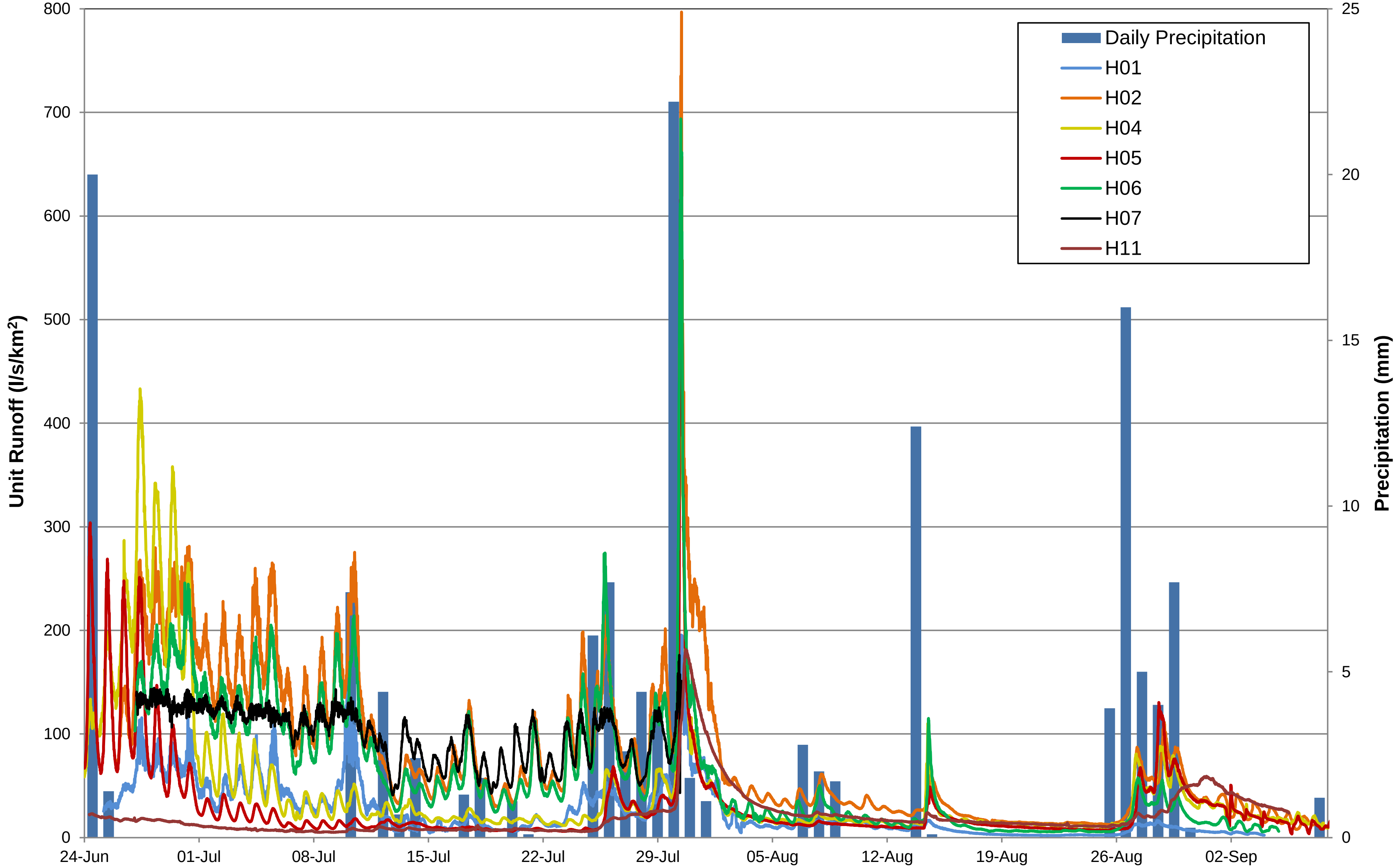


Figure 14 **H11 - Sheardown Lake Tributary (SDLT-1) 2017 Streamflow Record**



NOTE:
1. DAILY PRECIPITATION DATA OBTAINED FROM THE MARY RIVER MINE SITE CLIMATE STATION

Figure 15 **2017 Unit Runoff and Daily Precipitation**

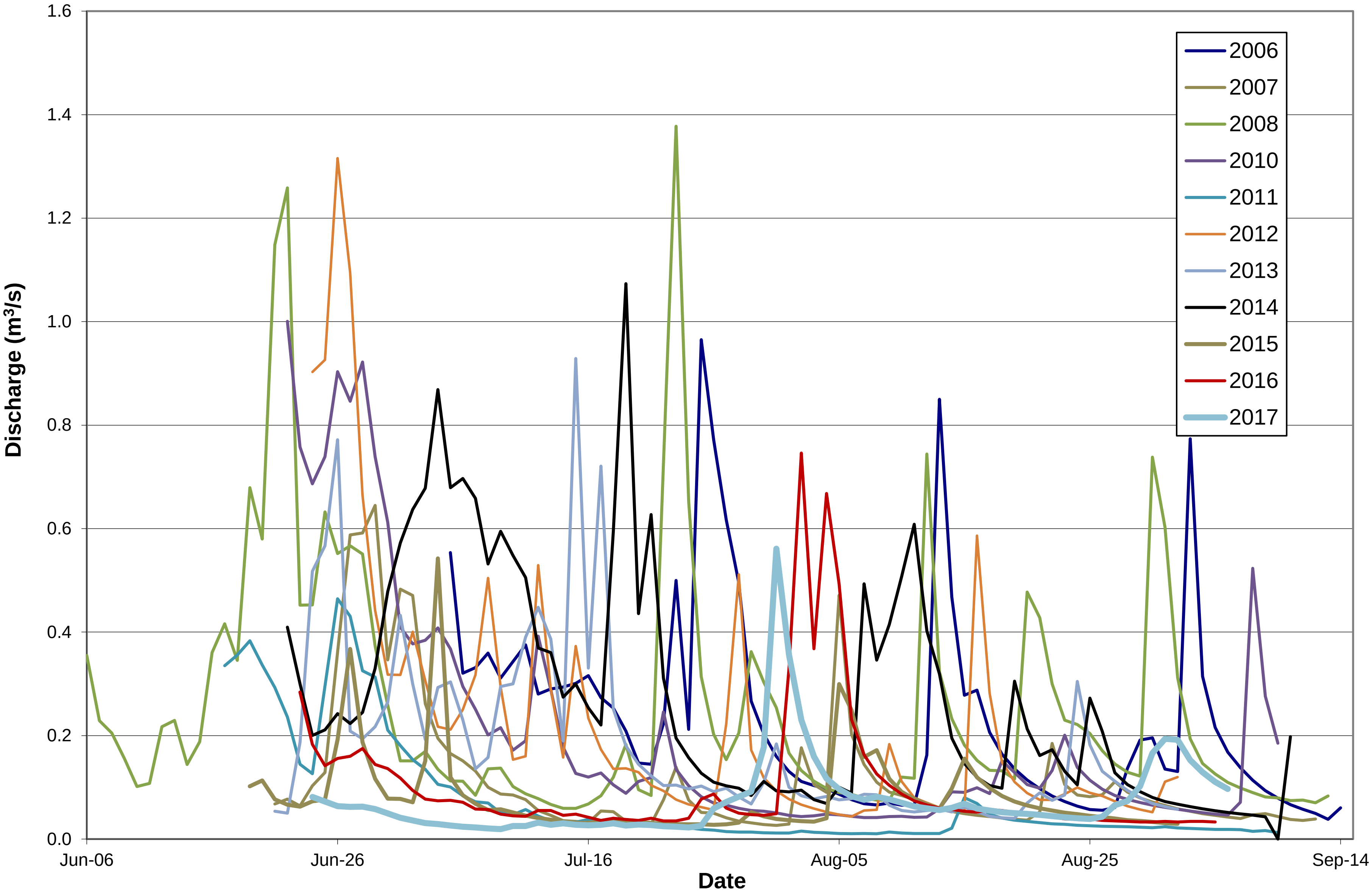


Figure 16 **H05 - Camp Lake Tributary (CLT-1) Measured Streamflow Hydrographs 2006 - 2017**

APPENDIX E.9.4

2017 PHASE 1 EEM INTERPRETIVE REPORT

Mary River Project Phase 1
Environmental Effects Monitoring (2017)
Interpretive Report

Prepared for:
Baffinland Iron Mines Corporation
Oakville, Ontario

Prepared by:
Minnow Environmental Inc.
Georgetown, Ontario

January 2018

Mary River Project Phase 1
Environmental Effects Monitoring (2017)
Interpretive Report

Paul LePage, M.Sc.
Project Manager

Pierre Stecko, M.Sc.
Senior Project Advisor

EXECUTIVE SUMMARY

The Mary River Project is an operating high-grade iron mine located in the Qikiqtani Region of northern Baffin Island, Nunavut. Owned and operated by Baffinland Iron Mines Corporation (Baffinland), the mine began commercial operation in 2015. Mining activities at the Mary River Project include open pit ore extraction, ore haulage, stockpiling, crushing, and screening, followed by transport by truck to Milne Port for subsequent seasonal loading onto bulk carrier ships for transfer to European markets. No milling or additional processing of the ore is conducted on-site and therefore no tailings are produced at the Mary River Project. Mine waste management facilities at the Mary River Project thus consist simply of a mine waste rock stockpile and surface runoff collection/containment ponds currently situated near the mine waste rock stockpile and ore stockpile areas.

The Mary River Project became subject to the Metal Mining Effluent Regulations (MMER) under the *Fisheries Act* in July 2015. The MMER outline requirements for routine effluent and water quality monitoring and for biological monitoring, collectively referred to as Environmental Effects Monitoring (EEM) studies. The objective of EEM is to determine whether mine effluent is causing an effect on the fish population, the use of fisheries resources (i.e., mercury accumulation in fish tissues) and/or fish habitat (benthic invertebrate communities). A Study Design for the initial phase of biological EEM at the Mary River Project was submitted to, and following comments and discussions, approved by Environment and Climate Change Canada (ECCC). The field component of the Phase 1 EEM biological study at Mary River Project was implemented in August 2017 using the approach outlined in the approved study design, focusing on the evaluation of effects at effluent-exposed areas of two watercourses, Mary River Tributary-F and Mary River. In accordance with MMER requirements, this Interpretive Report provides a summary of effluent and water quality monitoring data and the results of the Mary River Project Phase 1 EEM biological study.

Effluent from the Mary River Project primary discharge (MS-08) met all MMER limits during normal mine operations in 2015, 2016 and, with the exception of the discharge of effluent with low pH and elevated mean monthly Total Suspended Solids (TSS) concentrations in August and/or September, also met MMER limits in 2017. The mine effluent was non-acutely lethal to rainbow trout and *Daphnia magna* in each of 2015 and 2016, but was acutely toxic to both test species in an August 2017 test and to *D. magna* in a September 2017 test. Due diligence and corrective actions related to these non-compliant discharges were undertaken by Baffinland in 2017 (Appendix B). Sublethal toxicity tests conducted using final effluent samples showed no effects on survival or growth of fathead minnow or on growth of green algae over the Phase 1 EEM period. Occasional effects on survival and/or reproduction of planktonic invertebrates and more consistent growth inhibition to duckweed were shown in effluent sublethal toxicity tests conducted from 2015 to 2017. However, effects to these test organisms were observed at effluent concentrations higher than those typically expected within the mine receiving environment, suggesting limited potential for similar sublethal toxicity effects within the immediate Mary River Tributary-F effluent-exposed area. Effluent concentrations estimated for the immediate receiving waters of Mary River Tributary-F were less than 1% after complete mixing based on extrapolation of field specific conductance measures and hydrological gauging station data in 2017.

Water chemistry at effluent-exposed areas of Mary River Tributary-F showed slightly elevated ammonia, nitrate and/or sulphate concentrations compared to reference conditions during periods of effluent discharge in 2016 and 2017, but concentrations of these parameters were consistently well below applicable water quality guidelines (WQG). Within the effluent-exposed area of Mary River, average nitrate concentrations were slightly elevated compared to the applicable reference area, but only in 2017 and concentrations remained well below WQG, suggesting that the elevated nitrate concentrations were not ecologically meaningful.

The benthic invertebrate community survey indicated no significant differences in primary EEM endpoints of density, richness, Simpson's Evenness and Bray-Curtis Index between effluent-exposed and reference areas of Mary River Tributary-F. In turn, this suggested no adverse influences to the benthic invertebrate community of Mary River Tributary-F associated with exposure to mine effluent. The fish population survey indicated no substantial differences in community species composition between the effluent-exposed and reference areas of Mary River, but potentially higher abundance of fish at the effluent-exposed area due to natural habitat factors. The Mary River arctic charr (*Salvelinus alpinus*) population showed no significant difference in size (length-frequency) structure, and no significant difference in proportion of young-of-the-year (YOY) individuals between the effluent-exposed and reference areas. In addition, length and weight of non-YOY arctic charr did not differ significantly between populations sampled at the effluent-exposed and reference areas of Mary River. Although non-YOY arctic charr captured at the effluent-exposed area had significantly lower condition (length-at-weight relationship) than those captured at the reference area, the magnitude of this difference was small (i.e., -4.5%) and within the applicable fish condition Critical Effect Size of ±10% used for EEM studies, suggesting that this difference was not ecologically meaningful.

Overall, the Mary River Project Phase 1 EEM indicated very low effluent concentrations within the immediate Mary River Tributary-F receiving environment. Commensurately, only minor effluent-related influences on water quality of this watercourse and farther downstream at Mary River during periods of effluent discharge were indicated, with pH and concentrations of all parameters potentially associated with the mine effluent consistently meeting applicable WQG in both watercourses. Although Mary River non-YOY arctic charr had lower condition at the effluent-exposed area than at the reference area, concentrations of mine-related parameters well below WQG and no effluent-related influences on primary EEM benthic invertebrate community endpoints closer to the effluent discharge at Mary River Tributary-F suggested that factors other than mine-effluent accounted for this difference in non-YOY arctic charr condition.

Based on the prescribed EEM frequency under the MMER, the Study Design for the next Mary River Project EEM biological study must be submitted to ECCC no later than six months prior to implementing field collections in 2020. Using the EEM framework, the next phase of biological monitoring (Phase 2) will require an effects assessment, in part, to determine whether the occurrence of the difference in fish condition indicated in this initial Phase 1 EEM is consistent. The corresponding Interpretive Report will be required to be submitted to ECCC by January 10th, 2021.

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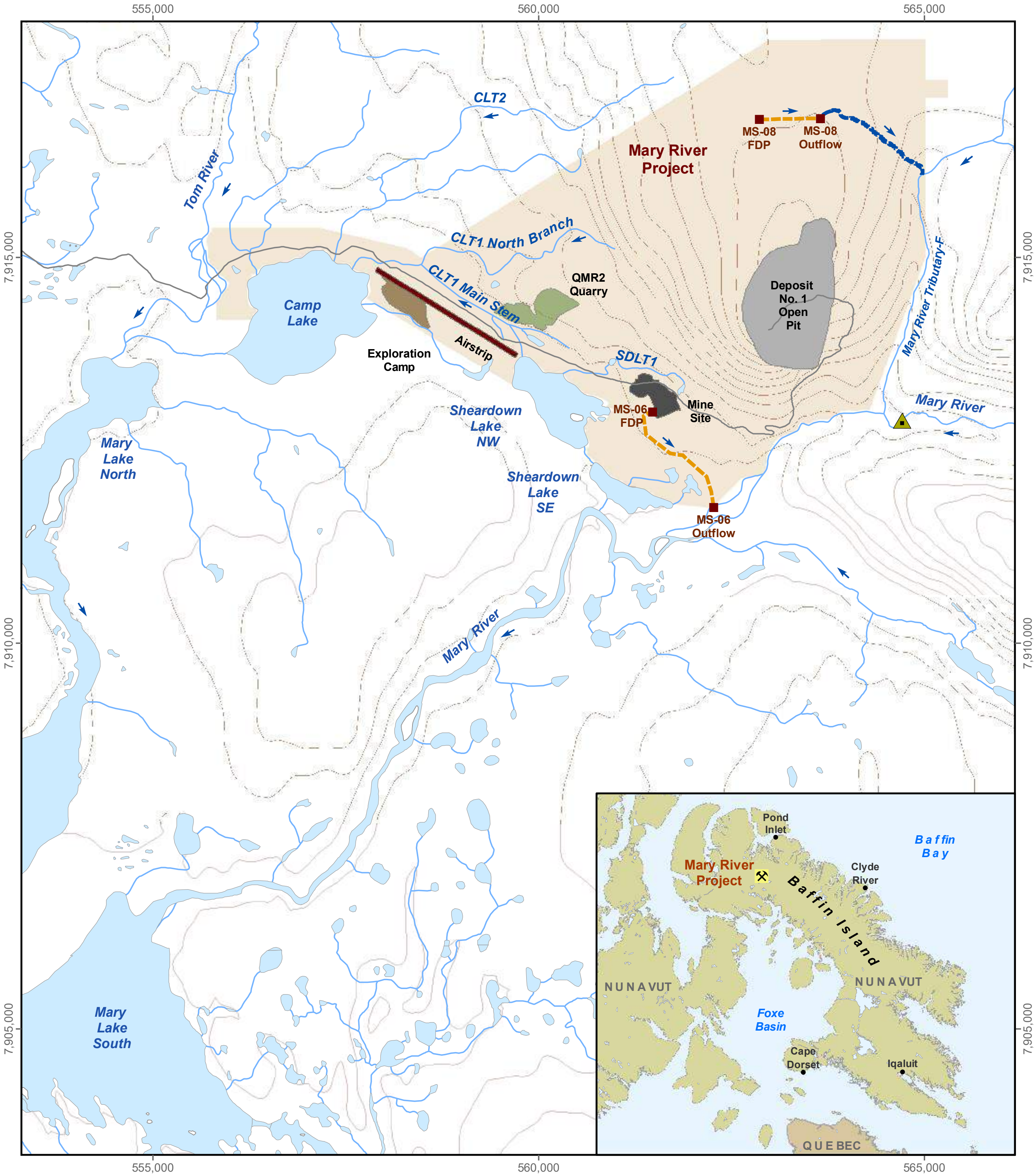
1 INTRODUCTION

The Mary River Project, owned and operated by Baffinland Iron Mines Corporation (Baffinland), is a high-grade iron ore mining operation located in the Qikiqtani Region of northern Baffin Island, Nunavut (Figure 1.1). Open pit mining, including pit bench development, ore haulage and stockpiling, and the crushing and screening of high-grade iron ore, commenced at the Mary River Project in mid-September 2014. No milling or additional ore processing is conducted on-site. For the initial mining stages at the Mary River Project, as much as 4.2 million tonnes (Mt) of crushed/screened ore is transported annually by truck to Milne Port, which is located approximately 100 km north of the mine site. At Milne Port, the ore is stockpiled before being loaded onto bulk carrier ships for transport to European markets during the summer ice-free period. No tailings are produced during ore processing, and therefore mine waste management facilities at the Mary River Project include a mine waste rock stockpile and surface runoff collection ponds currently situated near the mine waste rock stockpile and ore stockpile areas.

The Mary River Project became subject to the Metal Mining Effluent Regulations (MMER) under the *Fisheries Act* in July 2015 as a result of the discharge of effluent in excess of 50 cubic meters (m^3) per day from a temporary mine waste rock settling pond. The MMER outline requirements for routine effluent and water quality monitoring and for biological monitoring, collectively referred to as Environmental Effects Monitoring (EEM) studies, as a condition governing the authority to discharge effluent (Environment Canada 2012; Government of Canada 2017). The objective of EEM is to determine whether mine effluent is causing an effect on the fish population, the use of fisheries resources (i.e., mercury accumulation in fish tissues) and/or fish habitat (benthic invertebrate communities; Environment Canada 2012). In August 2016, a Study Design for the initial phase of biological EEM at the Mary River Project (herein referred to as the Mary River Project Phase 1 EEM) was provided to Environment and Climate Change Canada (ECCC; Minnow 2016a). Approval of the study design was received from ECCC following comment and discussions conducted at the site on August 16th and 17th, 2017 (Appendix A). The field component of the initial Phase 1 EEM biological study at the Mary River Project was implemented in August 2017 with no deviations from the approved Study Design. In accordance with MMER requirements, this Interpretive Report provides a summary of effluent and water quality monitoring data and the methods, results and conclusions of the Mary River Project Phase 1 EEM biological study.



LEGEND

- Final Discharge Point (FDP)
- Mary River Cascade Barrier
- Discharge Line
- Overland Effluent Channel
- QMR2 Quarry
- Airstrip
- Exploration Camp
- Mine Site
- Open Pit
- Mary River Project

Baffinland Iron Mines Corporation, Mary River Project Location

0 1 2 4 km

Map Projection: UTM Zone 17N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Rights of Canada, Department of Natural Resources Canada. All rights reserved.

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Project 177202.0033

minnow environmental inc.

Figure 1.1

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2 METHODS

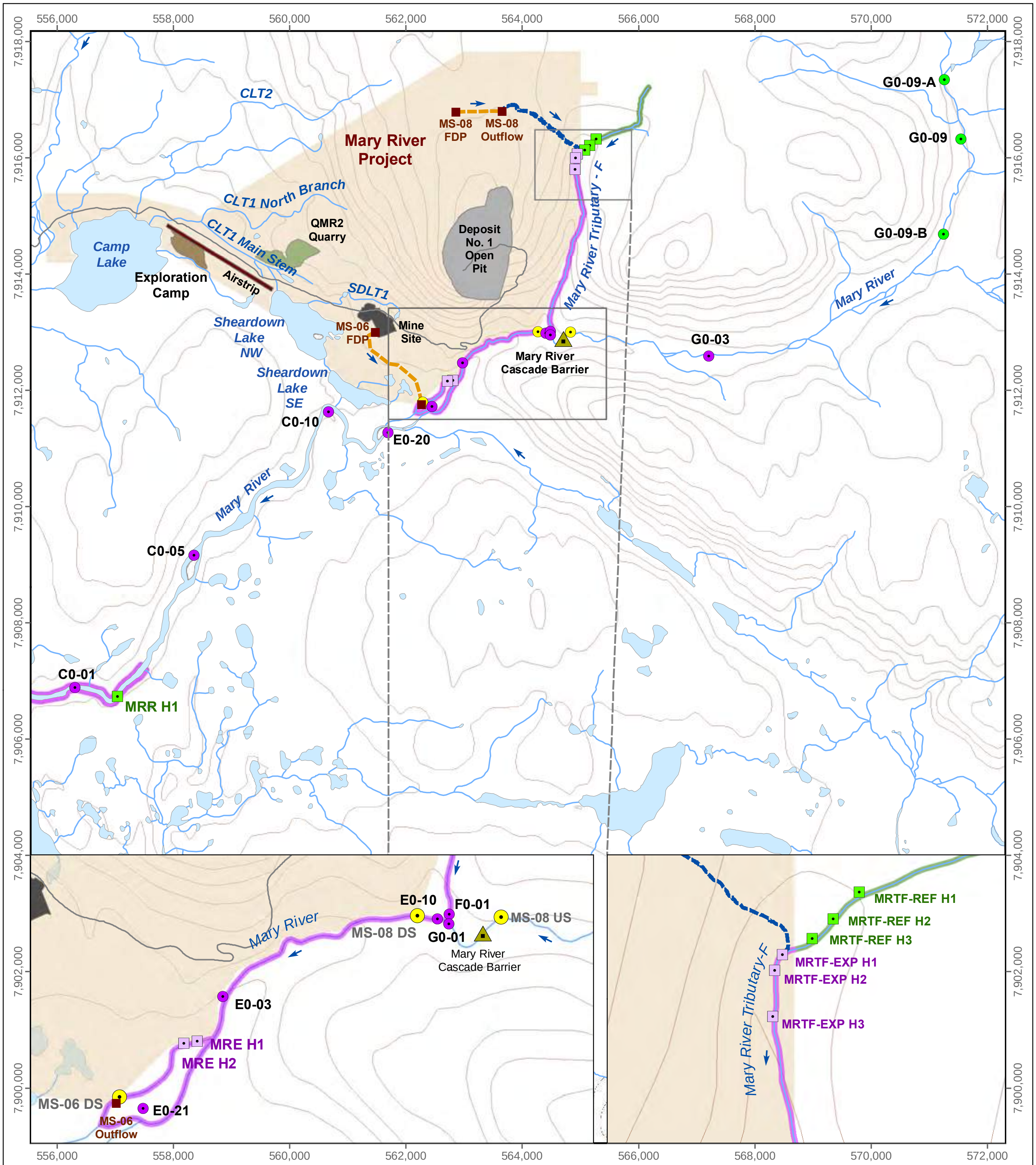
2.1 Overview

The EEM program consists of effluent and receiving environment water quality studies and biological studies (Government of Canada 2017). Effluent characterization, effluent sublethal toxicity testing, and receiving environment water quality monitoring was conducted by Baffinland environment department personnel during periods of effluent discharge in accordance with EEM requirements (Environment Canada 2012) over the 2015 to 2017 Phase 1 EEM period. Additional receiving environment water quality data were also collected at the same time as implementation of the biological monitoring field study. The Mary River Project Phase 1 EEM biological study, including a benthic invertebrate community survey and a fish population survey, was implemented from August 24th to 28th, 2017 led by Minnow Environmental Inc. (Minnow) biologists. The Phase 1 EEM biological field study also included collection of habitat information to support the interpretation of benthic invertebrate community and fish population data (Appendix C). Effluent total mercury concentrations were consistently below 0.10 µg/L since the mine became subject to the MMER in July 2015, and therefore no fish tissue survey was required as part of the Mary River Project Phase 1 EEM biological study in accordance with the MMER statutes (Environment Canada 2012; Minnow 2016a). Each EEM study component incorporated a data quality program to provide checks for sample collection and analysis, and to allow for data quality to be assessed in the context of the study objectives. A description of the Mary River Project Phase 1 EEM study areas and the methods used for sample collection, sample processing and data analysis for each study component are described in the sub-sections below.

2.2 Study Area Locations and Habitat Characterization

Wastewater management at the Mary River Project includes the collection of surface and seepage water originating from the mine waste rock stockpile into a containment pond. Following solids removal via pond-based settling and verification that effluent quality is compliant with applicable territorial and federal limits, effluent is piped to a Final Discharge Point (FDP) located approximately 875 m southeast of the containment pond, referred to as Station MS-08 (Figure 2.1). At the MS-08 FDP, mine effluent is released overland (i.e., no defined channel) into a depression that then meets with an unnamed tributary to the Mary River, herein referred to as Mary River Tributary-F, approximately 2.2 km southeast of the discharge point. From this confluence, Mary River Tributary-F flows south approximately 3.3 km before discharging into Mary River (Figure 2.1).

For the purposes of the Phase 1 EEM biological study, Mary River Tributary-F downstream of the effluent confluence and Mary River extending approximately 2 km downstream of the Mary River



LEGEND

- Final Discharge Point (FDP)

Habitat Station

- Effluent-Exposed
- Reference

CREMP Water Quality Monitoring Station

- Mine Exposed
- Reference

- EEM Water Quality Monitoring Station
- Discharge Line
- Overland Effluent Channel
- EEM Effluent-Exposed Area
- EEM Reference Area

Mary River Project Water Quality Monitoring and Field Study Habitat Stations

0 1.5 3 6 km

Map Projection: UTM Zone 17N NAD 1983
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minnow environmental inc.

Figure 2.1

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Tributary-F confluence served as the mine effluent-exposed areas for the benthic invertebrate community survey and fish population survey, respectively (Figure 2.1). Reference areas for the 2017 EEM study included Mary River Tributary-F upstream of the effluent channel for the benthic invertebrate community survey, and Mary River just upstream of Mary Lake for the fish population survey (Figure 2.1). Separate reference areas were required for the benthic invertebrate and fish community surveys because in part, as confirmed during the Phase 1 EEM biological study, fish are naturally absent from Mary River Tributary-F. Similarly, an approximately 20 m high cascade located on Mary River just upstream of the Mary River Tributary-F confluence acts as an impassable barrier to fish migration, contributing to the natural absence of fish from areas located upstream of this confluence and precluding its use as a reference area. Following consultation with ECCC during meetings held on August 16th and 17th, 2017, it was agreed that Mary River upstream of Mary Lake would serve as an appropriate reference area for the fish population survey given known differences in water quality at other candidate reference areas (e.g., Tom River) and authorized fish collection permit conditions.

Habitat characterization was conducted at the Phase 1 EEM study areas to allow evaluation of comparability in abiotic and biotic features between the effluent-exposed and reference study areas used for the benthic invertebrate community and fish population surveys (Figure 2.1). At each study area, a general characterization of riffle habitat was conducted at one to three stations[1] that included transect measurements of wetted and bankfull channel width (m), water depth (cm), water velocity (m/s) and substrate size (intermediate axis diameter in mm). In addition, determination of stream gradient, and qualitative estimates for features including stream morphology, relative substrate composition, instream vegetation (e.g., algae and/or macrophytes) and relative amounts of functional instream fish cover structure was conducted at each station. At each transect, channel width was determined using a measuring tape, and water depth and velocity were measured from 3 – 19 points[1] using a standard wading rod and a Hach FH950 Velocity Flow Meter with electromagnetic sensor (Hach, Loveland, CO), respectively. Gradient was determined using a Suunto PM-5/360 PC clinometer (Suunto, Vantaa, Finland). The habitat characterization data formed the basis for habitat descriptions for each study area, which are appended in this report (Appendix C). Where station replication allowed (i.e., minimum of three stations per area), quantitative data were compared statistically between the effluent-exposed

[1] Habitat characterization was conducted at three stations from each benthic invertebrate community study area, two stations at the effluent-exposed fish population study area, and one station at the reference fish population study area. The number of stations, and number of sampling points along transects, varied based on channel width, habitat complexity and relative ease of sampling (as dictated by depth, water velocity and safety concerns associated with these variables).

and reference areas. These results, as well as the general comparisons of qualitative features, were taken into consideration during interpretation of the EEM biological data.

2.3 Effluent and Water Quality Monitoring

Effluent monitoring (effluent volume, chemical characterization, and sub-lethal toxicity) and receiving environment water quality monitoring (chemical characterization) were conducted at the Mary River Project in accordance with MMER requirements (Environment Canada 2012). As part of its EEM requirements, Baffinland must provide an annual effluent and receiving environment water quality monitoring report to ECCC by March 31st of the following year that includes sampling locations, dates, methods and results together with information on quality assurance and quality control (QA/QC) for this sampling (Government of Canada 2017). Only a summary of routine effluent and water quality monitoring data need be included in the EEM interpretive report, and therefore the following paragraphs provide a brief overview of the effluent and receiving environment water quality monitoring methods. Additional receiving environment water quality samples were collected at the same time as the biological study to support interpretation of the benthic invertebrate community and fish population data, and therefore more detailed methods pertaining to the collection and analyses of these samples are provided below.

2.3.1 Effluent Quality

Effluent quality monitoring included routine monitoring for MMER deleterious substances, effluent characterization, and effluent sub-lethal toxicity sampling and testing. During periods of discharge, effluent volume and chemistry samples for routine MMER sampling and chemical characterization were collected at two final discharge points of compliance, referred to as Station MS-08 and Station MS-06 (Figure 2.1). Volumes of effluent discharged from the final discharge points monitored continuously in cubic metres per day (m^3/day) were compared using monthly averages and cumulative totals (in m^3) by year. In addition to MMER deleterious substances (total suspended solids, arsenic, copper, lead, nickel, zinc and radium-226) and pH, effluent characterization included analysis of temperature, conductivity, hardness, alkalinity, ammonia, nitrate, sulphate and other metals required for EEM (i.e., aluminum, cadmium, iron, mercury, molybdenum and selenium). Effluent characterization samples were collected up to four times per calendar year at intervals of not less than 30 days apart from the final effluent discharge point in accordance with the MMER[2]. Monthly means were calculated for each of the monitored parameters, with those for deleterious substances and mercury compared to MMER limits and to

[2] Because effluent is discharged intermittently over the course of a relatively short open-water period (i.e., approximately 3 – 4 months), the requirement that effluent characterization and sublethal toxicity samples be collected not less than 30 days apart can result in a frequency of sampling events lower than four and two times per year, respectively.

the EEM fish tissue survey trigger limit (i.e., 0.1 µg/L), respectively. The monthly mean data were also compared over the Phase 1 EEM period as a means to track changes in effluent quality over time.

Effluent samples were collected monthly for acute lethality testing, and up to two times per calendar year for sublethal toxicity testing using effluent collected at Station MS-08[2]. Final effluent samples were collected into pre-labelled plastic containers provided by the toxicity laboratory, put on ice inside coolers, and shipped to the toxicity laboratory where they arrived within 48 hours of collection. Acute toxicity tests were conducted using rainbow trout (*Oncorhynchus mykiss*) and the invertebrate *Daphnia magna* in accordance with standard Environment Canada (1990, 2000) protocols. Sublethal toxicity tests were conducted using fathead minnow (*Pimephales promelas;* 7-day survival and growth test), a cladoceran invertebrate (*Ceriodaphnia dubia;* 7-day survival and reproduction test), duckweed (*Lemna minor*; 7-day growth inhibition test), and a green alga (*Pseudokirchneriella subcapitata*; 3-day growth inhibition test) using standard test methods (i.e., Environment Canada 2007a,b,c; 2011). For fathead minnow and *C. dubia* tests, an LC_{50} (i.e., lethal concentration to 50% of test organisms) was calculated from the mortality data by laboratory personnel. Chronic toxicity test IC_{25} (inhibitory concentration that reduced larval fathead minnow growth by 25%, reduced the number of *C. dubia* neonates produced by 25%, inhibited *P. subcapitata* and *L. minor* growth and/or frond production by 25%) values were calculated from the growth or reproductive data. Reference toxicant testing was employed to ensure that all test systems met protocol criteria during effluent testing. All IC_{25} data were derived by the toxicity laboratory using non-linear regression models or linear interpolation, as appropriate, aided by Comprehensive Environmental Toxicity Information System (CETIS) software (Tidepool Scientific Software, McKinleyville, CA). As required under the MMER, the sub-lethal toxicity data were reported to ECCC as part of Baffinland quarterly and annual reporting for the Mary River Project, the results of which are summarized in this report.

2.3.2 Receiving Environment Water Quality

2.3.2.1 Sample Collection and Laboratory Analysis

Receiving environment water quality monitoring included collection of *in situ* measurements and samples for water chemistry analysis. During biological monitoring, *in situ* water temperature, dissolved oxygen, pH and specific conductance (i.e., temperature standardized measurement of conductivity) was measured near the bottom of the water column at all benthic invertebrate community (benthic) stations and fish population study areas. These measurements were made using a calibrated YSI ProDSS (Digital Sampling System) meter equipped with a 4-Port sensor (YSI Inc., Yellow Springs, OH). Additional supporting water quality information, including observations of water colour and clarity, were also recorded at each benthic station during EEM biological sampling.

Receiving environment water quality monitoring data were collected routinely by Baffinland personnel at two designated MMER-EEM stations located on Mary River. Water sampling for EEM is conducted at an effluent-exposed station located downstream of the Mary River Tributary-F confluence on Mary River (Station MS-08-DS), and at a reference station situated upstream of the cascade barrier and Mary River Tributary-F confluence on Mary River (Station MS-08-US; Figure 2.1). In accordance with the MMER, the routine receiving environment water samples were collected during periods of effluent discharge not less than 30 days between sampling events up to four times per calendar year[3]. In addition to the sampling stations indicated above, routine water quality monitoring is conducted on Mary River Tributary-F (Station FO-01) and additional reference (GO series stations), effluent-exposed (EO series stations) and other (CO series stations) locations on Mary River (Figure 2.1) to meet environmental regulatory requirements outside of the MMER. Water chemistry samples were collected by hand from mid-column directly into labelled sample bottles pre-dosed with required chemical preservatives or into collection bottles triple-rinsed with ambient water for analyses not requiring sample preservation using methods consistent with Baffinland standard operating procedures. Following collection, the water quality samples were placed in coolers and maintained at cool temperatures during shipment to the analytical laboratory. Water quality samples collected during the biological field study were shipped to ALS Global (Waterloo, ON) for analysis. The water chemistry samples were analyzed for the same parameters indicated previously for routine effluent monitoring and effluent characterization using standard laboratory methods. Although holding times for water chemistry samples were generally adhered to, logistical constraints related to the remoteness of the Mary River Project occasionally resulted in the analysis of parameters such as pH that were outside of recommended holding times.

2.3.2.2 Data Analysis

In situ water quality measurements were compared statistically between Mary River Tributary-F effluent-exposed and reference benthic study areas, and between Mary River fish population survey study areas using Analysis-of-Variance (ANOVA). Prior to conducting the ANOVA tests, data were $\log_{10}$ transformed as required to meet assumptions of normality and homogeneity of variance. In instances where normality could not be achieved through data transformation, non-parametric Mann-Whitney U-tests were used to validate the statistical results from the ANOVA

[3] Because effluent is discharged intermittently over the course of a relatively short open-water period (i.e., approximately 3 – 4 months), the requirement that receiving environment water chemistry samples be collected not less than 30 days apart can result in a frequency of sampling events lower than four times per year.

tests. Similarly, in instances in which variances of normal data could not be homogenized by transformation, pair-wise comparisons were conducted using Student's t-tests assuming unequal variance to validate the statistical findings of the ANOVA tests. All statistical comparisons were conducted using SPSS Version 12.0 software (SPSS Inc., Chicago, IL). In addition to these comparisons, dissolved oxygen and pH data from each station were compared to applicable Water Quality Guidelines for the protection of aquatic life (WQG)[4]. Effluent concentration in the mine receiver at the time of EEM biological sampling was estimated through extrapolation of field measured specific conductance at the benthic effluent-exposed and reference areas and daily average specific conductance of the MS-08 effluent discharge from August 30th to September 5th, 2017 (i.e., 2,658 µS/cm) as described in Environment Canada (2012).

Water chemistry data were compared between the mine effluent-exposed and reference areas and to applicable WQG. To simplify the discussion of results, the magnitude of difference in parameter concentrations was calculated as the effluent-exposed area concentration divided by the respective reference area concentration. The magnitude of difference in parameter concentrations was qualitatively assigned as slightly, moderately or highly elevated compared to concentrations measured at the reference area using the categorization described in Table 2.1.

Table 2.1: Magnitude of Difference Categorizations for Water Chemistry Comparisons

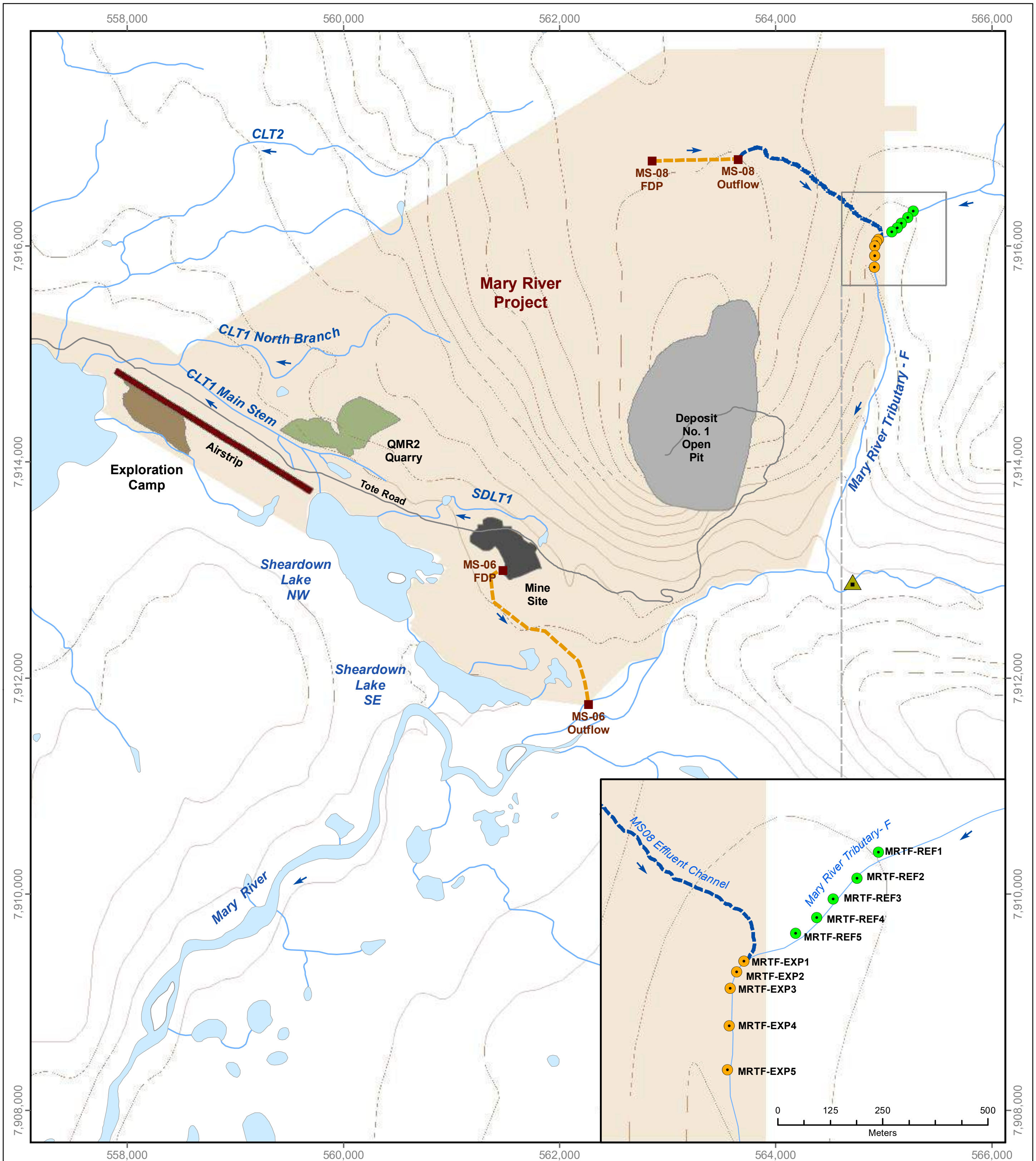
Categorization	Magnitude of Difference Criterion
Slightly elevated	Concentration 3-fold to 5-fold higher at effluent-exposed area versus the reference area.
Moderately elevated	Concentration 5-fold to 10-fold higher at effluent-exposed area versus the reference area.
Highly elevated	Concentration ≥ 10-fold higher at effluent-exposed area versus the reference area.

2.4 Benthic Invertebrate Community Survey

2.4.1 Overview

A standard EEM benthic invertebrate community (benthic) survey was conducted for the Mary River Project Phase 1 EEM (Minnow 2016a). The benthic survey employed a Control-Impact design with sampling conducted at Mary River Tributary-F downstream (MRTF-EXP; effluent-exposed) and upstream (MRTF-REF; reference) of the channel receiving effluent from the MS-08 FDP (Figure 2.2). Five stations were sampled at each study area to provide adequate statistical

[4] Canadian Environmental Quality Guidelines (CCME 1999, 2017) were used as the primary source for WQG. For parameters in which no CCME guideline was available, Ontario Provincial Water Quality Objectives (OMOEE 1994) or British Columbia Water Quality Guidelines (BCMOE 2017) were used as WQG.



LEGEND

Benthic Invertebrate Station

- Effluent-Exposed
- Reference
- Final Discharge Point (FDP)
- Mary River Cascade Barrier
- Discharge Line
- Overland Effluent Channel

Benthic Invertebrate Community Station Locations for the Mary River Project EEM, August 2017

0 0.75 1.5 3 km

N W E S

Map Projection: UTM Zone 17N NAD 1983
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Figure 2.2

Document Path: S:\Projects\177202\177202.0033 - Baffinland 2017\2 - Mapping\Interpretive Report\17-33 Fig 2.2 BI Station Locations.mxd power to detect differences in benthic metrics of ± two standard deviations at an α and β of 0.10, which is consistent with EEM guidance (Environment Canada 2012). Habitat features including sampling depth and physical properties of the substrate were standardized among stations and between areas, to the extent possible, to minimize natural habitat influences as a factor contributing to benthic invertebrate community differences between study areas.

2.4.2 Sample Collection and Laboratory Analysis

Shallow (≤0.3 m) riffle-run habitat characterized by cobble-gravel substrate (i.e., erosional habitat) was targeted for benthic sampling at study areas within the Mary River Tributary-F (MRTF) system. Water depths in riffle habitat at MRTF study areas at the time of the August 2017 EEM field study were typically less than 10 cm (Appendix C) and at least 15 cm of water is required to effectively sample with a Hess sampler. Water depths as little as 3 cm can be sampled using a Surber sampler and therefore, following consultation with ECCC, the collection equipment for the EEM benthic invertebrate community survey was changed to a Surber sampler rather than a Hess sampler as indicated in the original Minnow (2016a) study design[5]. The Surber sampler used to collect the benthic samples had a sampling area 0.093 m^2 and was equipped with 500-μm mesh. At each station, one sample representing a composite of three sub-samples (i.e., 0.279 m^2 total area), was collected to ensure a representative sample. Each sub-sample was collected by carefully placing the sampler on undisturbed substrate and subsequently scrubbing all coarse material within the sampler area (to a depth of approximately 10 cm) while allowing the current to carry all dislodged organisms into the sampler net. After all substrate within the sampler was completely washed, the sampler was moved to the next sub-sample location and the procedure repeated. Following collection of the third sub-sample using the above procedure, all material and organisms retained in the collection net were carefully transferred into pre-labeled wide-mouth plastic jars. As a precautionary measure, internal sample labels were also used to ensure correct sample identification at the lab. Supporting information collected at each station included measurement of sampling depth (cm), water velocity (m/s), and substrate size (intermediate axis diameter in mm), qualitative estimates of substrate embeddedness (%) and vegetation presence (type and %), general habitat notes (e.g., presence of oxyhydroxide precipitate/deposition), *in situ* surface water quality at the sediment-water interface (see Section 2.3.2), and global positioning system (GPS) coordinates (recorded in latitude and longitude decimal degrees and based on the North America Datum of 1983 [NAD 83]).

The benthic samples were preserved to a level of 10% buffered formalin in ambient water following collection. At the conclusion of the field study, the benthic samples were submitted to

[5] The change is sampling equipment was requested through, and granted by, Erik Allen (ECCC, Prairie and Northern Regions) via e-mail correspondence on August 24, 2017.

Zeas Inc. (Nobleton, ON) for analysis following standard sorting methods and incorporating recommended Environment Canada (2012) QA/QC procedures for assessing sub-sampling error and sorting recovery checks (Appendix E). Upon arrival at the laboratory, a biological stain was added to each benthic invertebrate community sample to facilitate greater sorting accuracy. The samples were washed free of formalin in a 500 µm sieve and the remaining sample material was then examined under a stereomicroscope at a magnification of at least ten times by a technician. All benthic invertebrates were removed from the sample debris and placed into vials containing a 70% ethanol solution according to major taxonomic groups (e.g., phyla, orders). A senior taxonomist later enumerated and identified the benthic organisms to the lowest practical level (typically to genus or species) using up-to-date taxonomic keys. Following identification, representative specimens of each taxon were preserved in a 75% ethanol/3% glycerol solution, placed in separately labeled vials, and stored as part of a voucher collection for potential future reference for the Mary River Project EEM.

2.4.3 Data Analysis

Analysis of benthic invertebrate community data was completed at both family level (FL) and lowest practical level (LPL) of taxonomic identification. Although statistical analysis of the data was conducted at both levels of taxonomy (Appendix E), FL taxonomy was used as the basis for evaluation of ‘effects’ as this level of taxonomy is recommended for EEM (Environment Canada 2012), with the LPL taxonomy used to provide more comprehensive evaluation of the benthic data. Benthic invertebrate communities were assessed using EEM primary metrics of mean taxonomic richness (number of taxa), mean invertebrate abundance (or “density”; average number of organisms per m^2), Simpson’s Evenness Index (E) and the Bray-Curtis Index of Dissimilarity as required under the MMER (Table 2.2; Environment Canada 2012). Simpson’s E and Bray-Curtis indices were calculated separately for FL and LPL taxonomy using formula provided by Environment Canada (2012). Additional comparisons were conducted using absolute densities and the percent composition of dominant/indicator taxa, functional feeding groups and habitat preference groups (calculated as the abundance of each respective taxon group relative to the total number of organisms in the sample). Dominant/indicator taxon groups were defined as those groups representing greater than 10% of the community at any one station and/or an average of greater than 5% of the community at any one study area, or any groups considered to be important indicators of environmental stress. Functional feeding groups (FFG) and habitat preference groups (HPG) were assigned based on Pennak (1989), Mandaville (2002), and/or Merritt et al. (2008) designations for each taxon.

All required and supplementary benthic invertebrate community endpoints were summarized by separately reporting mean, median, minimum, maximum, standard deviation, standard error and

Table 2.2: Required and Supporting Endpoints to be Examined for EEM Benthic Invertebrate Community Survey

Response	Endpoint	Critical Effect Size
Effects on Benthic Invertebrates [a]	Organism density (number of invertebrates·m^2)	± 2 reference standard deviations of the mean
	Taxonomic richness (number of taxa)	± 2 reference standard deviations of the mean
	Simpson's Evenness	± 2 reference standard deviations of the mean
	Bray-Curtis Index of dissimilarity	± 2 reference standard deviations of the mean
Supporting Response Variables [b]	Proportion of dominant groups	-
	Proportion of metal-sensitive groups	-
	Proportion of Functional Feeding Groups (FFG)	-
	Shannon-Wiener Diversity	-
	Proportion of Habitat Preference Groups (HPG)	-

[a] Endpoints to be used for determining "effects" as designated by statistically significant differences betw een effluent-exposed and reference areas (Environment Canada 2012)

[b] These analyses are for informational purposes and significant differences betw een exposure and reference areas are not necessarily used to designate an effect (Environment Canada 2012).

sample size for each study area. Differences between the effluent-exposed and reference areas were preferentially tested using ANOVA and untransformed, normally distributed data. However, in the event that data were determined to be non-normal, a suite of transformations including $\log_{10}$, square root, fourth root, and power_2 was applied to the data and evaluated for normality. The transformation that resulted in normal data with lowest skew and kurtosis values was then used for statistical testing using ANOVA. In instances where normality could not be achieved through data transformation, non-parametric Mann-Whitney U-tests were used to validate the statistical results from the ANOVA tests. All statistical comparisons were conducted using R programming (R Foundation for Statistical Computing, Vienna, Austria). An effect on the benthic invertebrate community was defined as a statistically significant difference in taxon richness, density, Simpson's E or Bray-Curtis Index, calculated at FL taxonomy, between the effluent-exposed area and the reference area at an alpha level of 0.10 (Environment Canada 2012).

In addition to statistical comparisons, the magnitude of difference between effluent-exposed and reference area means was calculated for each benthic invertebrate community metric where a significant difference was detected. The benthic invertebrate community survey was designed to have sufficient power to detect a difference (effect size) of ± two standard deviations (SD), and therefore, the magnitude of the difference was calculated to reflect the number of reference mean SD (SD_{REF}) using equations provided by Environment Canada (2012). A Critical Effect Size for the benthic invertebrate community survey (CES_{BIC}) of $\pm$ 2 SD_{REF} was used to define any ecologically relevant 'effects', which is analogous to differences beyond those expected to occur naturally between two areas that are uninfluenced by any anthropogenic inputs (i.e., between pristine reference areas; see Munkittrick et al. 2009; Environment Canada 2012). If a significant difference between areas was not detected for a benthic invertebrate community metric, then the minimum effect size that would be detectable was calculated using the mean square error generated from the ANOVA as an estimate of variability, with alpha and beta equal to 0.10. The minimum detectable effect size was calculated using equations provided by Environment Canada (2012), which are based on the minimum number of reference area standard deviations.

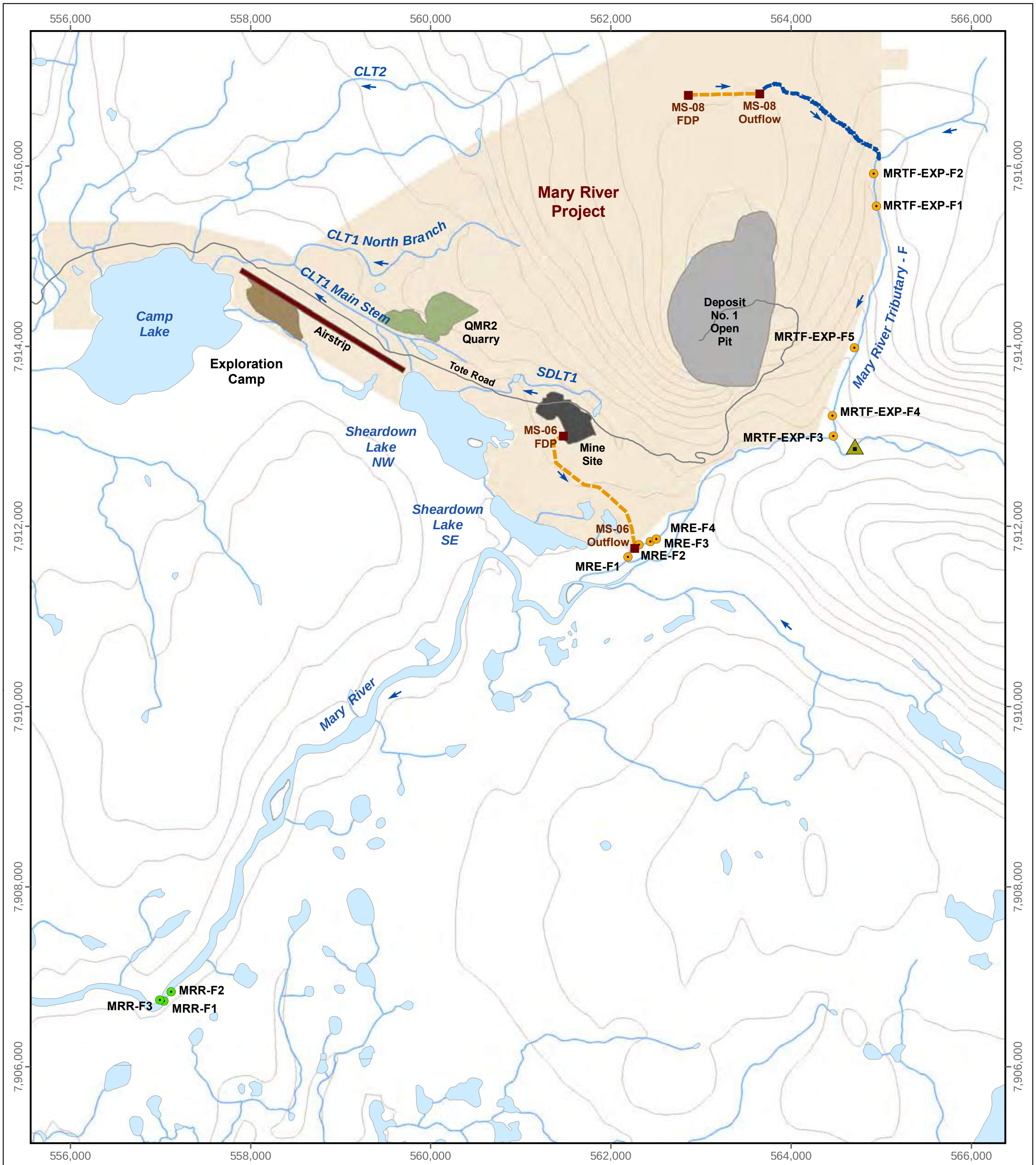
2.5 Fish Population Survey

2.5.1 Overview

The Mary River Project Phase 1 EEM fish population survey employed a non-lethal sampling approach targeting arctic charr (*Salvelinus alpinus*) at representative effluent-exposed and reference study areas (Minnow 2016a). Initial fish sampling conducted at Mary River Tributary-F study areas that were used for benthic sampling indicated that fish were absent at these areas, as well as the entire length of Mary River Tributary-F extending to Mary River (Appendix F). The absence of fish at Mary River Tributary-F is believed to reflect the combination of complete freezing overwinter, a relatively higher stream gradient, and the presence of natural in-stream barriers. An average gradient of 12% was documented through the lower approximate 750 m of Mary River Tributary-F during EEM fish population sampling. In addition, an approximately 1.75 m high step-drop over large boulder habitat occurred approximately 50 m upstream of Mary River on Mary River Tributary-F (Appendix Photo Plate C.1), presenting an impassable barrier for upstream migration by fish. As a result of the natural absence of fish from Mary River Tributary-F, two areas of Mary River were sampled for the EEM fish population survey. A safely-accessible reach on Mary River, located near the confluence with Mary River Tributary-F, and a downstream reach, located near the Mary River outlet to Mary Lake, served as effluent-exposed and reference study areas, respectively, for the fish population survey as agreed upon during meetings held between Baffinland, ECCC and Minnow on August 16th and 17th, 2017 (Figure 2.3)[6].

The targeting of only arctic charr for the Mary River Project EEM, as opposed to two species normally recommended for EEM (Environment Canada 2012), reflected the fact that only this species had been captured in the Mary River system previously (Baffinland 2014). A non-lethal

[6] See Section 2.2 for additional details regarding selection of study areas for the fish population survey.



LEGEND

Fish Survey Sampling Location

- Reference
- Effluent-Exposed
- Final Discharge Point (FDP)
- Mary River Cascade Barrier
- Discharge Line
- Overland Effluent Channel

Fish Survey Sampling Locations for the Mary River Project EEM, August 2017

0 1 2 4 km

Map Projection: UTM Zone 17N NAD 1983

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Figure 2.3

Document Path: S:\Projects\177202\177202.0033 - Baffinland 2017\2 - Mapping\Interpretive Report\17-33 Fig 2.3 Fish Survey Sampling Locations.mxd sampling approach was implemented, in part, because typically only juvenile arctic charr migrate upstream from lakes into rivers and creeks of the Mary River Project region as the latter freeze entirely in the winter (NSC 2015; Minnow 2016a). Moreover, adult arctic charr spawn only every two to three years at latitudes similar to those of the Mary River Project and thus, for those few adults that migrate upstream in rivers, less than half would be expected to be in sufficient reproductive condition, resulting in unacceptable sacrifice to support a lethal sampling approach (Minnow 2016a)[7]. Consistent with EEM sample size requirements for EEM, a minimum of 100 arctic charr juveniles older than young-of-the-year (YOY; referred to as non-YOY herein) were targeted from each study area. Habitat features including sampling depth and physical properties of the substrate were standardized as much as possible between areas during fish population sampling to minimize natural habitat influences as a factor contributing to differences in fish population endpoints between study areas.

2.5.2 Sample Collection and Field and Laboratory Processing

Sampling for the fish population survey was conducted by an electrofishing team consisting of a backpack electrofisher operator and a single netter. At Mary River effluent-exposed and reference study areas, 'open station' sampling was conducted in an upstream direction at four side-channel stations and three shoreline stations, respectively (Figure 2.3). Fish captured at each station were placed into buckets containing aerated water. At the conclusion of sampling at each station, total shocking effort (i.e., electrofishing seconds) was recorded to allow calculation of time-standardized catch, station upstream and downstream boundaries were georeferenced using a handheld GPS unit, and habitat notes pertinent to the fish population survey were recorded. All captured fish were identified, enumerated and with the exception of arctic charr retained for subsequent body measurements (see description below), released at the area of capture. Following the collection of body measurements, arctic charr were released to the waters from which they were captured with the exception of individuals sacrificed for age structure removal.

All retained arctic charr were transported to a dedicated field laboratory for measurements, general observations, and collection of age determination samples required for EEM as timely as possible following collection (Environment Canada 2012). Initial observations conducted at the outset of the processing of individual fish included external condition evaluation for abnormalities and presence/incidence of parasites. For each fish, fork and total length were measured to the nearest millimetre using a standard measuring board, and weight was measured to the nearest

[7] Approximately 39% of arctic charr in the 'adult' size range sampled in August 2015 from Mary River Project area lakes contained sufficiently developed gonads suitable for assessment of reproductive endpoints, of which almost all (97%) of those showing sufficient gonad development were female (Minnow 2016b).

milligram using a digital balance outfitted with a surrounding draft shield. A subset of individuals spanning the entire size range of captured fish was sacrificed for age determination (i.e., approximately 10% of the total number of fish sampled from each study area). These fish were placed in labelled plastic bags following collection of all required morphometric data, and then frozen upon return from the field, for later removal of otoliths for age determination.

Aging samples were shipped frozen to AAE Tech Services Inc. (LaSalle, Manitoba) for otolith removal and processing at the completion of the field program. Pectoral fin rays and/or scales were used as backup aging structures for age determinations. Otoliths were prepared for aging using a “crack and burn” method. If fin rays were used, each was cleaned, embedded in epoxy resin and, after the epoxy hardened, sectioned using a Buehler Isomet (Lake Bluff, IL) low-speed diamond saw. Each otolith or fin ray sample was then mounted on a glass slide using a mounting medium and examined under a compound microscope using transmitted light to determine fish age. For each structure, the age and edge condition was recorded along with a confidence rating for the age determination. Age determinations for half of the otolith samples were also conducted by a second independent analyst to satisfy recommended QA/QC for EEM studies that suggest age confirmation be conducted on a minimum of 10% of samples (Environment Canada 2012).

2.5.3 Data Analysis

Fish community data from respective Mary River effluent-exposed and reference study areas were compared based on total fish species richness, total catch, and total catch-per-unit-effort (CPUE), the latter calculated as the number of fish captured per electrofishing minute. The fish population survey data analysis initially included calculation of mean, median, minimum, maximum, standard deviation, standard error and sample size statistics for arctic charr length, weight and age measurement data by study area, separating YOY from non-YOY (juvenile/adult) life history stages where applicable. These data were used as the basis for evaluating four response categories (survival, growth, reproduction and energy storage; Table 2.3) according to the procedures outlined for a non-lethal, small-bodied fish assessment (Environment Canada 2012). Length-frequency distributions were compared using a non-parametric two-sample Kolmogorov-Smirnov (K-S) goodness of fit test. The size-frequency distributions and confirmatory aging were used to distinguish YOY (age-0) fish from non-YOY age classes, which were then subject to separate evaluation of health endpoints between study areas.

Potential differences in reproductive success between EEM study areas was based on evaluation of the relative proportion of arctic charr YOY between the effluent-exposed and reference areas, and by comparing the results of KS tests conducted with and without YOY individuals included in the data sets. Mean length and body weight were compared between the effluent-exposed and reference study areas using ANOVA, with data evaluated for normality and homogeneity of

Table 2.3: Endpoints to be Examined for EEM Lethal and Non-Lethal Fish Population Survey

Response			Endpoint	Statistical Test[c,d,e]	Critical Effect Size
Lethal Comparisons	Effects on Fish[a]	Survival	Age	ANOVA	± 25%
			Age-frequency distribution	K-S Test	-
		Growth	Size-at-age (body weight against age)	ANCOVA	± 25%
		Reproduction	Relative gonad size (gonad weight against body weight)	ANCOVA	± 25%
		Energy Storage	Condition (body weight against length)	ANCOVA	± 10%
			Relative liver size (liver weight against body weight)	ANCOVA	± 25%
	Supporting Response Variables[b]	Growth	Size-at-age (length against age)	ANCOVA	± 25%
		Reproduction	Relative fecundity (# of eggs against body weight)	ANCOVA	± 25%
		Energy Storage	Relative egg size (mean egg weight against body weight)	ANCOVA	± 25%
Non-Lethal Comparisons	Effects on Fish[a]	Survival	Length-frequency distribution	K-S Test	-
		Growth	Length	ANOVA	± 25%
			Weight	ANOVA	± 25%
		Reproduction	Relative abundance of YOY (% composition)	None	-
		Energy Storage	Condition (body weight against length)	ANCOVA	± 10%

[a] Endpoints to be used for determining "effects" as designated by statistically significant differences between exposure and reference areas (Environment Canada 2012).

[b] These analyses are for informational purposes and significant differences between exposure and reference areas are not necessarily used to designate an effect (Environment Canada 2012).

[c] ANOVA (Analysis of Variance) used except for non-parametric data, where Mann Whitney U-test may be used to verify the results by ANOVA.

[d] ANCOVA (Analysis of Covariance). For the ANCOVA analyses, the first term in parentheses is the endpoint (dependent variable Y) that is analyzed for an effluent effect. The second term in parentheses is the covariate, X (age, weight, or length).

[e] K-S Test (Kolmogorov-Smirnov test).

variance before applying parametric statistical procedures. In cases where data did not meet the assumptions of ANOVA despite transformation, a non-parametric Mann-Whitney U-test was performed to test for/validate significant differences between study areas indicated by the ANOVA. Differences in non-YOY arctic charr condition (weight-at-length relationship) between the effluent-exposed and reference areas were assessed using Analysis of Covariance (ANCOVA) according to methods recommended for EEM by Environment Canada (2012).

Prior to conducting the ANCOVA tests, scatter plots of all variable and covariate combinations were examined to identify outliers, leverage values or other unusual data. The scatter plots were also examined to ensure there was adequate overlap between the effluent-exposed and reference area groups, and that there was a linear relationship between the variable and the covariate. In order to verify the existence of a linear relationship, each relationship was tested using linear regression analysis by area and evaluated at an alpha level of 0.05. If it was determined that there was no significant linear regression relationship between the variable and covariate for the effluent-exposed and/or reference areas, then the ANCOVA was not performed.

Once it was determined that ANCOVA could be used for statistical analysis, the first step in the ANCOVA analysis was to test whether the slopes of the regression lines for the reference and exposure areas were equal. This was accomplished by including an interaction term (dependent × covariate) in the ANCOVA model and evaluating if the interaction term was significantly different, in which case the regression slopes would not be equal between areas and the resulting ANCOVA would provide spurious results. In such cases, two methodologies were employed to assess whether a full ANCOVA could proceed. In order of preference these were: 1) removal of influential points using Cook's distance and re-assessment of equality of slopes; and 2) Coefficients of Determination that considered slopes equal regardless of an interaction effect (Environment Canada 2012). For the Coefficients of Determination, the full ANCOVA was completed to test for main effects, and if the r^2 value of both the parallel regression model (interaction term) and full regression model were greater than 0.8 and within 0.02 units in value, the full ANCOVA model was considered valid (Environment Canada 2012). If both methods proved unacceptable, the magnitude of effect calculation was estimated at both the minimum and maximum overlap of covariate variables between areas (Environment Canada 2012). In this event of a statistically significant interaction effect (slopes are not equal), the calculation of the magnitude of difference at the minimum and maximum values of covariate overlap was not assigned statistical difference as it would under a full ANCOVA model. If the interaction term was not significant (i.e., homogeneous slopes between the two populations), then the full ANCOVA model was run without the interaction term to test for differences in adjusted means between the two populations. The adjusted mean was then used as an estimate of the population mean based on the value of the covariate in the ANCOVA model.

For endpoints showing significant area differences, the magnitude of difference between reference and exposure areas was calculated as described by Environment Canada (2012) using mean (ANOVA), adjusted mean (ANCOVA with no significant interaction) or predicted values (ANCOVA with significant interaction). The anti-log of the mean, adjusted mean, or predicted value was used in the equations for endpoints that were log_{10}-transformed. In addition, the magnitude of difference for ANCOVA with a significant interaction was calculated for each of the minimum and maximum values of the covariate. If there was no significant difference indicated between areas, the minimum detectable effect size was calculated as a percent difference from the reference mean for ANOVA or adjusted reference mean for ANCOVA at alpha = beta = 0.10 using the square root of the mean square error (generated during either the ANOVA or ANCOVA procedures) as a measure of variability in the sample population based on the formula provided by Environment Canada (2012). If outliers or leverage values were observed in a data set(s) upon examination of scatter plots and residuals, then the values were removed and ANOVA or ANCOVA tests were repeated with the reduced data, with both sets of results then provided. Similar to the Critical Effect Sizes (CES) applied to the benthic invertebrate community survey, a fish population survey CES magnitude of difference of ± 25% was applied to general endpoints (CES_G) of survival, growth, reproduction and relative liver size, and a magnitude of difference of ± 10% was applied for condition (CES_C) to define any ecologically relevant differences, consistent with those recommended for EEM (Table 2.3; Munkittrick et al. 2009; Environment Canada 2012).

Finally, an *a priori* power analysis was completed to determine appropriate fish sample sizes for future surveys as recommended by Environment Canada (2012). These analyses were completed based on the mean square error values generated during the ANOVA or ANCOVA procedures and were calculated with alpha and beta set equally at 0.10 for the analysis. Two main assumptions served as the basis for the power analysis. The first assumption was that the fish caught in each of the effluent-exposed and reference areas were representative of the population at large (i.e., similar distribution and variance with respect to the parameters examined). The second assumption was that the characteristics of the populations as a whole would not change substantially prior to the next study. Results were reported as the minimum sample size (number of fish/area) required to detect a given magnitude of difference (effect size) between the effluent-exposed and reference area populations for each endpoint. The magnitude of the difference was presented as a percentage of the reference mean for each endpoint as measured during the fish population study.

3 EFFLUENT QUALITY AND SUBLETHAL TOXICITY

3.1 Effluent Volume and Quality

Effluent discharge from the MS-08 Final Discharge Point (FDP) over the Phase 1 EEM period occurred in July and August in 2015, and from July to September in each of 2016 and 2017 (Figure 3.1), corresponding to the usual open-water period for non-coastal areas of the Mary River Project region. The total monthly volume of effluent discharge ranged from approximately 517 to 7,429 cubic metres (m^3) over this period (Figure 3.1). Notably, effluent was released intermittently on an as-needed basis (i.e., to attempt to maintain sufficient capacity for a 1 in 10-year storm event in the containment pond), typically for a duration of one to three days but up to a maximum of 14 days (Appendix Table D.1). Monthly and cumulative volumes of effluent discharged to the receiving environment were considerably higher in 2017 than in the previous two years of the Phase 1 EEM period (Figure 3.1). Relatively high amounts of effluent released in 2017, on both a daily and cumulative basis (Figure 3.1; Appendix Table D.1), reflected the discharge of site waters stored from the previous season and upgrades to the waste management infrastructure at the Mary River Project between the open water periods of 2016 and 2017. Effluent was discharged from the MS-06 FDP on only a single day in 2016, on September 12th, when approximately 86 m^3 of effluent was discharged from the MS-06 FDP directly to Mary River (Appendix Table D.6).

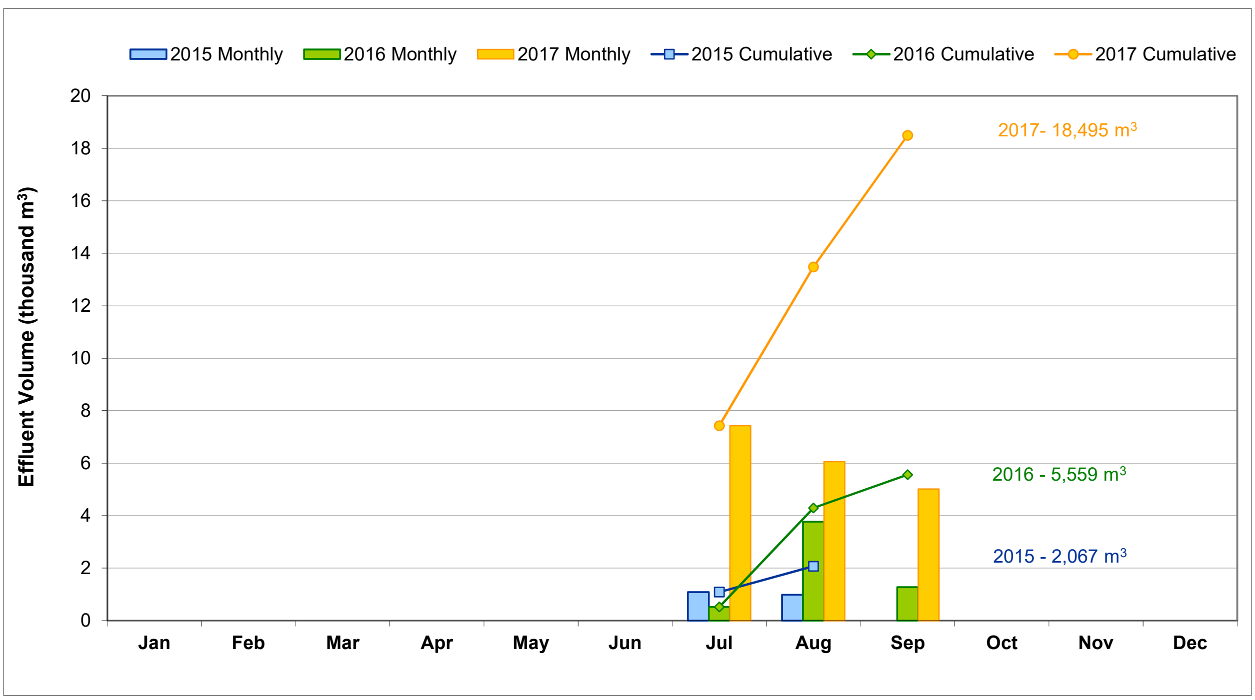


Figure 3.1: Mary River Project Average Monthly and Cumulative Effluent Discharge (Station MS-08) for the Phase 1 EEM Period (2015 - 2017)

Final effluent at MS-08 met MMER authorized pH limits and monthly mean and grab-sample concentration limits in 2015 and 2016 (Table 3.1; Appendix Tables D.2 and D.3). With the exception of pH below the MMER range limit in August and September, and a total suspended solids (TSS) concentration above the MMER monthly mean concentration limit (August) the MS-08 final effluent met all MMER deleterious substance concentration grab limits in 2017 (Table 3.1; Appendix Table D.4). Additional information regarding the non-compliant discharges are appended (Appendix B). Effluent characterization indicated that individual grab-sample mercury concentrations were well below the 0.10 µg/L trigger for an EEM fish tissue survey throughout the Phase 1 EEM period (Appendix Tables D.2 to D.4). On average, MS-08 effluent alkalinity, conductivity, hardness and concentrations of ammonia, cadmium, iron, nickel, nitrate and zinc were higher in August and September 2017 than corresponding monthly averages in 2015 and 2016 (Table 3.1). Higher concentrations of these parameters in 2017 was potentially related to additional containment pond treatment to raise effluent pH (e.g., use of soda ash, Na_2CO_3) and adsorption to suspended particles associated with TSS concentrations (Appendix B). Higher concentrations of some of these parameters (e.g., metals) may have also reflected changes in water chemistry sourcing from the waste rock stockpile in association with upgrades to the waste management infrastructure over the 2016 – 2017 winter period. Final effluent at MS-06 met MMER authorized pH limits and grab-sample concentration limits for the single discharge event in September 2016 (Appendix Table D.6).

Final effluent at MS-08 was consistently non-lethal to rainbow trout (*Oncorhynchus mykiss*) and *Daphnia magna* from July 2015 to July 2017 (n = 6 for both test species; Table 3.1; Appendix Table D.5). However, acutely lethal test results occurred for both test organisms using effluent samples collected August 1st, and for *D. magna* using an effluent sample collected September 5th, in 2017 (Appendix Table D.5). Review of effluent chemistry data for the 2017 samples resulting in acute toxicity suggested a potential causal link with low pH and/or one or more of the parameters indicated above that were shown to be elevated in August and September 2017 (Table 3.1).

3.2 Effluent Sublethal Toxicity

Sublethal toxicity tests conducted using MS-08 final effluent samples over the Phase 1 EEM period showed no adverse effects on survival or growth of fathead minnow (*Pimephales promelas*), or on growth of the green alga, *Pseudokirchneriella subcapitata* (Table 3.2). Survival and reproduction of *Ceriodaphnia dubia* was generally not affected in tests conducted from 2015 through July 2017 (Table 3.2). However, *C. dubia* survival and reproduction was affected at effluent effect concentrations of 20% and 6.5%, respectively, for the effluent sample collected in August 2017. Effluent iron and nickel concentrations were notably higher in the August 2017

Table 3.1: Summary of Routine MMER and Effluent Characterization Data (Station MS-08)[a] for the Mary River Project Phase 1 EEM period, 2015 to 2017

	Analyte	Units	MMER Monthly Mean Limit [d]	2015		2016		2017		
				July	August	July	August	July	August	September
Routine Monitoring [b]	pH (lab)	pH units	6.0 - 9.5	7.51	7.61	7.38	7.05	6.93	6.25	5.75
	Total Suspended Solids	mg/L	15	11.0	7.2	7.3	5.4	3.9	16.8	13.2
	Arsenic (As)	mg/L	0.5	0.0004	0.0001	0.0001	0.0001	0.0001	0.0010	0.0010
	Copper (Cu)	mg/L	0.3	0.0012	0.0013	0.0045	0.0023	0.0048	0.0163	0.0100
	Lead (Pb)	mg/L	0.2	0.0006	0.0002	0.0005	0.0002	0.0004	0.0030	0.0005
	Nickel (Ni)	mg/L	0.5	0.0116	0.0226	0.0118	0.0638	0.0275	0.2643	0.3980
	Zinc (Zn)	mg/L	0.5	0.0037	0.0033	0.0104	0.0070	0.0084	0.0340	0.0320
	Radium-226	Bq/L	0.37	0.010	0.013	0.010	0.015	0.011	0.023	-
Acute Toxicity	Rainbow trout [e]	Pass/Fail	NL	NL (n=1)	NL (n=1)	NL (n=1)	NL (n=2)	NL (n=1)	L (n=1), NL (n=1)	NL (n=1)
	Daphnia magna [e]	Pass/Fail	-	NL (n=1)	NL (n=1)	NL (n=1)	NL (n=2)	NL (n=1)	L (n=2), NL (n=1)	L (n=1)
Effluent Characterization [c]	Specific Conductance (lab)	µS/cm	-	948	1,320	63	1,270	656	3,330	-
	Hardness	mg/L	-	465	724	25	701	318	1,990	-
	Alkalinity	mg/L	-	31.7	44.0	11.0	18.5	10.0	82.0	-
	Ammonia (NH_3)	mg/L	-	0.40	0.47	0.02	0.71	0.43	1.67	-
	Nitrate (NO_3)	mg/L	-	3.8	4.9	0.2	5.1	2.5	8.0	-
	Aluminum (Al)	mg/L	-	0.3120	0.1165	0.6600	0.0385	0.0363	0.0500	-
	Cadmium (Cd)	mg/L	-	0.000070	0.000161	0.000010	0.000182	0.000057	0.000380	-
	Iron (Fe)	mg/L	-	0.47	0.33	0.77	0.30	0.48	7.10	-
	Mercury (Hg)	mg/L	0.0001	0.000010	0.000010	0.000010	0.000010	-	0.000010	-
	Molybdenum (Mo)	mg/L	-	0.0002	0.0003	0.0005	0.0001	0.0001	0.0005	-
	Selenium (Se)	mg/L	-	0.0014	0.0026	0.0001	0.0020	0.0012	0.0047	-

Indicates monthly mean value above applicable limit for deleterious substances, mercury concentration above fish usability assessment trigger value *or* acute toxicity test failure based on individual test result.

[a] In cases where analyte concentrations were less than Method Detection Limits (MDL), the MDL was used for calculation of mean values. Appendix C provides raw data.

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2017).

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2017).

[d] Limits indicated refer to maximum authorized monthly mean concentrations as per MMER except mercury, where the limit provided is the grab concentration trigger for conducting a fish tissue survey for EEM.

[e] Indicates that all acute toxicity tests must 'pass' test criteria (i.e., an effluent at 100% concentration that kills less than 50% of test organisms over a 96-hour [rainbow trout] or 48-hour [*D. magna*] period when tested in accordance with Environment Canada protocols). "NL" refers to a non-lethal 'pass' test result, "L" refers to a lethal 'failure' test result.

Table 3.2: Sublethal Toxicity Test Effluent Effect Concentration Results (% effluent)[a] using Mary River Project Final Effluent (Station MS-08), 2015 - 2017

Study Period	Sample Date	Fathead Minnow		*Ceriodaphnia dubia*		*Lemna minor*		*Pseudokirchneriella subcapitata*
		Survival LC_{50}	Growth IC_{25}	Survival LC_{50} [a]	Reproduction IC_{25} [a]	Dry Weight IC_{25}	Frond Increase IC_{25}	Growth IC_{25}
EEM Phase 1	11-Aug-15	>100	> 100	> 100	> 100	2.6 (1.3 - 4.2)	8.5 (6.0 - 11.7)	> 91
	19-Jul-16	>100	> 100	> 100	91 (60 - 97)	> 97	> 97	> 91 [b]
	30-Aug-16	>100	> 100	> 100	> 100	21.5 (6.9 - 75)	7.9 (5.5 - 9.7)	> 91 [b]
	25-Jul-17	>100	> 100	> 100	> 100	56.2 (33 - 89)	22.8 (16 - 28)	> 91
	24-Aug-17	>100	> 100	20 (9.0 - 100)	6.5 (3.4 - 10)	3.9 (1.7 - 6.1)	1.7 (0.8 - 4.3)	> 91
	Geometric mean	**100**	**100**	**72**	**57**	**16**	**12**	**> 91**

[a] LC_{50} is the effluent concentration causing 50% mortality among tested organisms; IC_{25} is the effluent concentration causing a 25% inhibition/reduction in endpoint compared to the control group for the organism tested.
[b] Significant stimulation of *P. subcapitata* growth was exhibited for tests conducted using final effluent in 2016.

sample compared to effluent used in all previous sublethal toxicity tests, suggesting a causal link. Because cladoceran invertebrates can be sensitive to high dissolved solids concentrations (Mount et al. 1997; Soucek and Kennedy 2005), greater major ion concentrations (e.g., hardness) in the August 2017 effluent sample potentially also contributed to greater sublethal toxicity to this test species than during previous testing. Duckweed (*Lemna minor*) growth inhibition was observed in most tests using the MS-08 effluent, with reduced frond weight and frond production occurring at effluent effect concentrations ranging from approximately 3% to 56% and 2% to 23%, respectively, in all tests conducted except the July 2016 sample in which no toxicity occurred (Table 3.2).

Maximum concentrations of MS-08 effluent at Mary River Tributary-F and Mary River were previously estimated as 1.7% and 0.04%, respectively, based on extrapolation of effluent discharge volumes and watershed hydrology data collected in 2015 (Minnow 2016a). Because the minimum effluent effect concentration for *C. dubia* (i.e., 6.5%) was well above the concentration of effluent expected in Mary River Tributary-F, no toxicity to representative planktonic invertebrates was likely in the MS-08 effluent receiving environment. However, the lowest effluent effect concentrations shown for duckweed were similar to maximum effluent concentrations estimated for Mary River Tributary-F immediately downstream of the MS-08 channel confluence in two of the five tests[8] conducted over the Phase 1 EEM period (Table 3.2). The latter suggested a low potential for effects on growth of a representative aquatic plant species within the immediate Mary River Tributary-F receiving environment. Notably, no aquatic vascular plants were observed at effluent-exposed and reference areas of both Mary River Tributary-F and Mary River during the EEM field study (Appendix C).

[8] This statement takes the 95% confidence limits of the sublethal toxicity test results into account.

4 WATER QUALITY

4.1 Mary River Tributary-F

In situ water temperature was significantly lower at the effluent-exposed area than at the reference area of Mary River Tributary-F at the time of the August 2017 EEM biological field study (Figure 4.1), likely reflecting natural influences of warming ambient air temperature between morning effluent-exposed area and afternoon reference area sampling, respectively, on the day of sampling. Dissolved oxygen (DO) concentrations did not differ significantly between the Mary River Tributary-F effluent-exposed and reference study areas, and were well above the WQG[9] lowest acceptable concentration for sensitive, early life stages of cold water biota (i.e., 9.5 mg/L) at both study areas (Figure 4.1). Although pH was significantly higher at the effluent-exposed area than at the reference area of Mary River Tributary-F, the mean incremental difference in pH between areas was very small (i.e., 0.012 units) and pH values were well within the WQG acceptable range for the protection of aquatic life (Figure 4.1). As a result, the difference in pH between the Mary River Tributary-F effluent-exposed and reference areas was not likely to be ecologically meaningful.

Specific conductance was significantly higher at the effluent-exposed area than at the reference area of Mary River Tributary-F at the time of the August 2017 EEM field study, with the small incremental difference between study areas (i.e., approximately 4 µS/cm) suggesting a slight effluent-related influence on water quality of the tributary (Figure 4.1). Notably, a substantial step increase in specific conductance was observed approximately 1.9 km downstream of the MS-08 effluent channel confluence on Mary River Tributary-F at the time of the August 2017 field study (Appendix Figure D.1). Specific conductance also became elevated at the same location in Mary River Tributary-F (relative to upstream) during reconnaissance sampling in August 2015. The higher specific conductance at this location and farther downstream in Mary River Tributary-F was attributed to the receipt of surface runoff from areas at which chloride salts (e.g., $CaCl_2$) were used to assist with exploratory/operational drilling through material exhibiting subsurface permafrost and/or natural variation in geological properties.

Extrapolation of field measured specific conductance at the benthic invertebrate community effluent-exposed and reference areas and daily average specific conductance of the MS-08 effluent discharge from August 30th to September 5th, 2017 (i.e., 2,658 µS/cm) was used to provide an estimate of effluent concentration in the immediate receiving environment. The corresponding

[9] Canadian Environmental Quality Guidelines (CCME 1999, 2017) were used as the primary source for WQG. For parameters in which no CCME guideline was available, Ontario Provincial Water Quality Objectives (OMOEE 1994) or British Columbia Water Quality Guidelines (BCMOE 2017) were used as WQG.

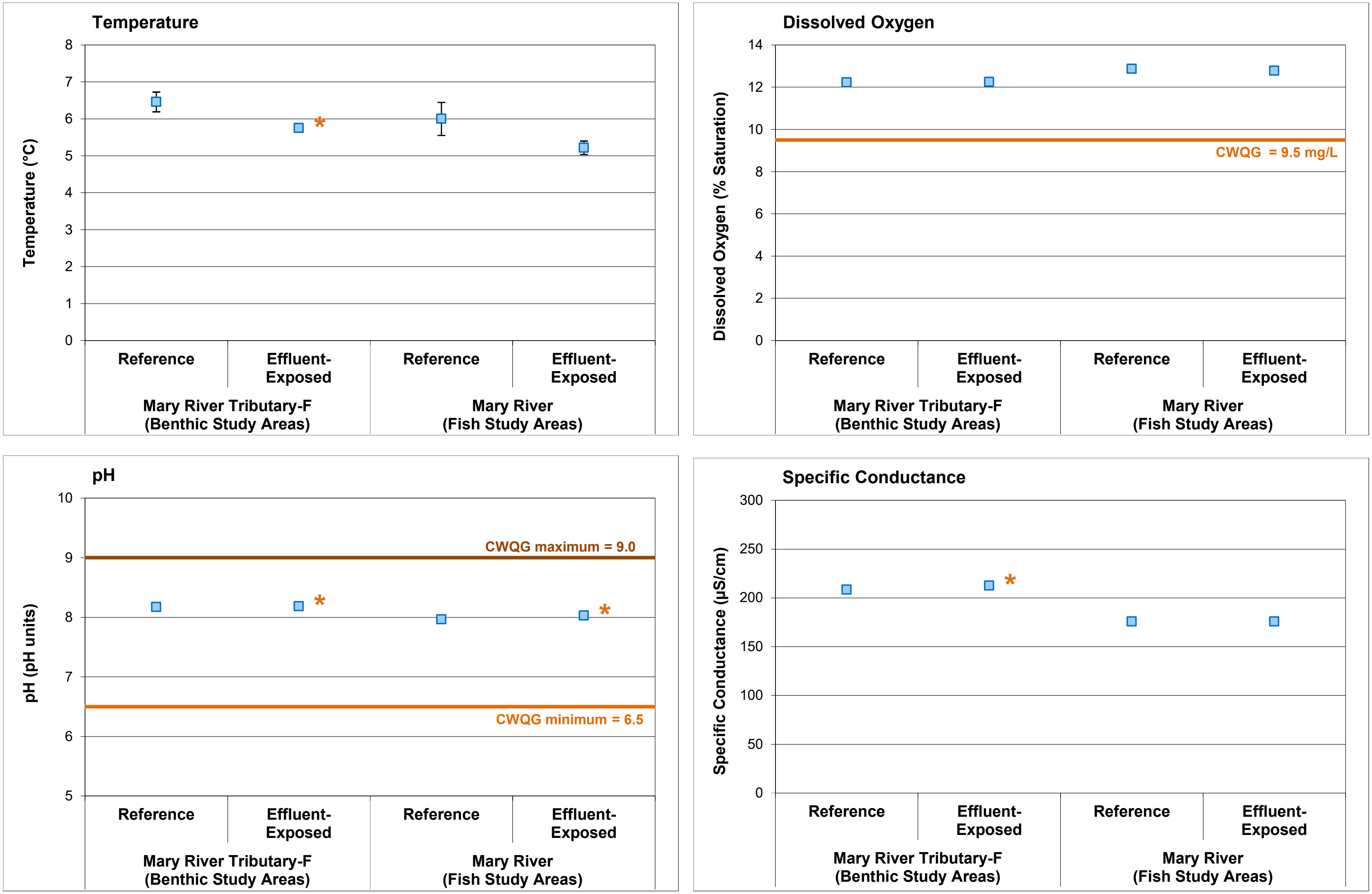


Figure 4.1: Comparison of *In Situ* Water Quality Variables (mean ± SE; n = 5) Measured at Mary River Tributary-F Benthic Stations and Mary River Fish Population Study Areas, Mary River Project Phase 1 EEM, August 2017

Note: An asterisk (*) next to effluent-exposed area data point indicates that the mean value differed significantly from that of the applicable reference area.

proportion of effluent at the Mary River Tributary-F effluent-exposed area immediately below the effluent channel confluence was estimated as 0.17%. Notably, the average daily effluent volume released from MS-08 on August 24th and 25th (i.e., 373 m^3/day) from which this effluent proportion at Mary River Tributary-F was estimated was approximately one-fifth the maximum MS-08 effluent discharge over the EEM Phase 1 period (Appendix Table D.1). The effluent concentration of 0.17% was within the effluent concentration range of 0.03 and 1.3% estimated by Minnow (2016a) for the immediate mine receiving environment using watershed discharge rates pro-rated from six Mary River Project mine site stream gauging stations and average volume of MS-08 discharged in 2015. Although a hydrological station was established within Mary River Tributary-F in 2017, a data logger malfunction resulted in the collection of flow data from June 27th to July 30th, of which only three days overlapped with that of the MS-08 effluent discharge. Using the same extrapolation approach used by Minnow (2016a), the effluent concentration estimated at Mary River Tributary-F immediately downstream of the MS-08 channel confluence ranged from 0.34% to 0.89% over a period of three days in late June 2017. Therefore, these data corroborated previous estimates that suggest effluent concentrations generally remain below 1% in Mary River Tributary-F.

Water quality monitoring conducted to meet regulatory requirements outside of EEM indicated that, on average, only ammonia, nitrate and/or sulphate concentrations were slightly elevated (i.e., three- to five-fold higher) at Mary River Tributary-F (Stations MRTF-1 and F0-01) compared to Mary River upstream reference conditions during periods of effluent discharge in 2016 and 2017 (Appendix Tables D.11 and D.12). However, concentrations of these parameters were consistently well below applicable WQG at Mary River Tributary-F (Appendix Tables D.11 and D.12). Although total concentrations of aluminum and iron were occasionally above respective WQG at effluent-exposed stations within Mary River Tributary-F in 2016 and 2017, similar or higher concentrations of these metals were observed at the Mary River upstream reference stations during any given sampling event (Appendix Tables D.11 and D.12), indicating natural elevation of total aluminum and iron concentrations in regional watercourses. Overall, the MS-08 effluent discharge resulted in only a marginal elevation in ammonia, nitrate and/or sulphate concentrations at Mary River Tributary-F.

4.2 Mary River

In situ water temperature and DO concentrations at the Mary River effluent-exposed area did not differ significantly from those measured at the Mary River reference area at the time of the August 2017 EEM fish population field study (Figure 4.1). In addition, DO concentrations at each of these study areas were well above the WQG lowest acceptable concentration for early life stages of cold water biota (i.e., 9.5 mg/L; Figure 4.1). Similar to differences between the Mary River

Tributary-F benthic study areas, pH was significantly higher at the Mary River fish population survey effluent-exposed area than at the reference area, but the mean incremental difference in pH between areas was very small (i.e., 0.06 units). The effluent-exposed area pH was also well within the WQG range considered protective of aquatic life (Figure 4.1). Thus, the difference in pH between the Mary River fish population survey effluent-exposed and reference study areas was not likely to be ecologically meaningful. No significant difference in specific conductance was indicated between the Mary River fish population survey effluent-exposed and reference study areas at the time of the EEM biological field study (Figure 4.1). The occurrence of highly comparable specific conductance between the Mary River study areas was consistent with previous estimates of effluent concentrations in Mary River, which indicated that effluent was likely to constitute less than 0.1% of flow in Mary River (Minnow 2016a).

Water quality monitoring at Mary River EEM stations indicated very similar annual average water chemistry upstream and downstream of the Mary River Tributary-F confluence over the Phase 1 EEM period (i.e., 2015 – 2017; Table 4.1). Although annual average concentrations of aluminum and iron were higher at the Mary River EEM effluent-exposed water quality station than at the upstream reference station in 2016, the magnitude of this difference was less than 1.5 times higher and a similar elevation was not observed in either 2015 or 2017 (Table 4.1). On average, total concentrations of aluminum and iron were above respective WQG at the Mary River effluent-exposed station from 2015 to 2017, but similar annual average concentrations of these metals were observed at the Mary River upstream reference station during any given sampling event (Table 4.1), indicating natural elevation of aluminum and iron concentrations in Mary River. Notably, of those parameters shown to be elevated at Mary River Tributary-F, only average concentrations of nitrate were elevated at the Mary River EEM effluent-exposed station compared to the respective reference station, and only in 2017 (Table 4.1; Appendix Tables D.10 – D.12). However, nitrate concentrations were consistently well below WQG at the Mary River effluent-exposed station, suggesting that the slight elevation in 2017 was not ecologically meaningful. Within the Mary River effluent-exposed area, water chemistry was consistently very similar between the EEM water quality station (i.e., MS-08-DS) and farther downstream at the fish population survey study area (i.e., Station E0-21[10]) during periods of effluent discharge in 2016 and 2017 (Appendix Tables D.11 and D.12). This suggested similar mine effluent exposure to fish inhabiting the Mary River EEM fish population survey effluent-exposed area and those inhabiting the effluent-exposed area closer to the Mary River Tributary-F confluence validating the use of the former area as a safe alternative sampling location.

[10] Water chemistry is monitored at Station EO-21 to meet Baffinland Core Receiving Environment Monitoring Program (CREMP) requirements, outside of sampling required by Baffinland to meet the MMER.

Table 4.1: Annual Average Water Chemistry at Mary River EEM Stations during Periods of Effluent Discharge, 2015 to 2017

Parameters		Units	Water Quality Guideline (WQG)[a]	Mary River Upstream (MS-08-US)			Mary River Downstream (MS-08-DS)		
				2015	2016	2017	2015	2016	2017
Conventionals	Conductivity (lab)	umho/cm	-	75	130	93	78	133	97
	pH (lab)	pH	6.5 - 9.0	8.07	7.99	8.35	7.96	8.09	8.15
	Hardness (as $CaCO_3$)	mg/L	-	52	56	42	55	57	44
	Total Suspended Solids (TSS)	mg/L	-	2.0	2.9	2.7	2.0	4.4	2.8
	Total Dissolved Solids (TDS)	mg/L	-	78		76	80		43
	Alkalinity (as $CaCO_3$)	mg/L	-	51	53	41	52	56	43
Nutrients and Anions	Total Ammonia	mg/L	variable[c]	0.05	0.02	0.02	0.05	0.02	0.02
	Nitrate	mg/L	13	0.02	0.02	0.02	0.02	0.02	0.05
	Total Organic Carbon	mg/L	-	1.0		1.4	1.0		1.5
	Total Phosphorus	mg/L	0.020^{α}	0.0058		0.0046	0.0051		0.0053
	Chloride (Cl)	mg/L	120	3.81		3.86	3.72		3.87
	Sulphate (SO_4)	mg/L	218^{β}	3.26		2.44	3.19		2.97
Total Metals	Aluminum (Al)	mg/L	0.100	0.312	0.343	0.122	0.305	0.440	0.122
	Antimony (Sb)	mg/L	0.020^{α}	0.0001		0.0001	0.0001		0.0001
	Arsenic (As)	mg/L	0.005	0.00010	0.00011	0.00010	0.00010	0.00012	0.00010
	Barium (Ba)	mg/L	-	0.00758		0.00907	0.00755		0.00949
	Cadmium (Cd)	mg/L	0.00012	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
	Calcium (Ca)	mg/L	-	11.3		13.1	11.3		13.2
	Chromium (Cr)	mg/L	0.0089	0.0005		0.0005	0.0005		0.0005
	Cobalt (Co)	mg/L	0.0009^{α}	0.0001		0.0001	0.0001		0.0001
	Copper (Cu)	mg/L	0.002	0.0010	0.0013	0.0010	0.0010	0.0013	0.0010
	Iron (Fe)	mg/L	0.30	0.184	0.271	0.102	0.166	0.368	0.097
	Lead (Pb)	mg/L	0.001	0.00018	0.00024	0.00011	0.00016	0.00030	0.00009
	Lithium (Li)	mg/L	-	0.001		0.001	0.001		0.001
	Magnesium (Mg)	mg/L	-	6.3		6.9	6.4		7.3
	Manganese (Mn)	mg/L	0.935^{β}	0.0019		0.0019	0.0020		0.0011
	Mercury (Hg)	mg/L	0.000026	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
	Molybdenum (Mo)	mg/L	0.073	0.00035	0.00032	0.00020	0.00035	0.00032	0.00020
	Nickel (Ni)	mg/L	0.025	0.0008	0.0006	0.0006	0.0008	0.0008	0.0005
	Potassium (K)	mg/L	-	1.02		1.04	1.02		1.06
	Selenium (Se)	mg/L	0.001	0.00053	0.00005	0.00005	0.00053	0.00005	0.00005
	Silicon (Si)	mg/L	-	1.4		0.99	1.39		1.02
	Silver (Ag)	mg/L	0.00025	0.00001		0.00005	0.00001		0.00005
	Sodium (Na)	mg/L	-	1.8		2.2	1.8		2.1
	Strontium (Sr)	mg/L	-	0.0077		0.0125	0.0077		0.0133
	Thallium (Tl)	mg/L	0.0008	0.00006		0.00001	0.00006		0.00001
	Titanium (Ti)	mg/L	-	0.012		0.006	0.011		0.005
	Uranium (U)	mg/L	0.015	0.0020		0.0023	0.0019		0.0024
	Vanadium (V)	mg/L	0.006^{α}	0.001		0.0005	0.001		0.0005
	Zinc (Zn)	mg/L	0.030	0.003	0.003	0.003	0.003	0.003	0.003

[a] Canadian Water Quality Guideline for the protection of aquatic life (CCME 2017) except those indicated by α (Ontario Provincial Water Quality Objective; OMOEE 1994) and β (British Columbia Water Quality Guideline; BCMOE 2017).

Indicates parameter concentration above applicable Water Quality Guideline.

5 BENTHIC INVERTEBRATE COMMUNITY SURVEY

Benthic invertebrate density, richness, Simpson's Evenness and Bray-Curtis Index[11] did not differ significantly between the Mary River Tributary-F effluent-exposed and reference study areas during the August 2017 survey (Figure 5.1; Table 5.1). Direct comparison of dominant benthic invertebrate community groups[12] indicated a subtle difference in community composition between the effluent-exposed and reference areas of Mary River Tributary-F that was driven entirely by significantly greater density of Simuliidae (blackflies) at the effluent-exposed study area (Figure 5.2; Table 5.1). Because blackflies exhibit a filter-feeding, clinging mode of existence in aquatic habitats (Merritt et al. 2008), differences in filterer FFG and clinger HPG densities between the Mary River Tributary-F effluent-exposed and reference study areas (Figure 5.2; Table 5.1) reflected the difference in blackfly densities shown between areas. Notably, with the removal of Simuliidae from the data set, no significant differences in any of the primary EEM benthic invertebrate community metrics of density, richness, Simpson's Evenness and Bray-Curtis Index, calculated at family-level and lowest-practical-level taxonomy, were indicated between the effluent-exposed and reference areas (Appendix Table E.7). In addition, no significant differences in any of the supporting taxonomic group, FFG and HPG metrics except the proportion of collector-gatherer FFG, were indicated between Mary River Tributary-F effluent-exposed and reference study areas with the removal of Simuliidae from the data set (Appendix Table E.7).

Higher densities of blackflies generally occur at the outlets of tributaries and in larger-sized streams (Carlsson 1967; Grillet and Barrera 1997; Pramul and Wongpakum 2010), possibly due to greater inputs of suspended organic matter, the predominant food source for blackflies, at these habitats (Carlsson et al. 1977). Therefore, a greater density of blackflies downstream of the MS-08 effluent channel confluence on Mary River Tributary-F may have reflected increased food resources originating from the effluent-channel. Notably, blackfly larval densities do not appear to be strongly influenced by plankton abundance (Carlsson 1967), suggesting that non-living organic matter received from runoff potentially accounted for higher densities of blackflies at the effluent-exposed area. No significant differences in densities of metal-sensitive chironomids were indicated between the Mary River Tributary-F effluent-exposed and reference study areas, suggesting that between-area differences in metal concentrations did not affect the composition of the benthic invertebrate community at the effluent-exposed area. In addition, no significant differences in sample replicate water velocity, substrate size, or substrate embeddedness were

[11] Unless otherwise indicated, primary EEM benthic invertebrate community metrics of richness, Simpson's Evenness and Bray-Curtis Index discussed in this section were calculated using family-level (FL) taxonomy.

[12] Dominant groups included taxonomic, functional feeding, or habitat preference groups representing ≥10% of the community at any one station, and/or an average ≥5% of the community at any one study area (Appendix Table E.5).

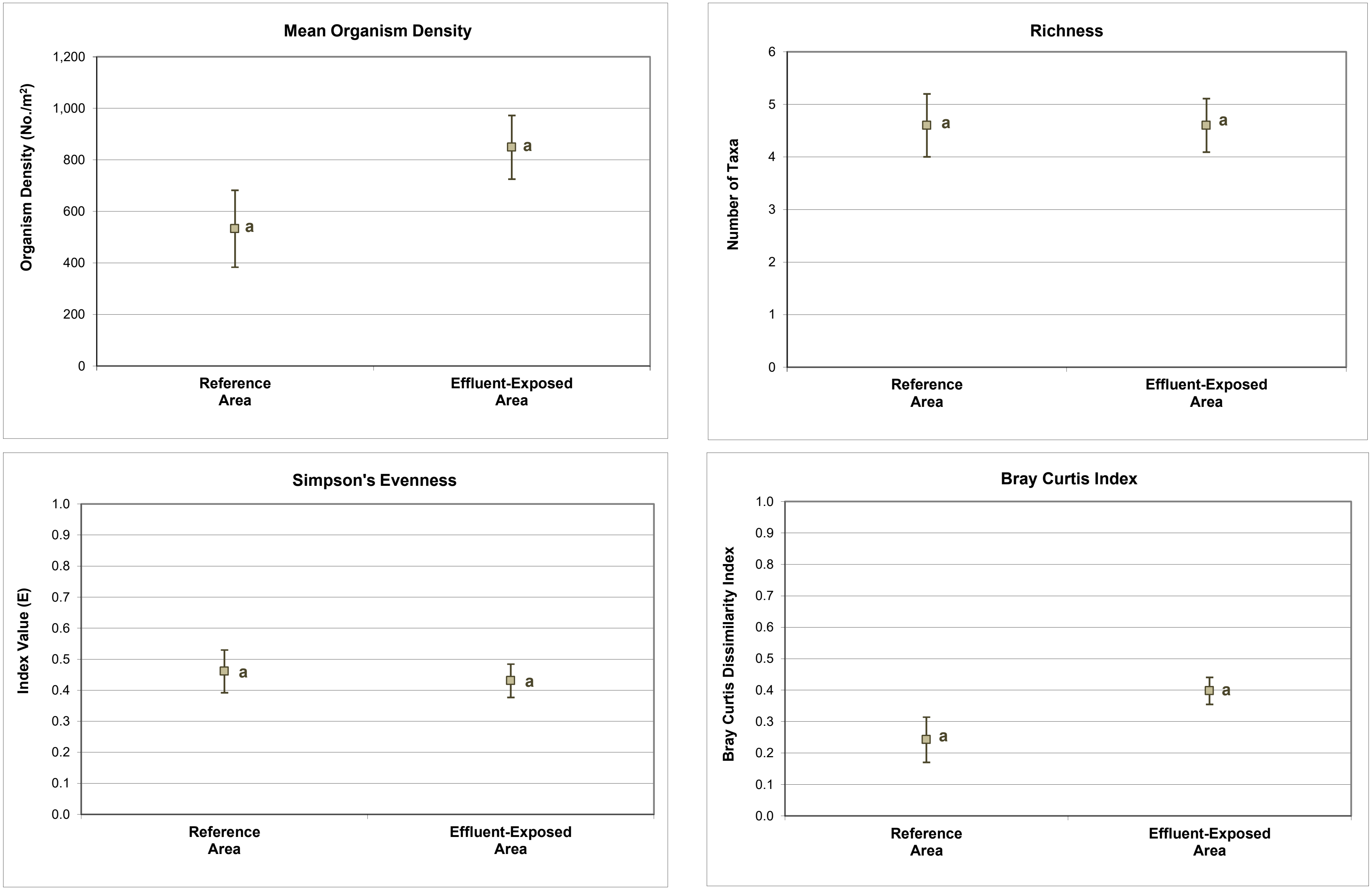


Figure 5.1: Comparison of Benthic Invertebrate Community Primary EEM Endpoints (mean ± SE, n = 5; calculated using Family Level taxonomy) for Mary River Tributary-F Effluent-Exposed and Reference Study Areas

Note: Data points with the same letter do not differ significantly.

Table 5.1: Benthic Invertebrate Community Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Study Areas Calculated for Primary EEM Metrics (Family Level Taxonomy) and Dominant Taxa, FFG and HPG

Metric	Two-Sample Comparison					Summary Statistics						
	Significant Difference Among Areas?	Trans-formation	Test	p-value	Magnitude of Difference [a] (No. of SD)	Area	Median	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Density (Individuals/m^2)	NO	fourth root	ANOVA	0.1238	~	Reference	474	533	334	149	188	1,058
						Effluent-Exposed	855	849	276	123	448	1,175
Richness (Number of Taxa)	NO	fourth root	ANOVA	0.9727	~	Reference	4.0	4.6	1.3	0.6	3.0	6.0
						Effluent-Exposed	5.0	4.6	1.1	0.5	3.0	6.0
Simpson's Evenness	NO	log_{10}	ANOVA	0.7872	~	Reference	0.430	0.461	0.154	0.069	0.297	0.689
						Effluent-Exposed	0.379	0.430	0.120	0.054	0.338	0.637
Bray-Curtis Index	NO	none	ANOVA	0.1006	~	Reference	0.204	0.242	0.161	0.072	0.069	0.439
						Effluent-Exposed	0.423	0.398	0.096	0.043	0.291	0.491
Chironomidae (No. per m^2)	NO	none	ANOVA	0.8030	~	Reference	241	309	170	76	102	531
						Effluent-Exposed	284	283	139	62	133	426
Metal Sensitive Chironomidae	NO	none	ANOVA	0.8397	~	Reference	107	121	59	27	40	199
						Effluent-Exposed	112	114	34	15	70	155
Simuliidae (No. per m^2)	YES	none	ANOVA	0.0137	2.0	Reference	161	205	169	75	75	487
						Effluent-Exposed	552	540	169	75	297	706
Collector-gatherers (No. per m^2)	NO	none	ANOVA	0.7417	~	Reference	240	310	173	77	102	532
						Effluent-Exposed	277	277	132	59	133	416
Filterers (No. per m^2)	YES	none	ANOVA	0.0137	2.0	Reference	161	205	169	75	75	487
						Effluent-Exposed	552	540	169	75	297	706
Clingers (No. per m^2)	YES	none	ANOVA	0.0151	2.0	Reference	165	212	175	78	79	505
						Effluent-Exposed	563	558	179	80	308	763
Sprawlers (No. per m^2)	NO	none	ANOVA	0.7510	~	Reference	240	305	166	74	102	517
						Effluent-Exposed	277	274	130	58	133	412

[a] Magnitude calculated by comparing the difference between the reference area and effluent-exposed area means divided by the reference area standard deviation.

Highlighted values indicates significant difference between study areas based on a p-value less than 0.10.

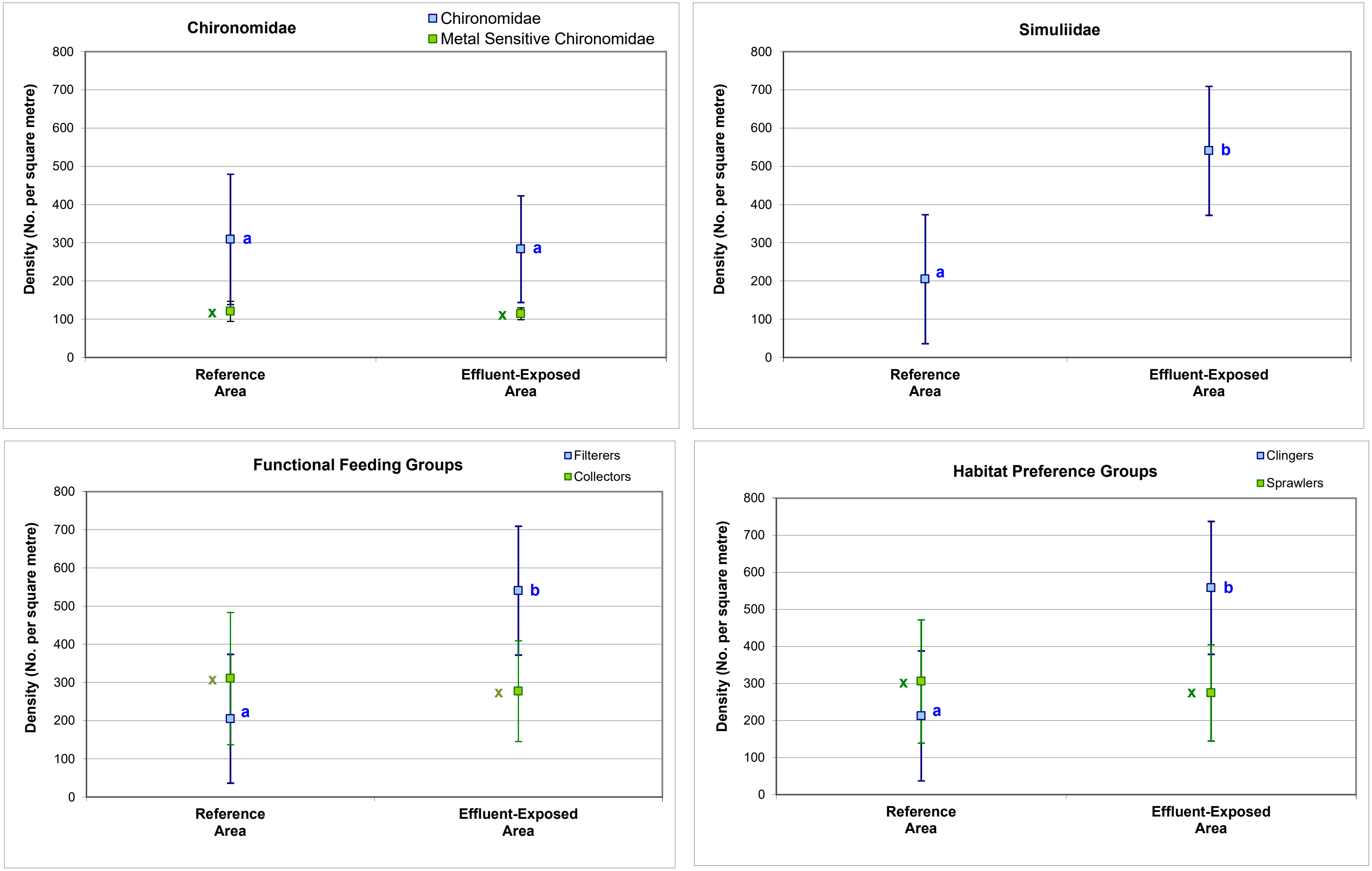


Figure 5.2: Comparison of Dominant Benthic Invertebrate Community Compositional Groups (density in m^2) between Mary River Tributary-F EEM Study Areas (mean ± SE, n = 5), Mary River Project Phase 1 EEM, August 2017

Note: Data points with the same, like-coloured letters do not differ significantly.

indicated between the Mary River Tributary-F effluent-exposed and reference study areas (Appendix Table E.3), suggesting that the difference in blackfly density between these areas was unrelated to these variables.

Overall, statistical similarity in primary EEM metrics of density, richness, Simpson's Evenness and Bray-Curtis Index between effluent-exposed and reference areas of Mary River Tributary-F indicated no effluent-related effects on the benthic invertebrate community in the receiving environment downstream of the MS-08 effluent discharge.

6 FISH POPULATION SURVEY

6.1 Fish Community

No fish were captured within Mary River Tributary-F either downstream or upstream of the MS-08 effluent discharge channel during the August 2017 fish population survey (Table 6.1; Appendix Table F.1). Fish sampling was conducted at reaches extending from the outlet to upstream of the effluent discharge (Figure 2.3), and therefore the lack of fish captures indicated that fish were naturally absent through the entire Mary River Tributary-F system. The natural absence of fish from Mary River Tributary-F presumably reflected the combination of complete freezing overwinter and an inability of fish to colonize the tributary due to relatively high stream gradient and the presence of natural in-stream barriers. An average gradient of 12% was documented through the lower 750 m of Mary River Tributary-F during the EEM fish population survey. In addition, an approximately 1.75 m high step-drop over large boulder habitat occurred approximately 50 m upstream of Mary River on Mary River Tributary-F (Appendix Photo Plate C.1), representing an impassable barrier for upstream migration by fish under the flow conditions observed at the time of the EEM fish population survey.

Table 6.1: Summary of Fish Catches at Mary River Project Phase 1 EEM Fish Population Study Areas, August 2017

Study Area	Total Effort		Summary Statistic Endpoint	Fish Species			Catch Summary	
	Distance Sampled (m)	Electrofishing Seconds		Arctic Charr		Ninespine Stickleback	Totals	Total No. Species
				YOY [b]	Non-YOY [b]			
Mary River Tributary-F Efffluent-Exposed	678	4,157	Total No. Caught	0	0	0	**0**	**0**
			CPUE[a]	0.0	0.0	0.0	**0.0**	
Mary River Effluent-Exposed	388	4,587	Total No. Caught	0	100	0	**100**	**1**
			CPUE[a]	0	1.30	0	**1.30**	
Mary River Reference	708	8,340	Total No. Caught	2	103	3	**108**	**2**
			CPUE[a]	0.01	0.75	0.02	**0.78**	

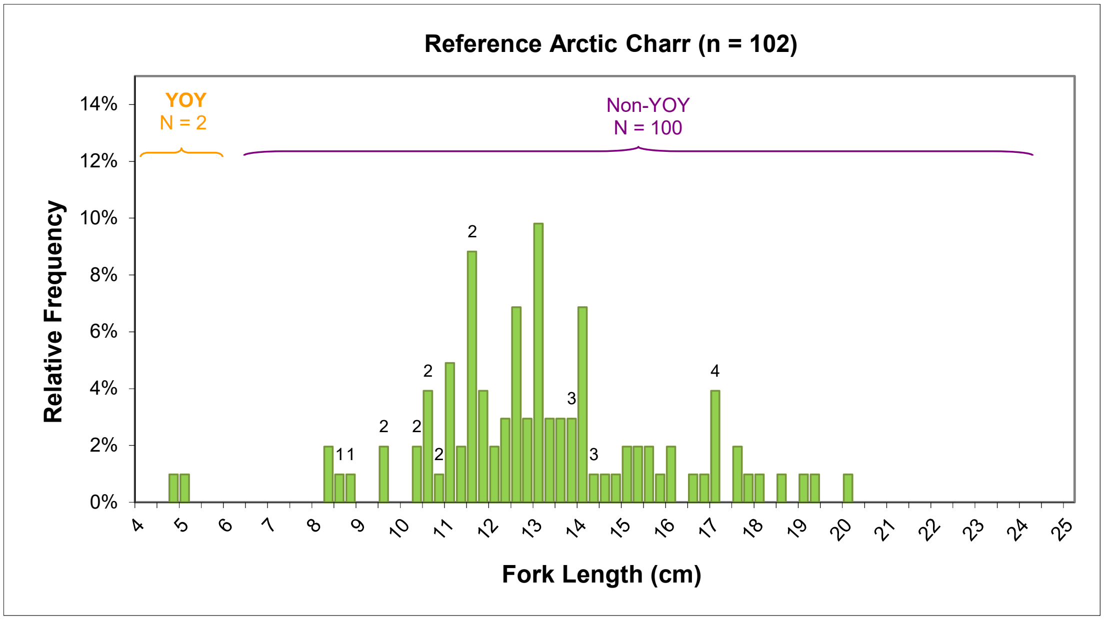
[a] Electrofishing catch-per-unit-effort (CPUE) represents number of fish captured per minute of electrofishing.
[b] Young-of-the-year (YOY).

The fish community at the effluent-exposed area of Mary River was represented only by arctic charr (*Salvelinus alpinus*), which differed slightly from that of the Mary River reference area where low numbers of ninespine stickleback (*Pungitius pungitius*) were captured in addition to arctic charr (Table 6.1; Appendix Table F.1). Arctic charr catch-per-unit-effort (CPUE) was substantially higher at the effluent-exposed area than at the reference area (Table 6.1), suggesting greater abundance of arctic charr at the effluent-exposed area. The between-area difference in arctic charr abundance may have reflected natural differences in the type of habitat sampled between the effluent-exposed and reference areas. At the effluent-exposed area, the predominant habitat consists of side and braided channels characterized by variable water velocity and large, loosely embedded cobble substrate, whereas at the reference area, habitat is dominated by a single main channel characterized by relatively deep, fast flowing water over highly embedded boulder substrate (Appendix Table C.4; Appendix Photo Plate C.2). These habitat features allowed fish sampling to be conducted throughout side-channels at the effluent-exposed area, but limited the sampling to shoreline areas at the reference area as a result of improved fish catch efficiencies potentially related to the field study team sampling mobility and commensurate safety concerns. Overall, no effluent-related influences on fish community composition and arctic charr abundance were apparent within the Mary River receiving environment.

6.2 Arctic Charr Population Evaluation

Non-lethal measurements of length and weight were collected from 102 and 100 arctic charr at Mary River effluent-exposed and reference study areas, respectively, for the assessment of EEM fish population endpoints (Appendix Tables F.2 and F.3). Arctic charr YOY were distinguishable from non-YOY individuals at a fork length of 50 mm based on evaluation of length-frequency distributions coupled with supporting age determinations (Figure 6.1). Based on this cut-off value, no YOY were captured at the effluent-exposed area, and only two YOY were captured at the reference area (i.e., approximately 2% of arctic charr population). As a result, the arctic charr population assessment focused on non-YOY individuals.

Arctic charr length-frequency distributions did not differ significantly between the effluent-exposed and reference areas of Mary River, regardless of whether YOY were included or excluded from the data set (Table 6.2; Figure 6.1; Appendix Figure F.1). Because the inclusion of YOY did not change the outcome of the length-frequency distribution statistical comparison, no difference in the proportion of YOY was indicated between the effluent-exposed and reference study areas (Table 6.2). Among non-YOY arctic charr, no separation of age (i.e., cohorts) was possible for either study area using the length-frequency distribution and confirmatory aging results (Figure 6.1). Nevertheless, visual evaluation of the plotted data suggested a similar arctic charr length-at-age relationship between the effluent-exposed and reference areas (Figure 6.1). Fork



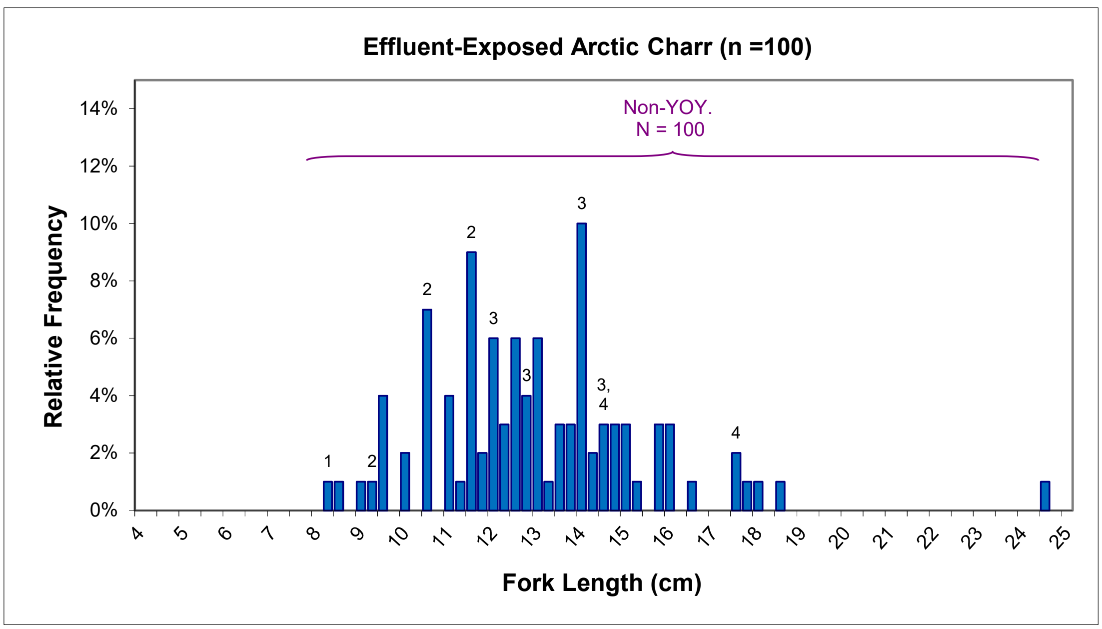


Figure 6.1: Length-frequency Distributions for Arctic Charr Collected at Mary River Project Phase 1 EEM Effluent-Exposed and Reference Study Areas, August 2017

Note: Numbers above bars represent individual fish ages, where available.

length and body weight of non-YOY arctic charr captured at the effluent-exposed area did not differ significantly from those captured at the reference area (Table 6.2; Appendix Figures F.2 and F.3). Although condition (i.e., weight-at-length relationship) of non-YOY individuals was significantly lower at the Mary River effluent-exposed area than at the reference area, the magnitude of this difference was within applicable CES (i.e., ±10%; Table 6.2; Figure 6.2; Appendix Table F.4) suggesting that this difference was not ecologically meaningful. No externally-visible abnormalities or parasitic infections were observed on any arctic charr captured at the Mary River effluent-exposed area (Appendix Table F.3). Overall, no significant, ecologically meaningful differences in arctic charr non-YOY health endpoints were indicated between the effluent-exposed and reference areas, suggesting limited influence of the MS-08 effluent on the health of this species at Mary River in 2017.

Table 6.2: Summary of Arctic Charr Population Statistical Comparison Results between Effluent-Exposed and Reference Areas of Mary River, August 2017

Endpoint		Significant Difference		Magnitude of Difference (%)
		Yes/No	p-value	
Survival – Length Frequency Distribution	All Fish	No	0.936	-
	Non-YOY only	No	0.906	-
Growth	Non-YOY length	No	0.523	-
	Non-YOY weight	No	0.200	-
Energy Storage	Non-YOY condition	Yes	<0.001	-4.5
Reproduction	YOY Proportion	No		

Figure 6.2: Comparison of Condition (Weight-at-Fork Length Relationship) for Arctic Charr Non-Young-of-the-Year (Non-YOY) Collected at Mary River Effluent-Exposed and Reference Areas, August 2017

7 CONCLUSIONS

The objective of the Mary River Project Phase 1 EEM biological study was to provide an initial evaluation of the influence of mine effluent on biota of the mine receiver. To meet this objective, effluent quality, receiving environment water quality, and habitat characterization data were used to support the interpretation of benthic invertebrate community and fish population survey data collected at effluent-exposed areas and respective reference areas of Mary River Tributary-F and Mary River. The principal conclusions from the Phase 1 EEM study are:

- Effluent from the Mary River Project primary discharge (MS-08) met all MMER limits during normal mine operations in 2015, 2016 and, with the exception of the discharge of effluent with low pH in some grab samples collected in August and September, and elevated mean monthly TSS concentrations in August, also met MMER limits in 2017. Mine effluent was non-acutely lethal to rainbow trout and *Daphnia magna* in 2015 and 2016, but was acutely lethal to one or both test species during individual tests conducted on August 1st and September 5th, 2017. Baffinland reported these non-compliances through the appropriate stakeholders and regulatory bodies and implemented corrective actions to mitigate effects and prevent future occurrences. Sublethal toxicity tests conducted using final effluent samples showed no effects on survival or growth of fathead minnow or on growth of green algae over the Phase 1 EEM period. Occasional effects on survival and/or reproduction of *Ceriodaphnia dubia* planktonic invertebrates and more consistent growth inhibition to duckweed were shown in effluent sublethal toxicity tests conducted from 2015 to 2017. However, effects to these test organisms were generally observed at effluent concentrations higher than those typically expected within the mine receiving environment, suggesting limited potential for similar sublethal toxicity effects within the immediate Mary River Tributary-F effluent-exposed area.

- Effluent concentrations estimated for the immediate receiving waters of Mary River Tributary-F were less than 1% based on extrapolation of field specific conductance measures (0.17% in August) and hydrological gauging station data (0.34% – 0.89% in late July) in 2017. The 2017 effluent concentration estimates were consistent with previous estimates for Mary River Tributary-F, which suggested that effluent concentrations range from 0.03% to 1.3% within the watercourse.

- Water chemistry at effluent-exposed areas of Mary River Tributary-F showed slightly elevated ammonia, nitrate and/or sulphate concentrations compared to reference conditions during periods of effluent discharge in 2016 and 2017, but concentrations of these parameters were consistently well below applicable WQG within the watercourse.

Within the effluent-exposed area of Mary River, average nitrate concentrations were slightly elevated compared to the applicable reference area, but only in 2017 and concentrations remained well below WQG, suggesting that the elevation in nitrate concentration was not ecologically meaningful.

- The benthic invertebrate community survey indicated no significant differences in primary EEM endpoints of density, richness, Simpson's Evenness and Bray-Curtis Index between effluent-exposed and reference areas of Mary River Tributary-F. In turn, this suggested no adverse influences to the benthic invertebrate community of Mary River Tributary-F associated with exposure to mine effluent.
- The fish population survey indicated no substantial differences in community species composition between the effluent-exposed and reference areas of Mary River, but potentially higher abundance of fish at the effluent-exposed area due to natural habitat factors. The Mary River arctic charr population showed no significant difference in size (length-frequency) structure, and no significant difference in proportion of YOY individuals between the effluent-exposed and reference areas. In addition, length and weight of non-YOY arctic charr did not differ significantly between populations sampled at the effluent-exposed and reference areas of Mary River. Although non-YOY arctic charr captured at the effluent-exposed area had significantly lower condition (length-at-weight relationship) than those captured at the reference area, the magnitude of this difference was small (i.e., -4.5%) and within the applicable fish condition Critical Effect Size of ±10% used for EEM studies, suggesting that this difference was not ecologically meaningful.

Overall, the Mary River Project Phase 1 EEM indicated very low effluent concentrations within the immediate Mary River Tributary-F receiving environment and commensurately, only minor effluent-related influences on water quality of this watercourse and farther downstream at Mary River during periods of effluent discharge. Although Mary River non-YOY arctic charr had lower condition at the effluent-exposed area than at the reference area, concentrations of mine-related parameters well below WQG and no effluent-related influences on primary EEM benthic invertebrate community endpoints closer to the effluent discharge at Mary River Tributary-F. In turn, this suggested that factors other than mine-effluent accounted for the difference in non-YOY arctic charr condition between the effluent-exposed and reference areas of Mary River.

Based on the prescribed EEM frequency under the MMER, the Study Design for the next Mary River Project EEM biological study must be submitted to Environment and Climate Change Canada (ECCC) no later than six months prior to implementing field collections in 2020. Using the EEM framework, the next phase of biological monitoring (Phase 2) will require an effects assessment, in part, to determine whether the occurrence of significantly lower arctic charr condition shown in the current EEM is consistent over study phases. The corresponding Phase 2 EEM Interpretive Report must be submitted to ECCC by January 10th, 2021.

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APPENDIX A

STUDY DESIGN APPROVAL CORRESPONDENCE

Environment and Climate Change Canada | Environnement et Changement climatique Canada

Prairie & Northern Region
Environmental Protection Operations Directorate
9250 – 49th Street NW
Edmonton, AB T6B 1K5

February 28, 2017

via email to: jim.millard@baffinland.com

James Millard
Environmental Manager
Baffinland Iron Mines
2275 Upper Middle Road East, Suite 300
Oakville,ON L6H 0C3

Dear Mr. Millard:

Subject: Metal Mining Effluent Regulations – Evaluation of 1st Environmental Effects Monitoring Study Design, Mary River Project, NU

This letter is to advise you that Environment and Climate Change Canada has reviewed your Environmental Effects Monitoring (EEM) biological study design report entitled "Mary River Project Environmental Effects Monitoring Phase 1 Study Design", received July 8, 2016. The review of study design reports takes into account information requirements in the *Metal Mining Effluent Regulations (MMER)* of the *Fisheries Act* and also offers comments on the study based on the EEM Technical Guidance Document and generally accepted standards of good scientific practice.

The compiled review comments and recommendations are attached. Comments in bold indicate where further information is required to meet regulatory requirements and should be addressed for the review of the report to be completed.

Should you have any questions or concerns regarding the EEM program or wish to discuss the review of the study design, please do not hesitate to contact me at (780) 717-4884 or at erik.allen@canada.ca.

Sincerely,

Erik Allen
Environmental Effects Monitoring Coordinator

cc:	Susanne Forbrich	Environment and Climate Change Canada, Edmonton
	Cristina Ruiu	Environment and Climate Change Canada, Regina
	Paula Siwik	Environment and Climate Change Canada, Edmonton
	Curtis Didham	Environment and Climate Change Canada, Iqaluit

Canada

Attachment: Review Comments and Recommendations on ‘Mary River Project Environmental Effects Monitoring Phase 1 Study Design’, July 2016 submission

Review Comments and Recommendations on 'Mary River Project Environmental Effects Monitoring Phase 1 Study Design', submitted July 2016

The following comments and recommendations are based on the review of the report by a Technical Advisory Panel (TAP) consisting of representatives from Environment and Climate Change Canada (ECCC), Nunavut Water Board (NWB) and Indigenous and Northern Affairs Canada (INAC).

Action items

1. p. 1, Section 1.1. The NWB currently has on file a copy of Baffinland Iron Mines Corporation's (BIMC) Aquatic Effect Monitoring Plan (AEMP) (Rev 2), which includes a Draft EEM Cycle Study Design as a subset of the AEMP. As the NWB is currently in the process of considering BIMC's AEMP for Approval, confirmation is required from BIMC on the extent to which changes included in the current EEM Study Design, which superseded the Draft EEM study design, may impact the NWB's ability to potentially approve the current version of the AEMP.
2. p. 7. The study design includes a description of how effluent mixes in the exposure area, based on extrapolated stream discharge volumes for Tributary-F. It would appear that daily effluent discharge was compared to a stream flow estimate based on annual average flows from nearby streams, however the methods were unclear. Please provide further details on how the stream discharge and effluent concentrations were estimated.
    a. Were extrapolated values based on the average flows from similarly-sized watersheds listed in Table A2? Were the watersheds similar to Tributary-F in elevation, gradient, and aspect?
    b. Was the extrapolated discharge for Tributary F based on 2015 data only?
    c. Were monthly and annual variations in streamflow considered in the estimates of effluent concentration?
    d. Where along Tributary-F do the estimates of effluent concentration apply (e.g., at the confluence with the effluent stream, or downstream at the confluence with Mary River)?
3. p. 12. The proponent is recommended to verify effluent concentrations with in-stream conductivity measurements during effluent discharge periods in 2017. Please provide details on an approach to assess effluent concentrations based on effluent and stream conductivity in the receiving environment, including sampling locations and calculations (refer to the Metal Mining EEM Guidance Technical Document (TGD), Sections 2.2.1.1 and 2.2.1.2).
4. p. 12, Section 2.3.4. It is recommended that the proponent provide details regarding measures implemented and monitoring that may be conducted to determine whether or not the effluent discharged from MS-08 may have any negative impact on the receiving environment, preceding the final discharge point.
5. Figure 2.4. The legend in Figure 2.4 indicates that 2015 data were used to estimate monthly discharge for the Mary River and Tributary-F. Table A-2 presents monthly discharge data for several stations from 2006 to 2014, but there are no 2015 data. Please provide the missing data.

6. p. 18. The study design did not describe methods for the collection of sediment samples for particle size and total organic carbon analyses, which are required if the study is conducted in an area where it is possible to sample sediment (MMER, Sched. 5, s. 16(a)(iii)). The description of the sampling areas (erosional habitat with gravel/cobble substrate) would suggest that sediment sampling will not be possible; please confirm or provide the missing information.

7. **p. 21. The study design suggests that low effluent concentration in the Mary River would exempt the proponent from the requirement to conduct a fish study, should no fish be collected from Tributary-F. The MMER require a fish population study if the effluent concentration in the exposure area is greater than 1% in the area located within 250 m of the final discharge point (FDP) (Sched. 5, s. 9(b)). Based on the information provided, the fish survey exemption does not apply to the proposed study. The fish survey should be initially conducted in Tributary-F as proposed, and if fish are determined to be absent or in low abundance, field crews should sample progressively downstream into the Mary River, where fish may be more abundant. Please provide information on potential reference sites for the Mary River exposure area. Given concerns over low fish abundance, the proponent is recommend to identify several reference site options for the Tributary-F and Mary River exposure areas.**

8. p. 21. The report indicates that mine effluent represented 0.02% - 0.035% of flow in the Mary River. On p.7, the effluent percentage of flow in the Mary River was given as 0.03% and 0.065%; please clarify.

9. p. 25. The study design indicates that stream velocity and channel dimensions will be measured, will discharge volumes be calculated?

10. p. 26. Please briefly describe field preservation and shipping protocols for water samples to ensure laboratory sample hold times are met, given the remote location of the study area.

11. p. 14. Section 3.5.6 It is recommended that the proponent provide details regarding further or continued monitoring and/or analyses that may be conducted to determine the extent to which mining activities may be contributing to the differences, over time, in results observed in the water quality parameters measured at Tributary F and the Mary River Up-stream Reference Station.

12. p. 26. Section 3.5. It is recommended that details regarding the exposure and reference areas to be monitored be confirmed in the EEM Study Design in the context of BIMC’s recommended discontinuation of monitoring for several stations potentially related to exposure and/or reference areas, based on the correspondence accompanying the AEMP (Rev 2).

13. **The proponent previously notified the authorization officer of the addition of a second FDP (MS-06) for the Mary River Project (letter from J. Millard to S. Forbrich, June 18, 2016). The MS-06 FDP was not described in the current study design. The MMER require a description of the manner in which the effluent mixes within the exposure area for each final discharge point (MMER, Sched. 5, s. 11(a)). Please provide any available information regarding effluent mixing from MS-06, and a description of plume delineation methods to be implemented in 2017 (as requested for MS-08; see comment #3).**

For mines with multiple effluent discharges, it is recommended that biological monitoring be conducted on the discharge with the greatest potential to have an adverse effect on the receiving environment, based on mass loading of deleterious substances, effluent mixing, and sensitivity of the receiving environment (TGD, Section 2.2.2.1). Potential confounding factors should also be considered. Based on the information provided to date, the TAP would support biological monitoring of the MS-08 FDP as proposed; however, additional information and rationale should be provided to demonstrate that MS-08 is most suitable for biological monitoring.

Please note that MMER requirements for annual effluent characterization and water quality monitoring apply to all FDPs (Sched. 5, s. 4, 7). Requirements for sublethal toxicity testing apply to the FDP with potentially the most adverse environmental impact on the environment, taking into the account the mass loadings of deleterious substances and the manner in which effluent mixes in the exposure area (Sched. 5, s. 5).

14. The MS-06 FDP will discharge to the Mary River through a treated sewage pipeline; will mine effluent and treated sewage be discharged concurrently?
15. Appendix A, Table A.4. Please indicate the location of stream sampling sites listed in Table A.4. Was there a noticeable difference in water chemistry between upstream and downstream sites on Tributary-F?

Other items

16. Fig. 2-4. The figure caption should refer to mean monthly stream discharge, not effluent discharge; please confirm.
17. p. 14. The proponent is recommended to conduct annual water quality monitoring in Tributary F near the confluence with the effluent discharge, and a comparable reference stream, in addition to proposed monitoring in the Mary River.
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19. p. 22. The proponent is advised to plan for up to 7 days of sampling per area to meet sample size targets for the fish survey.
20. p. 23. Please be advised that the TGD recommends independent confirmation of fish ageing for 10% of samples.
21. Table 3.2. The table indicates no statistical analysis for the reproduction endpoint. Please note that the non-lethal reproduction endpoint (relative abundance of YOY) can be analyzed by comparing exposure and reference length frequency distributions with the Kolmogorov-Smirnov test, with and without YOY. If the inclusion of YOY changes the outcome of statistical comparison, the proportion of YOY is considered to be different between sampling areas (TGD, Section 3.4.2.2).
22. p. 25. Please ensure collection of trip and field blanks for water chemistry QA/QC, as recommended by the TGD (Section 5.8.4).
23. An overview document outlining the amendments proposed for the MMER was shared with stakeholders in December 2016. If you have not received this

document and would like a copy, please contact Erik Allen. The proposed amendments are expected to be published in Canada Gazette, Part 1 in spring of 2017. Canada Gazette, Part II publication would likely occur 12 to 18 months following Canada Gazette Part 1 publication.

Minor comments and errata

p.1. The report refers to “Surface (contour strip) mining at the Mary River Project”. Please note that strip mining is not used at Mary River Project.

Figure 1.1. Baffinland Iron Mines Corporation, Mary River Project Location Map. For future reports, labelling Mary River Tributary-F (as in Figures 2.1 and 3.1) would help highlight the tributary and its flow direction.

p.3. The report states: “This mine closure EEM site characterization summarizes …”. It is unclear why EEM site characterization is referred to as ‘mine closure’.

p.4, 9. “The Mary River Project area (is situated/lies) within the Committee Belt” – this should refer to Committee Bay Belt.

p.9. “The belt … is divided into five main assemblages: the Archean, the Mary River Group, the Piling Group, the Bylot Supergroup, and the Turner Cliffs-Ship Formation (Aker Kvaerner 2008).” Please note that the Archean is not an assemblage but a geological eon. Suggest replacing with the Penrhyn Group, or some other assemblage found at/near the Project site.

August 10th, 2017

Mr. Erik Allen
Environmental Effects Monitoring Coordinator
Prairie and Northern Region
Environmental Protection Operations Directorate
9250 – 49th Street NW
Edmonton, Alberta T6B 1K5

Dear Mr. Allen,

Re: <u>Response to ECCC Action Items and Comments on the Mary River Project 1st Environmental Effects Monitoring Study Design</u>

Environment and Climate Change Canada (ECCC) reviewed the Mary River Project First Environmental Effects Monitoring (EEM) Study Design report submitted by Baffinland Iron Mines Corporation (Baffinland) and provided specific action items and comments applicable to the study as outlined in their letter dated February 28th, 2017. Baffinland has prepared this detailed response to address the fifteen action items and eight 'other items' provided by ECCC stemming from their review of the study design. As follow-up to this response, it is suggested that resolution to any potential outstanding issues can be achieved either through a teleconference arranged between ECCC and Baffinland prior to implementation of the field study (August 2017), or during the ECCC site visit to the Mary River Project from August 15th – 17th, 2017.

Sincerely,
Baffinland Iron Mines Corporation

Laura Taylor
Environmental Superintendent

Cc: William Bowden, Environmental Superintendent, Baffinland
Paul LePage, Minnow Environmental Inc.

Baffinland Iron Mines Corporation: Response to ECCC Comments on the Mary River Project 1st Environmental Effects Monitoring Study Design

PART A - Action Items

Action Item 1: "*p. 1, Section 1.1. The NWB currently has on file a copy of Baffinland Iron Mines Corporation's (BIMC) Aquatic Effect Monitoring Plan (AEMP) (Rev 2), which includes a Draft EEM Cycle Study Design as a subset of the AEMP. As the NWB is currently in the process of considering BIMC's AEMP for Approval, confirmation is required from BIMC on the extent to which changes included in the current EEM Study Design, which superseded the Draft EEM study design, may impact the NWB's ability to potentially approve the current version of the AEMP.*"

Response: The (2014) EEM study design presented as part of the Rev 2 AEMP had assumed a total of four Final Discharge Points (FDP) operating under full capacity of the Mary River Project as described in the Baffinland (2012) Final Environmental Impact Assessment. Currently, only two FDP are intermittently active (MS-08 East Pond, MS-06 Ore Stockpile Runoff). In addition, to date, annual effluent discharge rates from each of these FDP have been much lower than the discharge rates estimated in the Rev 2 AEMP EEM study design (i.e., 2,217 m^3 in 2015 versus 3,133,000 m^3/year estimated in the Rev 2 EEM study design for Station MS-08; 86 m^3 in 2016 versus 110,000 m^3/year estimated in the Rev 2 EEM study design for Station MS-06).

The current (2016) EEM study design better reflects conditions of existing mine operations, focusing on those watercourses that currently receive mine effluent under the more limited effluent flow rates. Specifically, biological sampling will focus on Mary River Tributary-F under the current (2016) EEM study design. Under the (2014) Rev 2 AEMP EEM Study Design, sampling areas were concentrated on Mary River and Camp Lake Tributary 1. However, intensive sampling, similar to that conducted for the EEM program, is currently conducted at both Mary River and Camp Lake Tributary 1 under Baffinland's Core Receiving Environment Monitoring Program (CREMP), which has been conducted annually following the commencement of mine operations. For instance, three and two mine-exposed biological monitoring areas have been established/ sampled on Mary River and Camp Lake Tributary 1, respectively, in addition to comparable reference areas. These same areas were proposed for sampling under the former (2014) Rev 2 AEMP EEM Study Design. The benthic invertebrate community survey and fish population survey approaches were very similar between the former (2014) Rev 2 AEMP EEM study design and the current (2016) EEM study design.

Therefore, through the additional focus on the watercourse most likely to be influenced by mine effluent (i.e., Mary River Tributary-F), the current (2016) EEM study design enhances the overall spatial coverage of environmental monitoring at the Mary River Project relative to the former (2014) Rev 2 AEMP EEM study design. Moreover, because the current CREMP included biological sampling at those areas proposed for monitoring under the former (2014) Rev 2 AEMP EEM study design, the changes between the 2014 and 2016 EEM study designs will not detract from the overall objectives of the AEMP (e.g., to evaluate short- and long-term effects of the Mary River Project on aquatic ecosystems) and will actually enhance the overall program (i.e., through the addition of Mary River Tributary-F as a sampling area).

Action Item 2: "*p. 7. The study design includes a description of how effluent mixes in the exposure area, based on extrapolated stream discharge volumes for Tributary-F. It would appear that daily effluent discharge was compared to a stream flow estimate based on annual average flows from nearby streams, however the methods were unclear. Please provide further details on how the stream discharge and effluent concentrations were estimated.*

a. Were extrapolated values based on the average flows from similarly-sized watersheds listed in Table A2? Were the watersheds similar to Tributary-F in elevation, gradient, and aspect?

b. Was the extrapolated discharge for Tributary F based on 2015 data only?

c. Were monthly and annual variations in streamflow considered in the estimates of effluent concentration?

***d. Where along Tributary-F do the estimates of effluent concentration apply (e.g., at the confluence with the effluent stream, or downstream at the confluence with Mary River)?*"**

Response: Streamflow of Tributary-F was estimated using average per unit watershed area flow data (m^3/day/km^2) from six nearby watercourses for the months of July and August collected in 2015. These average flow data were multiplied by the watershed area of Tributary F (in this case, 6.8 km^2 at the confluence with the effluent discharge) to determine the percent effluent following complete mixing using the average and maximum effluent discharge rate (148 and 293 m^3/day, respectively) over the period of effluent discharge in July/August 2015. The formula used to determine the percentage of effluent at the Tributary F/ effluent discharge confluence was as follows:

- effluent discharge (m^3/day) / [stream flow (m^3/day for the 6.8 km^2 area) + effluent discharge (m^3/day)]

This value was calculated separately for July and August, and then averaged to arrive at an extrapolated average effluent concentration during the period of mine effluent discharge. The same method was used to determine the percentage of effluent at the Mary River confluence with Tributary F (watershed area of 232.6 km^2).

a. Extrapolated values were taken from the six watershed sizes indicated in Appendix Table A.2, which ranged from 3.6 – 250 km^2. As indicated above, the average discharge per unit area ($m^3/day/km^2$) for these six watercourses was used to extrapolate the percentage of effluent at Tributary F and Mary River. In general, watercourses with smaller watershed sizes (i.e., under 10 km^2) more closely mirrored the elevation, gradient and aspect of Tributary F than watercourses with larger watersheds at the Baffinland hydrological monitoring stations.

b. Stream discharge data from 2015 became available for incorporation into the Study Design document in the later stages of preparation. Unfortunately, changes applicable to some of the text in the effluent dilution (Section 2.2.4) and fish population survey (Section 3.2.1) portions of the report were not consistently updated/adjusted to reflect the addition of the 2015 data. Text from the first paragraph of Section 2.2.4 should have read as follows (in bold):

Estimates of effluent dilution in the mine receiving environment were conducted using the 2015 final effluent discharge data together with watershed discharge rates pro-rated using data from six Mary River Project mine site stream gauging stations over the 2015 open-water period. Based on estimated annual average flow by watershed and average daily effluent discharge (i.e., 148 m^3/day during periods of discharge; see Section 2.2.2), the MS-08 effluent was estimated to constitute an average of 1.3% and 0.03% of flow during periods of effluent discharge in 2015 (i.e., July and August) at the effluent stream confluence with Mary River Tributary-F and Mary River, respectively (Figure 2.3). Assuming the maximum daily effluent volume discharged in 2015 (i.e., 293 m^3 on July 12, 2015), the MS-08 effluent was estimated to constitute approximately 2.5% and 0.065% of flow at the effluent stream confluence with Mary River Tributary-F and Mary River, respectively, during the July-August period of discharge in 2015, assuming average regional monthly flow conditions on the day of maximum discharge (Figure 2.3).

c. Based on the monthly 2015 streamflow data, average and maximum effluent concentrations were 1.3 ± 0.5% and 2.5 ± 0.9%, respectively, for the months of July/August at the Tributary-F confluence with the effluent channel based on the streamflow data from all six watercourses. Similarly, average and maximum effluent concentrations were 0.033 ± 0.019% and 0.065 ± 0.038%, respectively, for the months of July/August at the Mary River confluence with Tributary-F based on the 2015 streamflow data from the Mary River gauging station.

d. Effluent concentrations on Tributary F that were indicated on p. 7 applied to the confluence with the effluent stream (i.e., the initial mixing zone).

Action Item 3: "*p. 12. The proponent is recommended to verify effluent concentrations with in-stream conductivity measurements during effluent discharge periods in 2017. Please provide details on an approach to assess effluent concentrations based on effluent and stream conductivity in the receiving environment, including sampling locations and calculations (refer to the Metal Mining EEM Guidance Technical Document (TGD), Sections 2.2.1.1 and 2.2.1.2)*"

Response: Effluent concentrations within Tributary F and Mary River will be determined at the time of biological sampling in August 2017 using the approach suggested in the Metal Mining EEM TGD. Together with effluent specific conductance measured at the time of biological sampling, specific conductance measurements at reference and effluent-exposed benthic invertebrate community/fish monitoring stations will be used as the basis for determination of effluent concentrations at Tributary F and Mary River, as applicable. During site reconnaissance conducted by Minnow in 2015, a specific conductance survey conducted to estimate effluent concentrations along Tributary-F was confounded by runoff received from areas subject to drilling and/or hauling activity which resulted in higher aqueous specific conductivity in Tributary-F. Notably, calcium chloride ($CaCl_2$) is used to aid with drilling through permafrost at Baffinland, which was believed to result in elevated specific conductance in runoff feeding into Tributary-F at the time of the 2015 specific conductance survey.

Action Item 4: "*p. 12, Section 2.3.4. It is recommended that the proponent provide details regarding measures implemented and monitoring that may be conducted to determine whether or not the effluent discharged from MS-08 may have any negative impact on the receiving environment, preceding the final discharge point"*

Response: It is unclear as to the recommended location referred to in this Action Item (i.e, "preceding the final discharge point"). If referring to the lower 740 m length of channel that drains into Tributary-F, no monitoring is proposed for this portion of the system, with the exception of *in situ* water quality measurements conducted at the time of biological monitoring in August 2017. Flow in this intermittent section of the channel is likely to be represented entirely by effluent in August, and we believe there is very low likelihood that benthic invertebrate communities become well established in watersheds of this small size, confounding the ability to assess biological influences of the mine effluent on biota. The photograph below illustrates the portion of the channel just upstream of Tributary-F in August 2016 during effluent discharge. In this photo, the channel width is approximately 30 cm and water depths reach a maximum of approximately 5 cm.

Action Item 5: "*Figure 2.4. The legend in Figure 2.4 indicates that 2015 data were used to estimate monthly discharge for the Mary River and Tributary-F. Table A-2 presents monthly discharge data for several stations from 2006 to 2014, but there are no 2015 data. Please provide the missing data."*

Response: As indicated in the response to Action Item 2, stream discharge data from 2015 became available for incorporation into the Study Design document in the later stages of preparation. Appendix Table A.2 has been updated to include the 2015 data and is presented at the end of this response.

Action Item 6: "*p. 18. The study design did not describe methods for the collection of sediment samples for particle size and total organic carbon analyses, which are required if the study is conducted in an area where it is possible to sample sediment (MMER, Sched. 5, s. 16(a)(iii)). The description of the sampling areas (erosional habitat with gravel/cobble substrate) would suggest that sediment sampling will not be possible; please confirm or provide the missing information.*"

Response: Correct. Sediment sampling will not be collected concurrent with benthic invertebrate community samples given the presence of only erosional habitat (boulder with interspersed gravel/cobble) in Tributary-F. The photo below illustrates habitat typical of Tributary-F.

Action Item 7: "*p. 21. The study design suggests that low effluent concentration in the Mary River would exempt the proponent from the requirement to conduct a fish study, should no fish be collected from Tributary-F. The MMER require a fish population study if the effluent concentration in the exposure area is greater than 1% in the area located within 250 m of the final discharge point (FDP) (Sched. 5, s. 9(b)). Based on the information provided, the fish survey exemption does not apply to the proposed study. The fish survey should be initially conducted in Tributary-F as proposed, and if fish are determined to be absent or in low abundance, field crews should sample progressively downstream into the Mary River, where fish may be more abundant. Please provide information on potential reference sites for the Mary River exposure area. Given concerns over low fish abundance, the proponent is recommend to identify several reference site options for the Tributary-F and Mary River exposure areas."*

Response: From our consultant's perspective, greater clarity on the MMER definition of a "final discharge point (FDP)" is required in cases in which an overland effluent discharge point is concerned. Effluent concentrations in Tributary-F, the first 'permanent' flowing watercourse that the effluent meets during the open-water period (approximately late June to early September), appears to be approximately 1% within 250 m of the confluence with the effluent channel, on average. Extrapolation using maximum effluent flow data suggested that effluent concentrations in Tributary-F may periodically be greater than 1% within 250 m of the confluence with the effluent channel. Despite this, the ecological relevance of conducting a fish survey at Mary River, where effluent concentrations are estimated to be well less than 1% (i.e., average and maximum of 0.02% and 0.035%, respectively, based on data collected from 2006 – 2015, assuming continual effluent discharge), is questionable. Attributing potential differences in fish population endpoints between reference and effluent-exposed areas of Mary River to mine effluent exposure (the intent of the MMER) does not seem scientifically defensible in cases where the maximum effluent concentration is so low. Furthermore, the evaluation of effluent-related effects on Arctic charr populations of Mary River (and other watercourses in the Mary River Project region) is further limited by the fact that liquid water is generally present (and fish possibly present) only from early July through mid-September, and that mine effluent is only discharged intermittently (e.g., 16 days in 2015). Thus, very low effluent concentrations coupled with limited exposure period will preclude definitive assessment of mine effluent-related effects to fish populations of Mary River.

It is suggested that resolution of this Action Item occur through teleconference prior to implementation of the field study (August 2017) or during the ECCC site visit to the Mary River Project from August 15th – 17th, 2017.

Action Item 8: "*p. 21. The report indicates that mine effluent represented 0.02% - 0.035% of flow in the Mary River. On p.7, the effluent percentage of flow in the Mary River was given as 0.03% and 0.065%; please clarify."*

Response: On page 21, average and maximum concentrations of mine effluent in Mary River were 0.02% - 0.035%, respectively, based on average streamflow at the Baffinland Mary River hydrological station over the period of 2006-2015. On page 7, average and maximum concentrations of mine effluent in Mary River were 0.03% - 0.065%, respectively, based on average streamflow at the Baffinland Mary River hydrological station only in 2015 (July/August period). Please see response to Action Item 2 for additional clarity.

Action Item 9: "*p. 25. The study design indicates that stream velocity and channel dimensions will be measured, will discharge volumes be calculated?"*

Response: No, discharge volumes will not be calculated from the stream water velocity and channel dimension data collected for EEM. These data will be collected to provide general information on habitat characteristics of each study area to assist with the interpretation of biological data. The number of monitoring points along each transect, and the in-stream transect locations, are not intended to be sufficient for accurate discharge volume calculation.

Action Item 10: "*p. 26. Please briefly describe field preservation and shipping protocols for water samples to ensure laboratory sample hold times are met, given the remote location of the study area.*"

Response: Please refer to the attached Standard Operating Procedure (SOP) developed for water sampling at the Mary River Project.

Action Item 11: "*p. 14. Section 3.5.6 It is recommended that the proponent provide details regarding further or continued monitoring and/or analyses that may be conducted to determine the extent to which mining activities may be contributing to the differences, over time, in results observed in the water quality parameters measured at Tributary F and the Mary River Up-stream Reference Station*"

Response: Baffinland will conduct water quality monitoring at established EEM and AEMP (CREMP) stations at frequencies required under each respective approved monitoring plan. The locations and frequencies of sampling appear to be sufficient for monitoring spatial differences between mine-exposed and reference areas, and temporal changes over time, in water quality of Tributary-F and Mary River.

Action Item 12: "*p. 26. Section 3.5. It is recommended that details regarding the exposure and reference areas to be monitored be confirmed in the EEM Study Design in the context of BIMC's recommended discontinuation of monitoring for several stations potentially related to exposure and/or reference areas, based on the correspondence accompanying the AEMP (Rev 2).*"

Response: Because approval for changes suggested in correspondence accompanying the AEMP (Rev 2) has not been received from regulators and other stakeholders, no changes to stations will be implemented within the time period of the first EEM study

Action Item 13: "*The proponent previously notified the authorization officer of the addition of a second FDP (MS-06) for the Mary River Project (letter from J. Millard to S. Forbrich, June 18, 2016). The MS-06 FDP was not described in the current study design. The MMER require a description of the manner in which the effluent mixes within the exposure area for each final discharge point (MMER, Sched. 5, s. 11(a)). Please provide any available information regarding effluent mixing from MS-06, and a description of plume delineation methods to be implemented in 2017 (as requested for MS-08; see comment #3).*"

Response: Discharge of effluent from the MS-06 FDP was limited to a single day (September 12) in 2016, during which 86 m^3 of effluent was released. Because the EEM study design was required to be submitted by July 10, 2016, data pertaining to the MS-06 FDP effluent release were not provided. It is anticipated that effluent release from the MS-06 FDP discharge will occur rarely, and for very brief periods of time. To the extent possible, given potential safety concerns associated with high water velocities, water depths greater than 1 m, and large boulder substrate (safe footing issues), Baffinland will conduct a specific conductance survey as indicated in the response to Action Item 3 above within the Mary River receiver at the time of effluent release to characterize mixing features. Because a hydrological station is established on Mary River, extrapolation of effluent concentrations in Mary River can also be conducted on a daily basis, as required, following download of the data at the end of the open-water season.

As suggested in the response to Action Item 1, the MS-08 FDP is likely to release greater volume of effluent than the MS-06 FDP in any given year (e.g., 2,217 m^3 was released at MS-08 in 2015, and 86 m^3 was released at MS-06 in 2016). Therefore, the MS-08 FDP will served as the focus for biological studies in the current EEM phase.

Action Item 14: "*The MS-06 FDP will discharge to the Mary River through a treated sewage pipeline; will mine effluent and treated sewage be discharged concurrently?"*

Response: Although it is unlikely that the MS-06 FDP will discharge concurrently with the discharge of treated sewage, in the event that unusually high amounts of runoff, there may be periods in which both are discharged concurrently. Please note that it is currently anticipated that discharge from the MS-06 FDP will occur very rarely (a few days per year) on an intermittent basis.

Action Item 15: "*Appendix A, Table A.4. Please indicate the location of stream sampling sites listed in Table A.4. Was there a noticeable difference in water chemistry between upstream and downstream sites on Tributary-F?"*

Response: A map showing the locations of the CREMP lotic sampling sites indicated on Appendix Table A.4 accompanies this response. No difference in water chemistry has been indicated between Mary River stations located upstream and downstream of the Tributary-F confluence.

<u>PART B – Other Items</u>

Comment 16: "*Fig. 2-4. The figure caption should refer to mean monthly stream discharge, not effluent discharge; please confirm."*

Response: Correct. The caption for Figure 2.4 should refer to mean monthly stream discharge, not effluent discharge. Sorry for any confusion.

Comment 17: "*p. 14. The proponent is recommended to conduct annual water quality monitoring in Tributary F near the confluence with the effluent discharge, and a comparable reference stream, in addition to proposed monitoring in the Mary River.*"

Response: Acknowledged. Annual water quality monitoring will be conducted in Tributary-F near the confluence with the effluent discharge, and a comparable reference stream, in addition to proposed monitoring in the Mary River.

Comment 18: "*p. 15. The report states that ninespine stickleback have been captured in low abundance in the Mary River area, but later states that arctic charr are the only species captured in Mary River. Have ninespine stickleback been located in any of the streams identified for the biological monitoring study?*"

Response: To our knowledge, no ninespine stickleback have been captured in the Mary River or in any of the streams identified for the EEM biological study. However, because this species is known to inhabit streams, rivers and lakes, there is some potential for ninespine stickleback presence in streams and rivers of the Mary River Project area. It is anticipated that if present, ninespine stickleback are likely to be present in low abundance in area lotic habitats given low numbers captured in lentic habitat near the mine.

Comment 19: "*p. 22. The proponent is advised to plan for up to 7 days of sampling per area to meet sample size targets for the fish survey.*"

Response: Stream backpack electrofishing is the proposed method of fish capture for the EEM study. Given the relatively small size of Tributary-F, the determination of whether fish are present within this tributary will likely require less than a day by an experienced electrofishing team. It is proposed that, in the event that fish are determined to be absent in Tributary-F through the initial sampling, ECCC will be contacted to determine the best course of action. Continuing to conduct active sampling for a full seven days in the absence of fish is not considered practical or cost efficient. It is suggested that resolution of this item occur through teleconference prior to implementation of the field study (August 2017) or during the ECCC site visit to the Mary River Project from August 15^{th} – 17^{th}, 2017.

Comment 20: "*p. 23. Please be advised that the TGD recommends independent confirmation of fish ageing for 10% of samples.*"

Response: Acknowledged. Independent confirmation of fish ageing will be conducted on 10% of submitted samples.

Comment 21: "*Table 3.2. The table indicates no statistical analysis for the reproduction endpoint. Please note that the non-lethal reproduction endpoint (relative abundance of YOY) can be analyzed by comparing exposure and reference length frequency distributions with the Kolmogorov-Smirnov test, with and without YOY. If the inclusion of YOY changes the outcome of statistical comparison, the proportion of YOY is considered to be different between sampling areas (TGD, Section 3.4.2.2).*"

Response: Acknowledged.

Comment 22: "*p. 25. Please ensure collection of trip and field blanks for water chemistry QA/QC, as recommended by the TGD (Section 5.8.4).*"

Response: Acknowledged. Water chemistry trip and field blanks will be collected.

Comment 23: "*An overview document outlining the amendments proposed for the MMER was shared with stakeholders in December 2016. If you have not received this document and would like a copy, please contact Erik Allen. The proposed amendments are expected to be published in Canada Gazette, Part 1 in spring of 2017. Canada Gazette, Part II publication would likely occur 12 to 18 months following Canada Gazette Part 1 publication.*"

Response: Thank you for letting us know. We had received a copy of the overview document early in 2017.

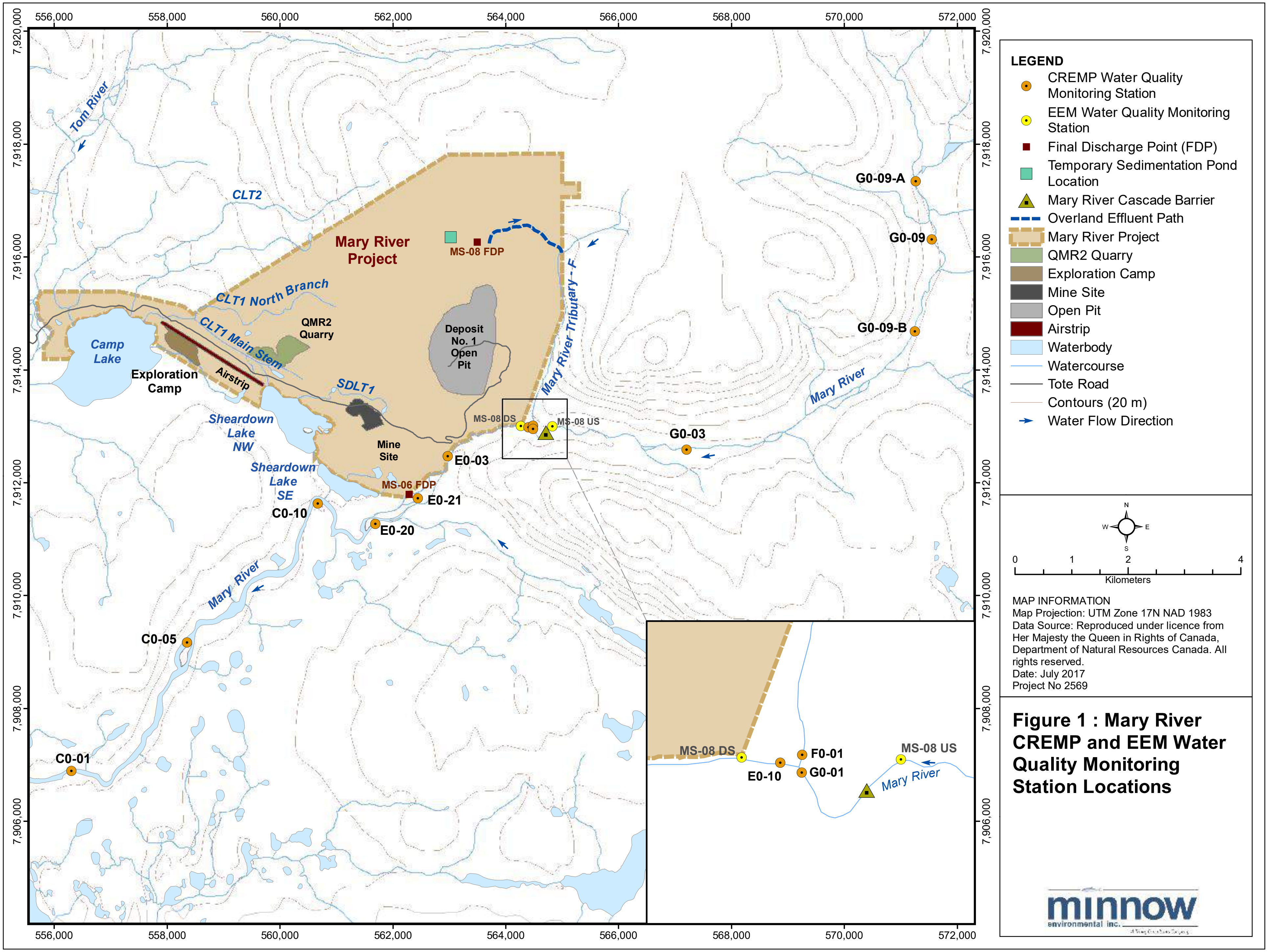

Figure 1 : Mary River CREMP and EEM Water Quality Monitoring Station Locations

Table A.2: Average monthly discharge data (m^3/s) collected from Mary River Project hydrological gauging stations, 2006 - 2015.

Year	Montth	Hydrological Station					
		H1 Phillips Creek Tributary (250 km^2)	H2 Tom River (210 km^2)	H4 Camp Lake Tributary2 (8.3 km^2)	H5 Camp Lake Tributary1 (5.3 km^2)	H6 Mary River (250 km^2)	H11 Sheardown Lake Trib1 (3.6 km^2)
2006	June	-	5.05	-	-	-	-
	July	14.65	19.20	0.83	0.38	26.64	-
	August	5.46	5.37	0.29	0.15	15.03	-
	September	7.42	3.07	0.29	0.17	24.01	-
2007	June	10.94	4.42	0.25	0.31		-
	July	6.93	7.78	0.21	0.10	11.68	-
	August	3.77	4.04	0.13	0.10	6.54	-
	September	1.62	1.14	0.07	0.05	4.22	-
2008	June	12.20	-	1.56	0.42	26.06	-
	July	10.31	-	0.38	0.22	16.96	-
	August	7.44	-	0.25	0.22	8.21	-
	September	5.33	-	0.17	0.12	7.06	-
2010	June	-	33.25	-	0.78	39.55	-
	July	-	14.34	-	0.19	18.76	-
	August	-	2.34	-	0.08	3.69	-
	September	-	5.42	-	0.14	7.13	-
2011	June	13.70	-	0.44	0.30	27.41	0.07
	July	3.11	-	0.07	0.05	5.29	0.02
	August	1.25	-	0.03	0.02	2.32	0.02
	September	1.56	-	0.03	0.02	1.89	0.02
2012	June	24.24	35.76	0.88	0.81	32.23	0.12
	July	7.49	13.42	0.39	0.22	11.63	0.07
	August	2.36	4.82	0.16	0.10	5.47	0.06
	September	3.90	-	0.28	0.17	8.00	0.08
2013	June	10.80	18.04	-	0.32	19.75	0.14
	July	9.74	17.95	0.09	0.25	20.98	0.12
	August	-	2.88	0.07	0.08	4.63	0.05
	September	-	-	0.05	0.06	3.07	0.06
2014	June	7.03	6.35	-	0.28	-	0.12
	July	13.42	21.28	-	0.42	31.09	0.09
	August	7.18	9.08	-	0.20	9.83	0.09
	September	2.14	1.90	-	0.05	1.88	0.04
2015	June	15.70	14.50	0.41	0.13	18.60	0.03
	July	8.80	6.00	0.20	0.06	9.20	0.04
	August	3.50	2.30	0.20	0.08	3.80	0.06
	September	-	0.90	0.03	0.03	1.10	0.03
Average	June	13.52	16.77	0.71	0.42	27.27	0.09
	July	9.31	14.28	0.31	0.21	16.91	0.07
	August	4.42	4.41	0.16	0.12	6.61	0.06
	September	3.66	2.49	0.13	0.09	6.48	0.04

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Prairie & Northern Region
Environmental Protection Operations Directorate
9250 – 49th Street NW
Edmonton, AB T6B 1K5

August 22, 2017

via email to: wayne.mcphee@baffinland.com

Wayne McPhee
Director Sustainable Development
Baffinland Iron Mines Corporation
2275 Upper Middle Road East, Suite 300
Oakville,ON L6H 0C3

Dear Mr. McPhee:

Subject: Metal Mining Effluent Regulations – Evaluation of 1st Environmental Effects Monitoring Study Design, Mary River Project, NU

This letter is to advise you that Environment and Climate Change Canada has reviewed your Environmental Effects Monitoring (EEM) biological study design report entitled "Mary River Project Environmental Effects Monitoring Phase 1 Study Design", received July 8, 2016 and an addendum to the report, received August 10, 2017. The review of study design reports takes into account information requirements in the *Metal Mining Effluent Regulations (MMER)* of the *Fisheries Act* and also offers comments on the study based on the EEM Technical Guidance Document and generally accepted standards of good scientific practice.

Review comments and recommendations are attached. No further response is required.

Regulated facilities are now required to submit reports to the Environmental Effects Monitoring Electronic Reporting system (EEMER). It is no longer necessary to submit electronic or paper copies directly to the authorization officer.

Environment and Climate Change Canada looks forward to receiving your interpretive report no later than January 10, 2018. Should you have any questions or concerns regarding the EEM program or wish to discuss the review of the study design, please do not hesitate to contact Erik Allen at (780) 717-4884 or at erik.allen@canada.ca.

Sincerely,

Susanne Forbrich
Regional Director
Regional Authorization Officer

Canada

cc:	William Bowden	Baffinland Iron Mines Corporation
	Laura Taylor	Baffinland Iron Mines Corporation
	Reg Ejeckam	Environment and Climate Change Canada, Winnipeg
	Paula Siwik	Environment and Climate Change Canada, Edmonton
	Erik Allen	Environment and Climate Change Canada, Edmonton
	Curtis Didham	Environment and Climate Change Canada, Iqaluit
	Sean Joseph	Nunavut Water Board, Vancouver
	Sarah Forté	Indigenous and Northern Affairs Canada, Iqaluit

Attachment: Review Comments and Recommendations on "Response to ECCC Comments on the Mary River Project 1st Environmental Effects Monitoring Study Design" (submitted August 10, 2017)

Review Comments and Recommendations on "Response to ECCC Comments on the Mary River Project 1st Environmental Effects Monitoring Study Design" (submitted August 10, 2017)

7. Regarding the fish survey, it was agreed during a meeting with the proponent and their consultant (Aug. 16/17) that fish sampling will be attempted in the Mary River near the confluence with Tributary-F, if no fish are located in the tributary. A downstream reach of the Mary River will be sampled as a reference area to the upstream Mary River exposure area, if needed. If fish sampling in Mary River is determined to be impractical, the facility is recommended to provide supporting information in the interpretative report.

19. With respect to the level of effort for the fish survey, the response suggests that less than a day would be needed to determine if fish are present in Tributary-F. During a meeting with the proponent and consultant (Aug. 16/17), ECCC noted that 7 days is the recommended level of effort to achieve target sample sizes, but that it could take less time to determine the presence or absence of fish. The sampling crew is recommended to apply an adequate level of effort to achieve the objective of the fish survey. Supporting information should be provided in the report to justify the level of effort.

APPENDIX B

2017 MS-08 DISCHARGE SUPPLEMENTAL INFORMATION

November 21, 2017

Curtis Didham
Enforcement Officer
Environment and Climate Change Canada
933 Mivvik Street
Iqaluit, Nunavut
X0A 0H0

Dear Mr. Didham,

Re: Investigation under subsection 36(3) of the Fisheries Act in regards to an effluent seepage and controlled discharges from the Waste Rock Stockpile Sedimentation Pond (WRSSP) located at Baffinland's Mary River Project (the Project).

Please find below a summary response prepared by Baffinland Iron Mines Corporation (Baffinland) in response to the investigation under the Fisheries Act and Metal Mining Effluent Regulations (MMER) initiated by Environment and Climate Change Canada (ECCC) on September 13, 2017.

<u>Project Development</u>

Baffinland proposed to develop the Project in a phased approach, and began construction for the Early Revenue Phase (ERP) in 2013, followed by the initial mining of Deposit 1 in September 2014. Prior to the development of Deposit 1, Baffinland had retained AMEC in 2012 to conduct water quality modelling of runoff and seepage originating from the Deposit 1 waste rock stockpile. The report concluded that, with the exception of total suspended solids (TSS), the water quality of runoff and seepage would meet the MMER discharge requirements. To address the estimated solids loading from the runoff and seepage and facilitate the monitoring of discharges, sedimentation ponds downstream of the waste rock stockpile(s) were proposed. In 2014, Baffinland retained AMEC to investigate the metal leaching and acid rock drainage (ML/ARD) potential of waste rock generated from ERP operations on Deposit 1. Results from AMEC's investigation were presented in a technical memo titled "Mary River Deposit 1, 5-Year Pit ML/ARD Characterization". AMEC had determined that approximately 85% of waste rock samples had neutralization potential ratios (NPR) greater than 2 pH and were classified as non-potentially acid generating and were unlikely to generate acidic drainage. Approximately 10% of the samples had NPR values of less than 1 pH, and 5% of the samples were classified as having uncertain acid generating potential (1<NPR<2). Humidity cell testing for historical samples of the Waste Rock Stockpile has stayed relatively consistent previous to 2017, indicating stable conditions in the majority of cells

Construction of the current WRSSP commenced in September 2015 and became operational in May 2016. A Construction Summary Report (CSR) produced by Hatch Ltd. (Hatch) for the current sedimentation pond, which was included in the 2016 Qikiqtani Inuit Association (QIA) and Nunavut Water Board (NWB) Annual

Baffinland

Report for Operations, was signed off by Baffinland in January 2017 and provided to regulators and stakeholders on March 31, 2017.

Under Part D, Item 18, of Baffinland's Type "A" Water License 2AMMRY1325 Amendment No. 1 (Water License), two annual geotechnical inspections are performed on water and waste retention structures. Barry H. Martin Consulting Engineer and Architect conducted two inspections in 2017. The Aug 1-10th bi-annual inspection did not identify integrity or containment issues concerning the WRSSP. Additionally, inspections of the facility from ECCC and Indigenous and Northern Affairs Canada (INAC) in 2016 and spring/early summer 2017 also did not identify seepage from the WRSSP or identify water quality concerns associated with the system. Internal compliance inspections are completed bi-monthly during the open water season on this facility and daily monitoring is completed during discharge which focuses on monitoring water quality in accordance with Baffinland's Water License and Schedule 4 of the MMER, as well as overall WRSSP conditions and operations. There were no issues of compliance with water quality limits in 2016 or in the first half of 2017.

The following summarizes the four incidents that occurred in August and September and remediation measures undertaken.

Spill Report 17-289

A heavy rain event was experienced over a period of several days in late July increasing the runoff into the pond and led to the requirement to de-water and maintain suitable pond freeboard. The pH results leading up to August 1st, which were measured by both YSI meter field readings and the ALS laboratory analyses, were consistently greater than 6.40. In early August low pH water was discharged to the environment on August 1st and 3rd. On August 1st, water chemistry and toxicity testing occurred. Results received indicated the pH of the water was below 6.0 which resulted in a toxicity failure for both Daphnia Magna and Rainbow Trout. No discharge to the environment occurred after receiving official ALS laboratory results.

August 10th - 24th:

- pH adjustment treatment of the WRSSP was planned with Wood Group PLC (formally AMEC Foster Wheeler) to determine the most effective treatment of the WRSSP with resources on site. On August 22-24th, batch treatment of the WRSSP was completed using sodium carbonate to effectively raise the pH from approximately 4 to 7.
- Golder Associates Ltd. (Golder) was consulted to commence work on increasing the storage capacity of the WRSSP.

Spill Report 17-312

On August 23, 2017 during an inspection of the WRSSP with ECCC and INAC, seepage was observed originating from the central toe of the WRSSP in approximately four discrete but closely clustered locations. Water quality samples were taken from the seepages occurring at the toe of the WRSSP in concert with ECCC and INAC on August 23rd and 24th during their on-site inspection and external analytical results indicated that, aside from nickel and TSS, water quality was compliant under the MMER and Water License.

August 25th:

- Construction of an emergency containment ditch downstream of the seepage.

September 1st:

- Hatch was consulted to explore options to stop the seepage from the toe of the WRSSP and identify potential remedial activities to the facility.
- Hatch recommended the placement of a till blanket upstream of the WRSSP liner key-in to allow for proper re-grading in an effort to reduce pooling on the inlet, as well as constructing two sumps to tie into the emergency containment ditch downstream of the WRSSP seepage.

September 2nd:

- Baffinland submitted a notification to regulators detailing the plan to mitigate the ongoing seepage at the WRSSP.

September 7th - 17th

- Construction of the till blanket and sumps were completed to the design specifications provided by Hatch from September 7th to 17th.

On September 26th, during an inspection of the WRSSP and down gradient seepage area, discoloured water was observed outside of the emergency containment ditch under ice and snow. Water quality sampling was conducted, which included acute toxicity testing. Analytical results showed nickel and TSS above applicable guidelines, though the acute toxicity test passed.

October 4th - 24th:

- Golder and Le Groupe Desfor (LGD) consulted to assess the situation and provide expert advice on locating the source and identifying potential remedial solutions.
- LGD Director of Civil Works concluded that the origin of the seepage could not be determined at that time under the existing conditions.
- Principal Geochemist from Golder conducted a detailed hydrological assessment and concluded that the pond design appears appropriate for its intended use.

October 19th:

- Story Environmental was contacted to provide recommendations for the utilization and implementation of using rhodamine dye to determine whether the WRSSP was the potential source of the seepage.
- Monitoring of the seepage for the presence of rhodamine occurred using a YSI meter with a rhodamine sensor. Rhodamine was detected in seepage grab samples indicating that the WRSSP liner's integrity may have been compromised. Current conditions limit the ability to confirm this to be true and further investigations into the matter are required when conditions allow.

October 21st – November 06:

- Construction of a new berm was completed around the outside perimeter of the emergency containment ditch to increase the ditch's containment capacity.
- Water was pumped from the containment ditch back to the WRSSP in order to effectively place ¾ inch rock at the base of the ditch to arrest further seepage.

Baffinland

Spill Report 17-328 and 17-361

On August 27th, visual observations of the turbidity of the WRSSP prompted the discharge to be shut down. Samples later confirmed that the TSS exceeded the Water License and MMER guidelines for an approximate 14-hour period. Discharge resumed again on August 28th after the pond had settled and TSS criteria was found to be below guidelines.

August 24th – 28th

- An Environment Effects Monitoring (EEM) study was performed by Minnow Environmental (Minnow). No exceedances were observed or recorded under applicable guidelines in discharge exposed Tributary F or Mary River except for aluminum. The aluminum is not exposure-related as aluminum was found to be present in the reference sites and is related to known historical turbidity-related colloidal effects in Mary River. The discharge from the WRSSP travels approximately 2.2 km from the Final Discharge Point (FDP) to where Tributary F becomes a defined channel which is non-fish bearing. The confluence with Mary River is located approximately 3 kilometers in distance from that location.

Discharging to the environment continued from August 30th to September 6th and water samples analyzed using the on-site ALS laboratory equipment run by Baffinland personnel were found to be compliant up to September 6th under the MMER and Water License discharge criteria for pH. In addition to the on-site laboratory results, samples were also shipped offsite to ALS Waterloo. The pH results received from the ALS laboratory in Waterloo from September 1st to 6th were below the MMER and Water License criteria. In consultation with the ALS Environmental Technical Director, it was determined that the initial pH measurements from the on-site laboratory taken by Baffinland Staff (within one to four hours of sampling) should be the most reliable and defensible pH measurements representing the conditions of the samples at time of sampling, rather than test results measured by ALS Waterloo which represent the pH of the sample after several days of potential acid rock drainage related redox reactions. The discharge to the environment was stopped on September 6th.

September 1st:

- Aquatic Effects Monitoring Plan (AEMP) data for stations at the confluence of the tributary, (Tributary F) that receives WRSSP effluent and the nearest fish bearing waters, were examined and did not show readily detectable influence from the discharge, exhibiting pH of approximately 8.

Additional Mitigation Measures

Additional mitigation measures were taken to address deficiencies identified with internal environmental systems, protocols and procedures:

- An Emergency Response Plan has been revised for the WRSSP in accordance with MMER requirements outlined in Section 30.
- A Working Near Water Containment Facilities Procedure has been drafted to provide a set of operational standards to ensure work is conducted in a safe and environmentally-compliant manner.

- The Site Environment team reporting structure was changed to include a Site Environmental Manager that will provide leadership and oversight to all site activities.

Additional mitigation measures that are in progress or planned are:

- Initiate a geochemical review of the waste rock dump layout and materials to develop a better understanding of low pH conditions observed on site and, if necessary, develop supplemental mitigation measures to reduce or eliminate production of acidic water from entering the WRSP.
- Review on-site equipment and consider whether additional equipment could more efficiently treat and discharge water from the WRSSP.
- Revise Waste Rock Management Plan to incorporate discharge and ARD mitigation measures
- Resource additional certified ALS Technician(s) and testing equipment during the summer season
- Evaluate and source appropriate coagulants if treatment required.
- Long Term - Design and implement fit for purpose AMD containment and treatment technology for prevention, source control and remediation.

Overall no impacts were observed in the receiving water bodies as shown through Baffinland's EEM and AEMP studies. Engineered mitigation measures to address water quality, seepage and pond capacity issues are currently being reviewed. Through the rhodamine testing early indications are that the source of the seepage is related to the integrity of the WRSSP liner, although further investigations are required to confirm these findings and upon confirmation we will immediately act upon.

Regards,

Todd Burlingame | Vice-President, Sustainable Development
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APPENDIX C

HABITAT CHARACTERIZATION INFORMATION

APPENDIX C HABITAT CHARACTERIZATION

C.1 Introduction

Habitat characterization provides information integral to the interpretation of effluent-related influences on benthic invertebrate communities and fish populations residing within aquatic environments that receive mine discharge. At Mary River Project, effluent is released overland into an intermittent channel that meets Mary River Tributary-F approximately 2 km east-northeast of the effluent discharge point. From this confluence, Mary River Tributary-F flows south approximately 3.3 km before discharging into Mary River. Mary River Tributary-F downstream of the effluent confluence and Mary River extending approximately 2.5 km downstream of the Mary River Tributary-F confluence served as the mine effluent-exposed areas for the benthic invertebrate community survey and fish population survey, respectively (Figure 2.1). Reference areas for the 2017 EEM study included Mary River Tributary-F upstream of the effluent channel for the benthic invertebrate community survey, and Mary River just upstream of Mary Lake for the fish population survey (Figure 2.1). Aquatic habitat characterization information collected at the Mary River Project EEM study areas (Table C.1) are summarized and contrasted herein to evaluate the degree to which natural habitat influences potentially contributed to differences in biological endpoints between like effluent-exposed and reference areas.

C.2 Mary River Tributary-F

Mary River Tributary-F occurs as a seasonally-flowing, second-order stream draining a watershed of approximately 6.8 square kilometres (km^2) at the confluence with the MS-08 mine effluent channel and 11.6 km^2 near the mouth at Mary River. Mary River Tributary-F exhibits a moderate gradient through the headwaters and mid-reaches, averaging approximately 4.5% and 6.3% at EEM benthic invertebrate community study areas located upstream and downstream of the MS-08 channel confluence, respectively (Table C.2; Photo Plate C.1). High gradients of approximately 10 to 12% are exhibited within approximately 0.8 km of the outlet to Mary River on Mary River Tributary-F (Photo Plate C.1). The channel of Mary River Tributary-F is typically well defined, exhibiting a slight meander, but areas of interstitial flow and/or channel braiding are not uncommon particularly in the upper and mid-reaches of the watercourse. Stream morphology of Mary River Tributary-F consists predominantly of riffle-run sequences separated by scour pools and rapids within the upper and mid-reaches (Table C.2), whereas riffle-cascade habitat is more prevalent at high gradient areas of the lower portion of the system. The combination of complete freezing overwinter, a relatively higher stream gradient, and the presence of natural in-stream barriers including an approximately

1.75 m high step-drop over large boulder habitat about 50 m upstream of the outlet to Mary River (Photo Plate C.1) are likely key factors contributing to the naturally fishless condition of Mary River Tributary-F (see Section 6).

The wetted and bankfull width of Mary River Tributary-F were greater immediately downstream of the MS-08 channel confluence than upstream at the time of the August 2017 field study, although only bankfull width differed significantly between areas (Tables C.2 and C.3). Notably, the determination of overall wet channel features was partly confounded by the occurrence of interstitial flow through boulder and/or large cobble substrate at these study areas. On average, water depths and water velocities were greater downstream than upstream of the MS-08 effluent channel confluence during the August 2017 sampling events, but the differences between areas were not significant (Tables C.2 and C.3). Maximum water depth of riffle habitat at both these areas was less than 10 cm deep, precluding the use of a Hess sampler for the sampling of benthic invertebrates during the August 2017 field study (see Section 2.4).

The substrate of Mary River Tributary-F is composed primarily of cobble and boulder (average of 54% and 35%, respectively, of in-stream substrate; Table C.2). Pebbles (i.e., 2 – 5 cm diameter material) and gravel constituted the remainder of in-stream substrate material during the August 2017 field study. Medium to coarse sand was observed only in trace amounts, and was primarily confined to areas of quiescent flow along channel banks and/or immediately downstream of large boulders. On average, substrate diameter (intermediate axis) was slightly larger downstream than upstream of the MS-08 effluent channel confluence on Mary River Tributary-F, although the difference in substrate diameter between these areas was not significant (Tables C.2 and C.3). In-stream vegetation was limited to a thin layer of periphyton (biofilms) attached to rocks not of sandstone or conglomerate origin based on visible and/or tactile assessment. No marked differences in periphyton growth were apparent between the Mary River Tributary-F effluent-exposed and reference study areas at the time of the August 2017 EEM field study (Table C.2).

C.3 Mary River

Mary River is a moderate gradient system (i.e., average gradient of 0.9%) characterized mainly by riffle-run morphology with some rapid/cascade habitat that includes an approximately 20 m high natural cascade located approximately 400 m upstream of the confluence with Mary River Tributary-F (Figure 2.1). At the confluence with Mary River Tributary-F, the Mary River flows through a deep gorge (Photo Plate C.1). The wetted channel width of Mary River decreases from an average of approximately 47 m to 19 m from upstream to downstream of this cascade, respectively, under typical late summer flow conditions. Commensurate with these changes in wetted width, average stream depth and water velocity were lower upstream of the cascade than downstream (0.30 and 0.48 m deep, and 0.43 and 0.85 m/s water velocity, respectively), based on sampling conducted in August 2015 (Minnow 2016). At the confluence with Mary River Tributary-F, Mary River has a watershed area of approximately 233 km^2.

The area of Mary River located a short distance downstream of the gorge served as the effluent-exposed area for the EEM fish population survey (Figure 2.3). At this location, Mary River occurs as a series of well defined, braided channels. Stream morphology of the braid sampled for the fish population survey consisted almost entirely of riffle habitat, with rapids also occurring in limited amounts (Table C.4). The wetted width and depth of this Mary River braid averaged approximately 20 m and 32 cm, respectively, at the time of the August 2017 field study (Table C.4). The substrate at the Mary River fish population survey effluent-exposed area is composed primarily of cobble (88% of in-stream habitat, on average; Table C.4; Photo Plate C.2). Similar to Mary River Tributary-F, medium to coarse sand was observed in trace amounts at this area of Mary River, and was limited primarily to locations with quiescent flow such as along channel banks and/or immediately downstream of large boulders. Substrate diameter (intermediate axis) averaged approximately 12 cm at the Mary River fish population survey effluent-exposed area (Table C.4).

Lower Mary River, near the outlet to Mary Lake, served as the reference area for the EEM fish population survey (Figure 2.3). At this area, Mary River occurs as a single, well-defined channel characterized mainly by riffle habitat and a minor amount of rapid habitat (Table C.4; Photo Plate C.2). The wetted width and depth of 73 m and 47 cm, respectively, at the Mary River reference area were much greater than the effluent-exposed area, reflecting braided channel dimensions at the latter, at the time of the August 2017 field study (Table C.4). Unlike the effluent-exposed area, the substrate at the Mary River reference area is composed primarily of boulders (75% of in-stream habitat) embedded in coarse sand rather than cobble (Table C.4). On average, the substrate diameter (intermediate axis) was 56 cm at the Mary River fish population survey reference area, which was much larger than at the corresponding effluent-exposed area (Table C.4). Overall, some differences in habitat features were apparent between the Mary River effluent-exposed and reference areas used for the fish population survey, including the occurrence of shallower mean depth and smaller substrate diameter (i.e., predominance of cobble versus boulder substrate) at the effluent-exposed area than at the reference area.

1) Mary River Tributary-F Benthic Reference Area.

2) Mary River Tributary-F Benthic Effluent-Exposed Area.

3) Mary River Tributary-F step-drop cascade barrier.

4) Mary River downstream of Mary River Tributary-F confluence.

Photo Plate C.1: Photographs of Mary River Tributary-F and Mary River at Gorge Area, August 2017

1) Mary River Fish Population Effluent-Exposed Area.

2) Mary River Fish Population Effluent-Exposed Area Substrate.

3) Mary River Fish Population Reference Area.

4) Mary River Fish Population Reference Area Substrate.

Photo Plate C.2: Photographs of Mary River Fish Population Survey Effluent-Exposed and Reference Areas, August 2017

Table C.1: Coordinates of Habitat Characterization Transect Stations Used for the Mary River Project Phase 1 EEM, August 2017

Study Area	Station	Date Sampled	Latitude (dd mm ss.s)[a]	Longitude (ddd mm ss.s)[a]
Mary River Tributary-F Reference	MRTF-REF H1	24-Aug-17	N 71 20 24.606	W 79 10 18.960
	MRTF-REF H2	24-Aug-17	N 71 20 21.098	W 79 10 30.182
	MRTF-REF H3	24-Aug-17	N 71 20 18.540	W 79 10 39.399
Mary River Tributary-F Effluent-Exposed	MRTF-EXP H1	24-Aug-17	N 71 20 16.499	W 79 10 52.095
	MRTF-EXP H2	24-Aug-17	N 71 20 14.465	W 79 10 55.513
	MRTF-EXP H3	24-Aug-17	N 71 20 08.213	W 79 10 56.806
Mary River Fish Reference	MRR H1	28-Aug-17	N 71 15 22.745	W 79 24 34.144
Mary River Fish Effluent-Exposed	MRE H1	27-Aug-17	N 71 18 13.014	W 79 14 39.495
	MRE H2	27-Aug-17	N 71 18 12.677	W 79 14 48.484

[a] Coordinates presented as dd mm ss.s (d-degrees, m-minutes, s-seconds) using 1983 North American Datum (NAD 83).

Table C.2: Summary of Habitat Features at Watercourses Evaluated as part of the Mary River Project EEM Benthic Invertebrate Community Survey, August 2017

Habitat Characteristic		Mary River Tributary-F Reference			Mary River Tributary-F Effluent-Exposed		
		MRTF-REF1	MRTF-REF3	MRTF-REF5	MRTF-EXP1	MRTF-EXP3	MRTF-EXP5
Mean Width (m)	Wetted	4.2	4.1	4.7	7.7	9.6	4.4
	Bankfull	20	20	21	25	25	23
Mean Depth (cm)	Average	4.8	5.4	5.6	6.8	7.4	13.8
Mean Velocity (m/s)	Average	0.05	0.07	0.07	0.04	0.10	0.10
Stream Morphology	% Pool	10	20	10	40	10	5
	% Rapid	10	5	5	10	10	15
	% Riffle	45	25	85	15	60	50
	% Run	35	50	-	35	20	20
	% Gradient	4.5	5	6	7	5	7
Substrate (% areal coverage)		0% bedrock 55% boulder 40% cobble 5% pebble 0% gravel 0% sand	0% bedrock 35% boulder 50% cobble 10% pebble 5% gravel 0% sand	0% bedrock 25% boulder 65% cobble 10% pebble 0% gravel 0% sand	0% bedrock 30% boulder 60% cobble 10% pebble 0% gravel 0% sand	0% bedrock 20% boulder 65% cobble 10% pebble 5% gravel 0% sand	0% bedrock 45% boulder 45% cobble 10% pebble 0% gravel 0% sand
Mean Substrate Size (cm)		12.9	9.7	6.7	12.5	10.7	16.8
Aquatic Vegetation (% areal coverage)	Periphyton Description	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks
	Macrophyte Coverage	none observed	none observed	none observed	none observed	none observed	none observed

Table C.3: Habitat Data Summary and Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Study Areas, August 2017

Channel Feature	Two-Area Comparison			Study Area	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		Minimum	Maximum
	Significant Difference between Areas?	p-value	Statistical Test					Lower Bound	Upper Bound		
Wetted Width (m)	NO	0.1310	α	Reference	4.3	0.3	0.2	3.5	5.1	4.1	4.7
				Effluent-Exposed	7.2	2.6	1.5	0.7	13.8	4.4	9.6
Bankfull Width (m)	YES	0.0058	β , ζ	Reference	20.3	0.6	0.3	18.9	21.8	20.0	21.0
				Effluent-Exposed	24.3	1.2	0.7	21.5	27.2	23.0	25.0
Water Depth (cm)	NO	0.1427	α , η	Reference	5.3	0.4	0.2	4.2	6.3	4.8	5.6
				Effluent-Exposed	9.3	3.8	2.2	-0.2	18.9	6.8	13.8
Water Velocity (m/s)	NO	0.4191	α , η	Reference	0.06	0.01	0.01	0.04	0.08	0.05	0.07
				Effluent-Exposed	0.08	0.03	0.02	0.00	0.16	0.04	0.10
Stream Gradient (% slope)	NO	0.1145	β , ζ	Reference	4.8	0.6	0.3	3.4	6.3	4.5	5.5
				Effluent-Exposed	6.3	1.2	0.7	3.5	9.2	5.0	7.0
Substrate Size (cm)	NO	0.2359	α	Reference	9.8	3.1	1.8	2.1	17.4	6.7	12.9
				Effluent-Exposed	13.3	3.2	1.8	5.5	21.2	10.7	16.8

Highlighted values indicate significant difference between study areas based on ANOVA p-value less than 0.05.

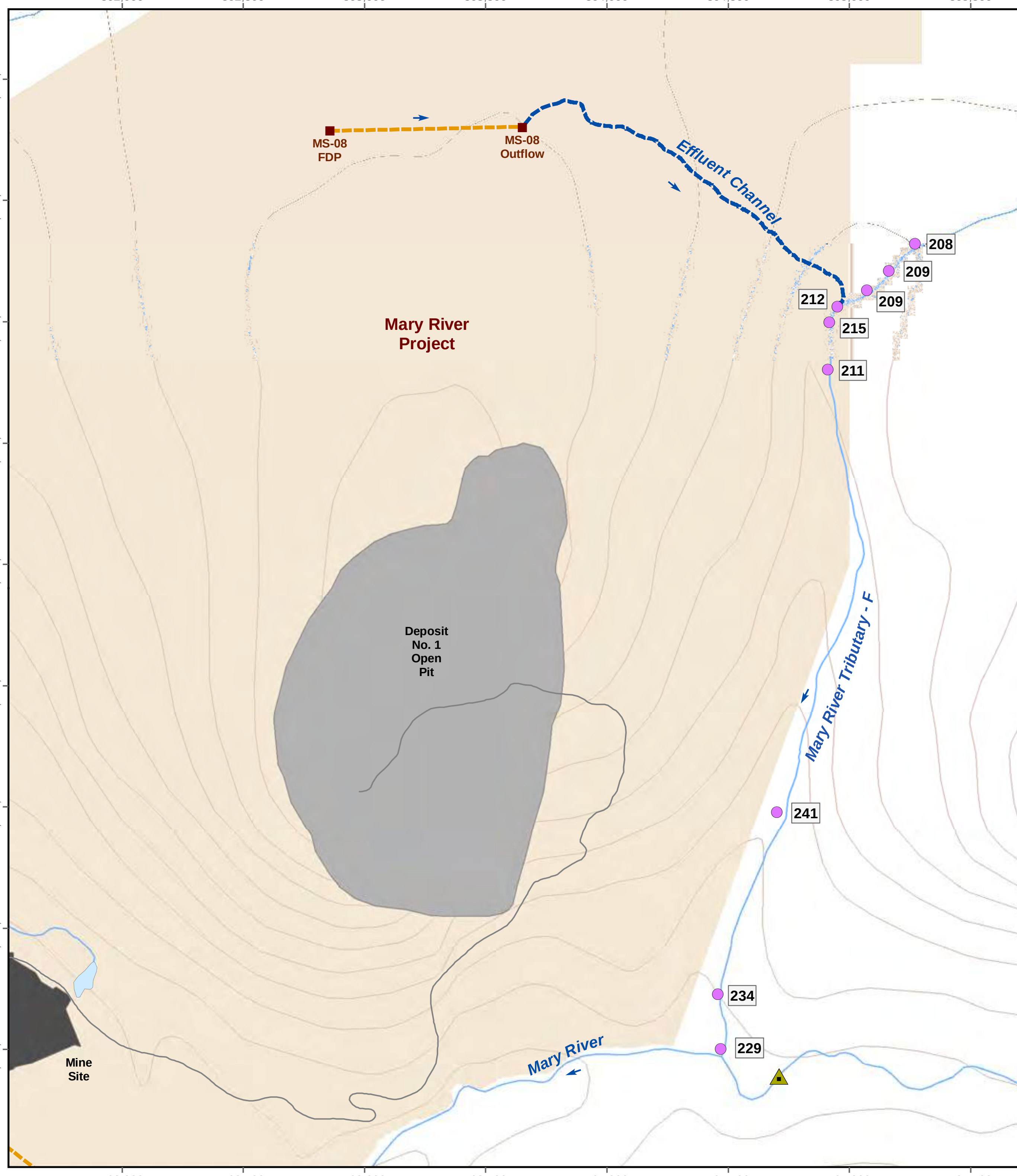
[a] Data analysis included: α - data untransformed, single factor ANOVA test conducted; β - data log-transformed, single factor ANOVA test conducted; γ - Mann-Whitney U-test conducted; ζ - single factor ANOVA test validated using Mann-Whitney U-test; η - single factor ANOVA test validated using t-test assuming unequal variance.

Table C.4: Summary of Habitat Features at Mary River Study Areas Used as part of the Mary River Project EEM Fish Population Survey, August 2017

Habitat Characteristic		Mary River Reference	Mary River Effluent-Exposed	
		Transect 1	Transect 1	Transect 2
Mean Width (m)	Wetted	72.9	14.8	25.8
Mean Depth (cm)	Average	47.7	29.7	35.1
Mean Velocity (m/s)	Average	0.30	-	-
Stream Morphology	% Pool	0	0	0
	% Rapid	10	20	0
	% Riffle	90	80	100
	% Run	0	0	0
Substrate (% areal coverage)		0% bedrock 75% boulder 15% cobble 5% pebble 0% gravel 5% sand	0% bedrock 5% boulder 85% cobble 10% pebble 0% gravel 0% sand	0% bedrock 5% boulder 90% cobble 5% pebble 0% gravel 0% sand
Mean Substrate Size (cm)		55.9	10.3	13.5
Aquatic Vegetation (% areal coverage)	Periphyton Description	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks	<0.5 mm thick of attached algae/periphyton on rocks
	Macrophyte Coverage	none observed	none observed	none observed

APPENDIX D

EFFLUENT AND WATER QUALITY DATA



LEGEND

- Sampling Location
- Final Discharge Point (FDP)
- Mary River Cascade Barrier
- Discharge Line
- Overland Effluent Channel
- 229 Specific Conductance (uS/cm)

Specific Conductance Data for Mary River Tributary-F During the EEM Field Study

0 0.25 0.5 1 km

Map Projection: UTM Zone 17N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Rights of Canada, Department of Natural Resources Canada. All rights reserved.

Date: January 2018
Project 177202.0033

minnow environmental inc.

Figure D.1

Document Path: S:\Projects\177202\177202.0033 - Baffinland 2017\2 - Mapping\Interpretive Report\17-33 Fig D.1 Specific Conductance Data.mxd

Table D.1: Station MS-08 Effluent Daily Discharge Volumes, 2015 - 2017

Year	Date	Volume Discharged (m^3)
2015	9-Jul-15	47
	10-Jul-15	64
	11-Jul-15	196
	12-Jul-15	293
	13-Jul-15	0.4
	20-Jul-15	80
	21-Jul-15	59
	27-Jul-15	203
	30-Jul-15	144
	5-Aug-15	124
	6-Aug-15	257
	7-Aug-15	149
	9-Aug-15	150
	10-Aug-15	150
	20-Aug-15	150
2016	20-Jul-16	135
	21-Jul-16	253
	22-Jul-16	129
	6-Aug-16	309
	7-Aug-16	656
	8-Aug-16	303
	17-Aug-16	84
	18-Aug-16	567
	19-Aug-16	767
	29-Aug-16	567
	30-Aug-16	232
	31-Aug-16	286
	1-Sep-16	585
	2-Sep-16	687
2017	2-Jul-17	1,716
	3-Jul-17	936
	8-Jul-17	12
	17-Jul-17	767
	18-Jul-17	20
	19-Jul-17	1,339
	20-Jul-17	249
	21-Jul-17	826
	29-Jul-17	335
	30-Jul-17	882
	31-Jul-17	346
	1-Aug-17	466
	3-Aug-17	369
	24-Aug-17	369
	25-Aug-17	376
	26-Aug-17	874
	27-Aug-17	523
	28-Aug-17	235
	29-Aug-17	604
	30-Aug-17	1,230
	31-Aug-17	1,008
	1-Sep-17	754
	2-Sep-17	437
	3-Sep-17	1,186
	4-Sep-17	794
	5-Sep-17	977
	6-Sep-17	864

Table D.2: Effluent Quality Monitoring Data for Mary River Project Station MS-08, 2015

	Variable	Units	MMER Grab Limit [a]	July			August	
				9-Jul-15	20-Jul-15	30-Jul-15	6-Aug-15	11-Aug-15
Routine Monitoring [b]	Volume	m^3/day	-	47	80	144	257	150
	pH	pH units	-	7.13	7.51	7.90	7.44	7.77
	TSS	mg/L	30	27	4	2	12	2
	Arsenic (As)	mg/L	1.00	0.0002	<0.00010	<0.0010	<0.00010	<0.00010
	Copper (Cu)	mg/L	0.60	0.0020	0.0005	<0.0010	0.0014	0.0011
	Lead (Pb)	mg/L	0.40	0.00082	0.00044	<0.00050	0.00023	0.00015
	Nickel (Ni)	mg/L	1.00	0.010	0.012	0.013	0.025	0.021
	Zinc (Zn)	mg/L	1.00	0.0051	<0.0030	<0.0030	0.0035	0.0031
	Radium-226	Bq/L	1.11	-	<0.0100	<0.0100	<0.0100	0.0160
Effluent Characterization [c]	Conductivity	µS/cm	-	-	948	-	1,320	-
	Hardness	mg/L (as $CaCO_3$)	-	223	495	678	667	780
	Alkalinity	mg/L (as $CaCO_3$)	-	18	32	45	-	44
	Ammonia (NH_4^+)	mg/L	-	0.36	0.44	0.38	-	0.47
	Nitrate (NO_3)	mg/L	-	1.9	4.0	5.5	-	4.9
	Aluminum (Al)	mg/L	-	0.804	0.065	0.067	0.115	0.118
	Cadmium (Cd)	mg/L	-	0.00005	0.00007	<0.000090	0.00018	0.00014
	Iron (Fe)	mg/L	-	1.120	0.164	0.138	0.479	0.178
	Mercury (Hg)	mg/L	0.000010	<0.000010	<0.000010	<0.000010	-	<0.000010
	Molybdenum (Mo)	mg/L	-	0.0001	0.0001	<0.00050	0.0002	<0.00050
	Selenium (Se)	mg/L	-	0.0007	0.0014	0.0021	0.0025	0.0027

Indicates grab sample concentration above applicable limit for deleterious substances *or* grab sample mercury concentration that exceeded fish usability assessment trigger value.

[a] Limits indicated refer to maximum authorized grab sample concentrations as per Schedule 4 of the MMER (Government of Canada 2016) except the limit for mercury, which has been included as a fish usability assessment trigger limit based on a grab sample concentration of 0.0001 mg/L.

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2016).

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2016).

Table D.3: Effluent Quality Monitoring Data for Mary River Project Station MS-08, 2016

	Variable	Units	MMER Grab Limit [a]	July		August				
				19-Jul-16	26-Jul-16	8-Aug-16	9-Aug-16	16-Aug-16	22-Aug-16	30-Aug-16
Routine Monitoring [b]	Volume	m^3/day	-	-	-	303	-	-	-	232
	pH	pH units	-	7.31	7.45	7.19	6.92	7.03	6.89	7.21
	TSS	mg/L	30	10	4	18	2	2	2	3
	Arsenic (As)	mg/L	1.0	0.00011.	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	Copper (Cu)	mg/L	0.6	0.0053	0.0036	0.0018	0.0047	0.0022	0.0016	0.0010
	Lead (Pb)	mg/L	0.4	0.00061	0.00030	0.00044	0.00010	0.00010	0.00010	0.00010
	Nickel (Ni)	mg/L	1.0	0.002	0.021	0.034	0.071	0.074	0.073	0.067
	Zinc (Zn)	mg/L	1.0	0.0050	0.0157	0.0052	0.0079	0.0078	0.0069	0.0070
	Radium-226	Bq/L	1.11	0.0100	0.0100	0.0100	0.0280	0.0140	0.0100	0.0110
Effluent Characterization [c]	Conductivity	µS/cm	-	63	-	-	-	1,240	-	1,300
	Hardness	mg/L (as $CaCO_3$)	-	25	-	-	-	683	-	718
	Alkalinity	mg/L (as $CaCO_3$)	-	11	-	-	-	21	-	16
	Ammonia (NH_4^+)	mg/L	-	0.02	-	-	-	0.69	-	0.72
	Nitrate (NO_3)	mg/L	-	0.2	-	-	-	5.0	-	5.2
	Aluminum (Al)	mg/L	-	0.660	-	-	-	0.020	-	0.057
	Cadmium (Cd)	mg/L	-	0.00001	-	-	-	0.00019	-	0.00017
	Iron (Fe)	mg/L	-	0.774	-	-	-	0.333	-	0.268
	Mercury (Hg)	mg/L	0.000010	0.00001	-	-	-	0.00001	-	0.00001
	Molybdenum (Mo)	mg/L	-	0.0005	-	-	-	0.0001	-	0.0001
	Selenium (Se)	mg/L	-	0.0001	-	-	-	-	-	0.0020

Indicates grab sample concentration above applicable limit for deleterious substances *or* grab sample mercury concentration that exceeded fish usability assessment trigger value.

[a] Limits indicated refer to maximum authorized grab sample concentrations as per Schedule 4 of the MMER (Government of Canada 2016) except the limit for mercury, which has been included as a fish usability assessment trigger limit based on a grab sample concentration of 0.0001 mg/L.

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2017).

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2017).

Table D.4: Effluent Quality Monitoring Data for Mary River Project Station MS-08, 2017

	Variable	Units	MMER Grab Limit [a]	July		August			September
				18-Jul-17	21-Jul-17	1-Aug-17	24-Aug-17	30-Aug-17	4-Sep-17
Routine Monitoring [b]	Volume	m^3/day	-	20	826	466	369	1,230	794
	pH	pH units	6.0 - 9.5	6.93	6.92	5.25	6.99	6.50	5.75
	TSS	mg/L	30	6	<2.0	11	13	26	13
	Arsenic (As)	mg/L	1.00	<0.00010	<0.00010	<0.0010	<0.0010	<0.0010	<0.0010
	Copper (Cu)	mg/L	0.60	0.0026	0.0070	0.0290	<0.010	<0.010	<0.010
	Lead (Pb)	mg/L	0.40	0.00033	0.00049	0.00764	<0.00050	0.00080	<0.00050
	Nickel (Ni)	mg/L	1.00	0.027	0.028	0.215	0.317	0.261	0.398
	Zinc (Zn)	mg/L	1.00	0.0067	0.0100	0.0420	<0.030	<0.030	0.0320
	Radium-226	Bq/L	1.11	0.0120	0.0100	0.0150	0.0300	-	-
Effluent Characterization [c]	Conductivity	µS/cm	-	-	656	-	3,330	-	-
	Hardness	mg/L (as $CaCO_3$)	-	-	318	-	1,990	-	-
	Alkalinity	mg/L (as $CaCO_3$)	-	-	10	-	82	-	-
	Ammonia (NH_4^+)	mg/L	-	-	0.43	-	1.67	-	-
	Nitrate (NO_3)	mg/L	-	-	2.5	-	8.0	-	-
	Aluminum (Al)	mg/L	-	-	0.036	-	<0.050	-	-
	Cadmium (Cd)	mg/L	-	-	0.00006	-	0.00038	-	-
	Iron (Fe)	mg/L	-	-	0.477	-	7.100	-	-
	Mercury (Hg)	mg/L	0.000010	-	-	-	<0.000010	-	-
	Molybdenum (Mo)	mg/L	-	-	<0.000050	-	<0.00050	-	-
	Selenium (Se)	mg/L	-	-	0.0012	-	0.0047	-	-

[shaded] Indicates grab sample concentration above applicable limit for deleterious substances *or* grab sample mercury concentration that exceeded fish usability assessment trigger value.

[a] Limits indicated refer to maximum authorized grab sample concentrations as per Schedule 4 of the MMER (Government of Canada 2017) except the limit for mercury, which has been included as a fish usability assessment trigger limit based on a grab sample concentration of 0.0001 mg/L.

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2017).

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2017).

Table D.5: Mary River Project Effluent (Station MS-09) Acute Lethality Results for Tests Conducted on Rainbow Trout and *Daphnia magna*, 2015 - 2017

Year	Date Sample Collected	Rainbow Trout (percent mortality in 100% effluent)	*Daphnia magna* (percent mortality in 100% effluent)
2015	-	0	0
	11-Aug-15	0	0
2016	19-Jul-16	0	0
	16-Aug-16	10	0
	30-Aug-16	0	0
2017	27-Jun-17	0	0
	11-Jul-17	0	0
	1-Aug-17	100	100
	24-Aug-17	0	6.7
	5-Sep-17	30	100

Table D.6: Effluent Quality Monitoring Data for Mary River Project Station MS-06, 2016

	Variable	Units	MMER Grab Limit [a]	MS-06
				12-Sep-16
Routine Monitoring [b]	Volume	m^3/day	-	86
	pH	pH units	-	7.98
	TSS	mg/L	30	4
	Arsenic (As)	mg/L	1.00	0.00014
	Copper (Cu)	mg/L	0.60	<0.0010
	Lead (Pb)	mg/L	0.40	0.00013
	Nickel (Ni)	mg/L	1.00	<0.00050
	Zinc (Zn)	mg/L	1.00	<0.0030
	Radium-226	Bq/L	1.11	0.0150
Effluent Characterization [c]	Conductivity	µS/cm	-	318
	Hardness	mg/L (as $CaCO_3$)	-	133
	Alkalinity	mg/L (as $CaCO_3$)	-	57
	Ammonia (NH_4^+)	mg/L	-	<0.020
	Nitrate (NO_3)	mg/L	-	0.7
	Aluminum (Al)	mg/L	-	0.078
	Cadmium (Cd)	mg/L	-	<0.000010
	Iron (Fe)	mg/L	-	0.110
	Mercury (Hg)	mg/L	0.000010	<0.000010
	Molybdenum (Mo)	mg/L	-	0.0039
	Selenium (Se)	mg/L	-	0.0001
Other Parameters	Total Dissolved Solids	mg/L	-	183
	Turbidity	NTU	-	7.5
	Chloride (Cl)	mg/L	-	9.9
	Fluoride (F)	mg/L	-	0.0880
	Total Kjeldahl Nitrogen	mg/L	-	0.4
	Phosphorus, Total	mg/L	-	0.0099
	Sulfate (SO4)	mg/L	-	78.4
	Dissolved Organic Carbon	mg/L	-	4.7
	Total Organic Carbon	mg/L	-	4.5
	Calcium (Ca)	mg/L	-	25.4
	Magnesium (Mg)	mg/L	-	16.9
	Manganese (Mn)	mg/L	-	0.0066
	Potassium (K)	mg/L	-	9.4
	Sodium (Na)	mg/L	-	4.0
	Thallium (Tl)	mg/L	-	0.000017
	Uranium (U)	mg/L	-	0.0037

Indicates grab sample concentration above applicable limit for deleterious substances *or* mercury concentration that exceeded fish usability trigger value.

[a] Limits indicated refer to maximum authorized grab sample concentrations as per Schedule 4 of the MMER (Government of Canada 2017) except the limit for mercury, which has been included as a fish usability assessment trigger limit based on a grab sample concentration of 0.0001 mg/L.

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2017).

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2017).

Table D.7: *In Situ* Water Quality Measurements Collected at Benthic Invertebrate Community Stations and Fish Population Study Areas for the Mary River Project EEM, August 2017

Study Area		Station	Date	Temperature (^oC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	pH (pH units)	Specific Conductance (µS/cm)
Mary River Tributary-F	Reference	MRTF-REF1	25-Aug-17	7.1	11.94	98.7	8.19	209
		MRTF-REF2	25-Aug-17	6.9	12.20	100.4	8.18	207
		MRTF-REF3	25-Aug-17	6.6	12.12	98.9	8.17	208
		MRTF-REF4	25-Aug-17	6.0	12.34	99.3	8.16	209
		MRTF-REF5	25-Aug-17	5.7	12.52	99.0	8.16	209
	Mine-exposed	MRTF-EXP1	25-Aug-17	5.8	12.23	97.9	8.19	212
		MRTF-EXP2	25-Aug-17	5.7	12.30	98.1	8.18	211
		MRTF-EXP3	25-Aug-17	5.8	12.28	98.0	8.18	215
		MRTF-EXP4	25-Aug-17	5.6	12.25	98.2	8.19	214
		MRTF-EXP5	25-Aug-17	5.9	12.22	97.9	8.18	211
Mary River	Reference	EF-REF-1	28-Aug-17	7.0	13.60	103.9	7.98	173
		EF-REF-2	28-Aug-17	7.1	12.50	102.7	7.99	172
		EF-REF-3	28-Aug-17	5.7	12.80	102.1	7.97	167
		EF-REF-4	28-Aug-17	5.3	12.71	100.4	7.94	184
		EF-REF-4	28-Aug-17	4.9	12.72	99.4	7.94	182
	Mine-exposed	EF-EXP-1	27-Aug-17	5.6	12.75	101.4	8.07	176
		EF-EXP-2	27-Aug-17	5.7	12.61	100.4	8.02	173
		EF-EXP-3	27-Aug-17	5.1	12.84	100.9	8.07	190
		EF-EXP-4	27-Aug-17	4.9	12.88	100.5	8.00	174
		EF-EXP-5	27-Aug-17	4.8	12.80	99.8	7.98	165

Table D.8: ***In Situ*** **Water Quality Data Summary and Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Benthic Study Areas, August 2017**

Metric	Two-Sample Comparison			Study Area	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		Minimum	Maximum
	Significant Difference between Areas?	p-value	Statistical Test					Lower Bound	Upper Bound		
Water Temperature (°C)	YES	0.0304	α , η	Reference	6.5	0.6	0.3	5.7	7.2	5.7	7.1
				Effluent-Exposed	5.8	0.1	0.1	5.6	5.9	5.6	5.9
Dissolved Oxygen (mg/L)	NO	0.7558	α , η	Reference	12.22	0.22	0.10	11.95	12.50	11.94	12.52
				Effluent-Exposed	12.26	0.03	0.02	12.21	12.30	12.22	12.30
Dissolved Oxygen (% saturation)	YES	0.0037	α	Reference	99.26	0.67	0.30	98.42	100.10	98.70	100.40
				Effluent-Exposed	98.02	0.13	0.06	97.86	98.18	97.90	98.20
pH (units)	YES	0.0804	α	Reference	8.17	0.01	0.01	8.16	8.19	8.16	8.19
				Effluent-Exposed	8.18	0.01	0.00	8.18	8.19	8.18	8.19
Specific Conductance (µS/cm)	YES	0.0017	α , η	Reference	208	1	0	207	210	207	209
				Effluent-Exposed	213	2	1	210	215	211	215

Highlighted values indicate significant difference between study areas based on ANOVA p-value less than 0.10.

[a] Data analysis included: α - data untransformed, single factor ANOVA test conducted; β - data log-transformed, single factor ANOVA test conducted; γ - Mann-Whitney U-test conducted; ζ - single factor ANOVA test validated using Mann-Whitney U-test; η - single factor ANOVA test validated using t-test assuming unequal variance.

Table D.9: ***In Situ* Water Quality Data Summary and Statistical Comparison Results between Mary River Effluent-Exposed and Reference Fish Population Study Areas, August 2017**

Metric	Two-Sample Comparison			Study Area	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		Minimum	Maximum
	Significant Difference between Areas?	p-value	Statistical Test					Lower Bound	Upper Bound		
Water Temperature (°C)	NO	0.1451	α , η	Reference	6.0	1.0	0.4	4.8	7.2	4.9	7.1
				Effluent-Exposed	5.2	0.4	0.2	4.7	5.7	4.8	5.7
Dissolved Oxygen (mg/L)	NO	0.6579	α	Reference	12.87	0.43	0.19	12.34	13.39	12.50	13.60
				Effluent-Exposed	12.78	0.10	0.05	12.65	12.91	12.61	12.88
Dissolved Oxygen (% saturation)	NO	0.2310	α , η	Reference	101.70	1.80	0.81	99.46	103.94	99.40	103.90
				Effluent-Exposed	100.60	0.60	0.27	99.86	101.34	99.80	101.40
pH (units)	YES	0.0158	α	Reference	7.96	0.02	0.01	7.94	7.99	7.94	7.99
				Effluent-Exposed	8.03	0.04	0.02	7.98	8.08	7.98	8.07
Specific Conductance (µS/cm)	NO	1.0000	α	Reference	176	7	3	167	184	167	184
				Effluent-Exposed	176	9	4	164	187	165	190

Highlighted values indicate significant difference between study areas based on ANOVA p-value less than 0.10.

[a] Data analysis included: α - data untransformed, single factor ANOVA test conducted; β - data log-transformed, single factor ANOVA test conducted; γ - Mann-Whitney U-test conducted; ζ - single factor ANOVA test validated using Mann-Whitney U-test; η - single factor ANOVA test validated using t-test assuming unequal variance.

Table D.10: Water Chemistry at Mary River Tributary-F and Mary River Stations during Periods of Effluent Discharge in 2015

	Variable	Units	CWQG [a]	MS-08-US Mary River Reference		MS-08-DS Mary River Effluent-Exposed	
				20-Jul-15	11-Aug-15	20-Jul-15	11-Aug-15
Routine Monitoring [b]	pH	pH units	6.0 - 9.5	7.98	8.16	7.97	7.95
	TSS	mg/L	-	<2.0	<2.0	<2.0	<2.0
	Arsenic (As)	mg/L	0.005	<0.00010	<0.00010	<0.00010	<0.00010
	Copper (Cu)	mg/L	0.002	0.0008	0.0011	0.0008	0.0011
	Lead (Pb)	mg/L	0.001	0.00022	0.00014	0.00019	0.00013
	Nickel (Ni)	mg/L	0.025	<0.00050	<0.0010	<0.00050	<0.0010
	Zinc (Zn)	mg/L	0.030	<0.0030	<0.0030	<0.0030	<0.0030
	Radium-226	Bq/L	-	<0.0100	<0.0100	<0.0100	<0.0100
Effluent Characterization [c]	Conductivity	µS/cm	-	75	-	78	-
	Hardness	mg/L (as $CaCO_3$)	-	36	68	38	71
	Alkalinity	mg/L (as $CaCO_3$)	-	36	65	38	66
	Ammonia (NH_4^+)	mg/L	-	<0.050	<0.050	<0.050	<0.050
	Nitrate (NO_3)	mg/L	13	<0.020	<0.020	<0.020	<0.020
	Aluminum (Al)	mg/L	0.100	0.390	0.233	0.383	0.227
	Cadmium (Cd)	mg/L	0.00012	<0.000010	<0.000010	<0.000010	<0.000010
	Iron (Fe)	mg/L	0.3	0.208	0.159	0.187	0.144
	Mercury (Hg)	mg/L	0.000026	<0.000010	<0.000010	<0.000010	<0.000010
	Molybdenum (Mo)	mg/L	0.073	0.0002	<0.00050	0.0002	<0.00050
	Selenium (Se)	mg/L	0.001	<0.0010	<0.000050	<0.0010	<0.000050
Other Parameters	Turbidity	NTU	-	-	4.4	-	2.0
	Total Dissolved Solids	mg/L	-	-	78	-	80
	Dissolved Organic Carbon	mg/L	-	-	<1.0	-	<1.0
	Total Organic Carbon	mg/L	-	-	<1.0	-	<1.0
	Total Kjeldahl Nitrogen	mg/L	-	-	0.21	-	<0.15
	Total Phosphorus	mg/L	0.02	-	0.0058	-	0.0051
	Fluoride (F)	mg/L	-	-	0.025	-	0.024
	Chloride (Cl)	mg/L	120	-	3.81	-	3.72
	Sulfate (SO4)	mg/L	218	-	3.26	-	3.19
	Antimony (Sb)-Total	mg/L	0.02	<0.00010	-	<0.00010	-
	Barium (Ba)-Total	mg/L	-	0.0076	-	0.0076	-
	Beryllium (Be)-Total	mg/L	0.011	<0.00050	-	<0.00050	-
	Bismuth (Bi)-Total	mg/L	-	<0.00050	-	<0.00050	-
	Boron (B)-Total	mg/L	-	<0.010	-	<0.010	-
	Calcium (Ca)-Total	mg/L	-	7.5	15.1	7.9	14.8
	Chromium (Cr)-Total	mg/L	0.0089	<0.00050	-	<0.00050	-
	Cobalt (Co)-Total	mg/L	-	<0.00010	-	<0.00010	-
	Lithium (Li)-Total	mg/L	-	<0.0010	-	<0.0010	-
	Magnesium (Mg)-Total	mg/L	-	4.23	8.38	4.44	8.44
	Manganese (Mn)-Total	mg/L	0.935	0.0019	0.0020	0.0022	0.0018
	Potassium (K)-Total	mg/L	-	0.93	1.11	0.94	1.10
	Silicon (Si)-Total	mg/L	-	1.40	-	1.39	-
	Silver (Ag)-Total	mg/L	0.00025	<0.000010	-	<0.000010	-
	Sodium (Na)-Total	mg/L	-	1.11	2.46	1.11	2.43
	Strontium (Sr)-Total	mg/L	-	0.0077	-	0.0077	-
	Thallium (Tl)-Total	mg/L	0.0008	<0.00010	<0.000010	<0.00010	<0.000010
	Titanium (Ti)-Total	mg/L	0.00010	0.012	-	0.011	-
	Uranium (U)-Total	mg/L	0.015	0.0008	0.0032	0.0008	0.0031
	Vanadium (V)-Total	mg/L	0.006	<0.0010	-	<0.0010	-

Indicates value above applicable Canadian Water Quality Guideline for the protection of aquatic life.

[a] Canadian Water Quality Guideline for the protection of aquatic life (CWQG; CCME 1999, 2016).

[b] Deleterious substances and pH as defined under Schedule 4 of the MMER (Government of Canada 2016) applicable to effluent quality

[c] Required effluent characterization and site-specific parameters as defined under Schedule 5 of the MMER (Government of Canada 2016) applicable to effluent quality.

Table D.11: Water Chemistry at Mary River Tributary-F and Mary River Stations during Periods of Effluent Discharge in 2016

	Parameters	Units	Water Quality Guideline (WQG)[a]	Mary River Tributary-F	Mary River Upstream			Mary River Downstream				
				FO-01 20-Aug-2016	MS-08-US 20-Jul-2016	MS-08-US 29-Aug-2016	G0-01 20-Aug-2016	E0-10 20-Aug-2016	MS-08-DS 20-Jul-2016	MS-08-DS 29-Aug-2016	EO-21 19-Aug-2016	CO-01 19-Aug-2016
Conventionals	Conductivity (lab)	umho/cm	-	261	70.5	189	174	186	73.5	193	172	170
	pH (lab)	pH	6.5 - 9.0	8.28	7.81	8.16	8.14	8.14	8	8.18	8.17	8.15
	Hardness (as $CaCO_3$)	mg/L	-	131	32	80	79	84	32	82	80	79
	Total Suspended Solids (TSS)	mg/L	-	3	<2.0	3.8	2.5	2.9	<2.0	6.8	3.4	2.5
	Total Dissolved Solids (TDS)	mg/L	-	141			69	102			86	89
	Alkalinity (as $CaCO_3$)	mg/L	-	118	33	72	75	82	37	75	68	72
Nutrients and Anions	Total Ammonia	mg/L	variable[c]	<0.020	0.02	0.02	<0.020	<0.020	0.02	0.02	0.026	0.022
	Nitrate	mg/L	13	0.096	0.02	0.02	<0.020	<0.020	0.02	0.022	<0.020	<0.020
	Total Organic Carbon	mg/L	-	1.4			1.5	2.3			1.5	1.6
	Total Phosphorus	mg/L	0.020$^{\alpha}$	0.0112			0.0098	0.0117			0.0157	0.0102
	Chloride (Cl)	mg/L	120	5.57			6.92	6.74			6.08	6.1
	Sulphate (SO_4)	mg/L	218$^{\beta}$	14.3			4.59	5.01			4.19	4.03
Total Metals	Aluminum (Al)	mg/L	0.100	0.251	0.211	0.475	0.484	0.418	0.308	0.572	0.431	0.32
	Antimony (Sb)	mg/L	0.020$^{\alpha}$	<0.00010			<0.00010	<0.00010			<0.00010	<0.00010
	Arsenic (As)	mg/L	0.005	0.00015	<0.00010	0.00012	0.00013	0.00014	<0.00010	0.00013	0.00014	0.00013
	Barium (Ba)	mg/L	-	0.0148			0.0142	0.0143			0.0143	0.0129
	Beryllium (Be)	mg/L	0.011$^{\alpha}$	<0.00010			<0.00010	<0.00010			<0.00010	<0.00010
	Bismuth (Bi)	mg/L	-	<0.000050			<0.000050	<0.000050			<0.000050	<0.000050
	Boron (B)	mg/L	1.5	<0.010			<0.010	<0.010			<0.010	<0.010
	Cadmium (Cd)	mg/L	0.00012	<0.000010	0.00001	0.00001	<0.000010	<0.000010	0.00001	0.00001	<0.000010	<0.000010
	Calcium (Ca)	mg/L	-	27			16.9	17.5			16.9	15.8
	Chromium (Cr)	mg/L	0.0089	0.00108			0.0011	0.00112			0.00108	0.00086
	Cobalt (Co)	mg/L	0.0009$^{\alpha}$	0.00024			0.00023	0.00022			0.00022	0.00018
	Copper (Cu)	mg/L	0.002	0.0019	<0.0010	0.0015	0.0016	0.0016	<0.0010	0.0015	0.0016	0.0017
	Iron (Fe)	mg/L	0.30	0.325	0.170	0.372	0.471	0.437	0.251	0.484	0.442	0.356
	Lead (Pb)	mg/L	0.001	0.00042	0.00016	0.00032	0.00041	0.0004	0.00019	0.0004	0.00039	0.00033
	Lithium (Li)	mg/L	-	0.0011			0.0011	<0.0010			<0.0010	<0.0010
	Magnesium (Mg)	mg/L	-	15.9			9.18	10.2			9.4	9.17
	Manganese (Mn)	mg/L	0.935$^{\beta}$	0.00498			0.00547	0.00531			0.00541	0.00526
	Mercury (Hg)	mg/L	0.000026	<0.000010	0.00001	0.00001	<0.000010	<0.000010	0.00001	0.00001	<0.000010	<0.000010
	Molybdenum (Mo)	mg/L	0.073	0.000337	0.000172	0.000471	0.000457	0.000425	0.000174	0.000465	0.000534	0.000463
	Nickel (Ni)	mg/L	0.025	0.00148	<0.00050	0.00076	0.00102	0.00111	<0.00050	0.00104	0.00117	0.00114
	Potassium (K)	mg/L	-	1.46			1.42	1.44			1.4	1.38
	Selenium (Se)	mg/L	0.001	0.000052	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Silicon (Si)	mg/L	-	1.25			1.73	1.56			1.66	1.41
	Silver (Ag)	mg/L	0.00025	<0.000050			<0.000050	<0.000050			<0.000050	<0.000050
	Sodium (Na)	mg/L	-	2.2			3.69	3.54			3.35	3.33
	Strontium (Sr)	mg/L	-	0.0197			0.0184	0.0188			0.0179	0.0165
	Thallium (Tl)	mg/L	0.0008	0.000013			0.000014	0.000015			0.000015	0.000013
	Tin (Sn)	mg/L	-	<0.00010			<0.00010	<0.00010			<0.00010	<0.00010
	Titanium (Ti)	mg/L	-	0.0156			0.0271	0.0245			0.0248	0.0185
	Uranium (U)	mg/L	0.015	0.00353			0.00468	0.0043			0.00406	0.00364
	Vanadium (V)	mg/L	0.006$^{\alpha}$	0.00078			0.00104	0.00101			0.00098	0.00082
	Zinc (Zn)	mg/L	0.030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0034	<0.0030	<0.0030	<0.0030

[a] Canadian Water Quality Guideline for the protection of aquatic life (CCME 1987, 1999) except those indicated by α (Ontario Provincial Water Quality Objective [PWQO]; OMOE 1994) and β (British Columbia Water Quality Guideline [BCWQG]; BCMOE 2013).

Indicates parameter concentration above applicable Water Quality Guideline.

Table D.12: Water Chemistry at Mary River Tributary-F and Mary River Stations during Periods of Effluent Discharge in 2017

Parameters		Units	Water Quality Guideline (WQG)[a]	Mary River Tributary-F			Mary River Upstream				Mary River Downstream						
				MRTF-1 24-Aug-2017	FO-01 8-Jul-2017	FO-01 1-Sep-2017	MS-08-US 21-Jul-2017	MS-08-US 24-Aug-2017	GO-01 8-Jul-2017	G0-01 1-Sep-2017	E0-10 1-Sep-2017	MS-08-DS 21-Jul-2017	MS-08-DS 24-Aug-2017	EO-21 8-Jul-2017	E0-21 1-Sep-2017	CO-01 8-Jul-2017	CO-01 27-Aug-2017
Conventionals	Conductivity (lab)	umho/cm	-	196	51.4	266	49.8	136	29.8	151	157.5	52.9	141	30.1	164	32.2	143
	pH (lab)	pH	6.5 - 9.0	8.12	7.57	8.22	7.62	8.06	7.22	8.08	8.095	7.63	8.04	7.32	8.04	7.44	8.01
	Hardness (as $CaCO_3$)	mg/L	-	96	27	134	22	61	13	70	74	24	63	13	78	14	72
	Total Suspended Solids (TSS)	mg/L	-	<2.0	7.3	5.2	3.4	<2.0	3.9	<2.0	<2.0	3.6	<2.0	<2.0	<2.0	3.4	3.3
	Total Dissolved Solids (TDS)	mg/L	-	106	35	136	-	76	19	74	76	-	43	17	79	25	71
	Alkalinity (as $CaCO_3$)	mg/L	-	97	22	107	24	58	11	66	69	24	61	10	69	14	63
Nutrients and Anions	Total Ammonia	mg/L	variable[c]	0.177	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
	Nitrate	mg/L	13	0.116	<0.020	0.134	<0.020	<0.020	<0.020	<0.020	0.035	0.075	<0.020	<0.020	0.058	<0.020	0.07
	Total Organic Carbon	mg/L	-	<1.0	0.95	1	<1.0	1.4	1.25	1.1	1.15	<1.0	1.5	1.46	1.1	1.24	1.3
	Total Phosphorus	mg/L	0.020[α]	<0.0030	0.0112	0.0067	0.0065	0.0046	0.0078	0.0036	0.0038	0.011	0.0053	0.0088	0.0037	0.0103	0.0066
	Chloride (Cl)	mg/L	120	1.26	<0.50	5.37	1.05	3.86	0.73	4.61	4.65	1.52	3.87	0.75	4.7	0.73	4.1
	Sulphate (SO_4)	mg/L	218[β]	2.8	1.23	25.3	0.62	2.44	0.32	2.93	4.34	0.73	2.97	0.39	7.53	0.61	3.79
Total Metals	Aluminum (Al)	mg/L	0.100	0.0573	0.133	0.187	0.0908	0.154	0.0986	0.0586	0.07085	0.0948	0.150	0.101	0.0704	0.123	0.219
	Antimony (Sb)	mg/L	0.020[α]	0.00043	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Arsenic (As)	mg/L	0.005	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Barium (Ba)	mg/L	-	0.0076	0.00355	0.0138	0.00386	0.00907	0.00299	0.00895	0.009345	0.00367	0.00949	0.0028	0.00973	0.003	0.0101
	Beryllium (Be)	mg/L	0.011[α]	<0.00010	<0.00050	<0.00050	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00010	<0.00010	<0.00050	<0.00050	<0.00050	<0.00010
	Bismuth (Bi)	mg/L	-	<0.000050	<0.00050	<0.00050	<0.000050	<0.000050	<0.00050	<0.00050	<0.00050	<0.000050	<0.000050	<0.00050	<0.00050	<0.00050	<0.000050
	Boron (B)	mg/L	1.5	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (Cd)	mg/L	0.00012	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Calcium (Ca)	mg/L	-	20.7	5.11	26.5	4.58	13.1	2.76	13.7	14.9	4.78	13.2	2.81	15.7	2.98	13.9
	Chromium (Cr)	mg/L	0.0089	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Cobalt (Co)	mg/L	0.0009[α]	<0.00010	0.00011	0.00017	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00013
	Copper (Cu)	mg/L	0.002	<0.0010	0.00061	0.00096	<0.0010	0.001	0.00052	0.00084	0.00081	<0.0010	<0.0010	0.00053	0.00085	0.00053	0.0011
	Iron (Fe)	mg/L	0.30	<0.050	0.189	0.237	0.09	0.114	0.071	0.043	0.0525	0.102	0.091	0.083	0.053	0.09	0.237
	Lead (Pb)	mg/L	0.001	0.000051	0.000225	0.000253	0.000112	0.000103	0.000087	<0.000050	0.0000565	0.000095	0.000089	0.000087	0.000073	0.000109	0.000175
	Lithium (Li)	mg/L	-	<0.0010	<0.0010	0.0015	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Magnesium (Mg)	mg/L	-	11.5	3.21	16.4	2.67	6.9	1.56	8.01	8.87	2.96	7.34	1.65	8.94	1.78	8.17
	Manganese (Mn)	mg/L	0.935[β]	0.00052	0.00333	0.00675	0.00164	0.00186	0.00177	0.000579	0.000985	0.00163	0.00105	0.00173	0.0051	0.00205	0.00536
	Mercury (Hg)	mg/L	0.000026	<0.000010	<0.000010	<0.000010		<0.000010	<0.000010	<0.000010	<0.000010		<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Molybdenum (Mo)	mg/L	0.073	0.000186	<0.000050	0.000255	0.000089	0.00031	<0.000050	0.00027	0.000255	0.000089	0.000315	0.00005	0.000556	0.000051	0.000323
	Nickel (Ni)	mg/L	0.025	<0.00050	0.00051	0.00068	0.0006	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.0005	<0.00050	0.0005	<0.00050	0.00078
	Potassium (K)	mg/L	-	0.902	0.37	1.38	0.469	1.04	0.35	0.92	0.965	0.455	1.06	0.35	0.98	0.37	1.11
	Selenium (Se)	mg/L	0.001	<0.000050	<0.0010	<0.0010	<0.000050	<0.000050	<0.0010	<0.0010	<0.0010	<0.000050	<0.000050	<0.0010	<0.0010	<0.0010	<0.000050
	Silicon (Si)	mg/L	-	0.88	0.5	1.23	0.64	0.99	0.5	0.99	1.02	0.64	1.02	0.57	1.01	0.56	1.11
	Silver (Ag)	mg/L	0.00025	<0.000050	<0.000010	<0.000010	<0.000050	<0.000050	<0.000010	<0.000010	<0.000010	<0.000050	<0.000050	<0.000010	<0.000010	<0.000010	<0.000050
	Sodium (Na)	mg/L	-	0.9	0.254	1.76	0.68	2.23	0.458	2.32	2.28	0.62	2.07	0.43	2.26	0.455	2.38
	Strontium (Sr)	mg/L	-	0.0108	0.00286	0.0191	0.0045	0.0125	0.00261	0.0132	0.0134	0.0044	0.0133	0.00259	0.0156	0.00265	0.0129
	Thallium (Tl)	mg/L	0.0008	<0.000010	<0.00010	<0.00010	<0.000010	<0.000010	<0.00010	<0.00010	<0.00010	<0.000010	<0.000010	<0.00010	<0.00010	<0.00010	<0.000010
	Tin (Sn)	mg/L	-	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)	mg/L	-	<0.00030	<0.010	0.014	0.00504	0.00572	<0.010	<0.010	<0.010	0.00538	0.00503	<0.010	<0.010	<0.010	0.0113
	Uranium (U)	mg/L	0.015	0.00251	0.000198	0.00261	0.000275	0.00231	0.000137	0.00278	0.00276	0.000269	0.00237	0.000142	0.00266	0.000154	0.00208
	Vanadium (V)	mg/L	0.006[α]	<0.00050	<0.0010	<0.0010	<0.00050	<0.00050	<0.0010	<0.0010	<0.0010	<0.00050	<0.00050	<0.0010	<0.0010	<0.0010	0.00055
	Zinc (Zn)	mg/L	0.030	0.0038	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

[a] Canadian Water Quality Guideline for the protection of aquatic life (CCME 1987, 1999) except those indicated by α (Ontario Provincial Water Quality Objective [PWQO]; OMOE 1994) and β (British Columbia Water Quality Guideline [BCWQG]; BCMOE 2013).

Indicates parameter concentration above applicable Water Quality Guideline.

APPENDIX E

BENTHIC INVERTEBRATE COMMUNITY DATA

Table E.1: Coordinates of Benthic Invertebrate Community Sampling Stations Used for the Mary River Project Phase 1 EEM, August 2017

Study Area	Station	Date Sampled	Latitude (dd mm ss.s)[a]	Longitude (ddd mm ss.s)[a]
Mary River Tributary-F Reference	MRTF-REF1	25-Aug-17	N 71 20 24.606	W 79 10 18.960
	MRTF-REF2	25-Aug-17	N 71 20 22.656	W 79 10 24.287
	MRTF-REF3	25-Aug-17	N 71 20 21.098	W 79 10 30.182
	MRTF-REF4	25-Aug-17	N 71 20 19.717	W 79 10 34.246
	MRTF-REF5	25-Aug-17	N 71 20 18.540	W 79 10 39.399
Mary River Tributary-F Effluent-Exposed	MRTF-EXP1	25-Aug-17	N 71 20 16.499	W 79 10 52.095
	MRTF-EXP2	25-Aug-17	N 71 20 15.709	W 79 10 53.884
	MRTF-EXP3	25-Aug-17	N 71 20 14.465	W 79 10 55.513
	MRTF-EXP4	25-Aug-17	N 71 20 11.597	W 79 10 56.085
	MRTF-EXP5	25-Aug-17	N 71 20 08.213	W 79 10 56.806

[a] Coordinates presented as dd mm ss.s (d-degrees, m-minutes, s-seconds) using 1983 North American Datum (NAD 83).

Table E.2: Replicate Habitat Measurements Collected at Benthic Invertebrate Community Stations, Mary River Project Phase 1 EEM, August 2017

Study Area	Station	Water Depth (cm)			Water Velocity (m/s)			Substrate Size[a] (cm)			Embeddedness		
		Replicate Grab 1	Replicate Grab 2	Replicate Grab 3	Replicate Grab 1	Replicate Grab 2	Replicate Grab 3	Replicate Grab 1	Replicate Grab 2	Replicate Grab 3	Replicate Grab 1	Replicate Grab 2	Replicate Grab 3
Mary River Tributary-F Reference	MRTF-REF1	6	7	6	0.27	0.25	0.26	6.6	6.4	6.8	0%	38%	13%
	MRTF-REF2	4	4	4	0.28	0.14	0.18	6.6	6.1	6.8	25%	13%	38%
	MRTF-REF3	3	3	3	0.19	0.14	0.15	6.7	6.1	4.9	13%	0%	13%
	MRTF-REF4	4	5	6	0.12	0.19	0.15	6.7	4.1	8.0	0%	25%	25%
	MRTF-REF5	4	4	4	0.13	0.11	0.29	6.2	5.5	5.0	25%	25%	38%
Mary River Tributary-F Effluent-Exposed	MRTF-EXP1	4	4	4	0.11	0.18	0.26	5.6	6.1	4.7	13%	25%	13%
	MRTF-EXP2	6	6	6	0.17	0.23	0.22	5.2	5.7	6.5	0%	25%	50%
	MRTF-EXP3	6	7	7	0.29	0.17	0.13	7.0	6.9	7.0	13%	13%	13%
	MRTF-EXP4	7	7	6	0.30	0.14	0.19	7.8	6.4	6.8	13%	38%	0%
	MRTF-EXP5	8	9	6	0.29	0.23	0.17	6.7	5.9	7.2	13%	25%	25%

[a] Substrate measurements taken on the intermediate axis of each individual particle observed within the Surber sampler area as viewed from the surface prior to sampling. Sample size ranged from 6 - 8 measurements per replicate grab, with a mean of 6.2 for the entire 2017 stream sampling program.

Table E.3: Replicate Station Habitat Feature Summary and Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Study Areas, August 2017

Channel Feature	Two-Area Comparison			Study Area	Mean	Standard Deviation	Standard Error	95% Confidence Interval for Mean		Minimum	Maximum
	Significant Difference between Areas?	p-value	Statistical Test					Lower Bound	Upper Bound		
Water Depth (cm)	YES	0.0706	α	Reference	4.5	1.3	0.6	2.9	6.0	3.0	6.3
				Effluent-Exposed	6.2	1.4	0.6	4.5	7.9	4.0	7.7
Water Velocity (cm/s)	NO	0.4811	α	Reference	19.0	4.3	1.9	13.7	24.3	15.3	26.0
				Effluent-Exposed	20.5	1.7	0.8	18.4	22.7	18.3	23.0
Substrate Size (cm)	NO	0.6103	α	Reference	6.2	0.4	0.2	5.6	6.7	5.6	6.6
				Effluent-Exposed	6.4	0.7	0.3	5.5	7.2	5.5	7.0
Substrate Embeddedness (%)	NO	0.8480	α	Reference	19.2	8.1	3.6	9.1	29.3	8.3	29.2
				Effluent-Exposed	18.3	4.8	2.1	12.4	24.2	12.5	25.0

Highlighted values indicate significant difference between study areas based on ANOVA p-value less than 0.1.

[a] Data analysis included: α - data untransformed, single factor ANOVA test conducted; β - data log-transformed, single factor ANOVA test conducted; γ - Mann-Whitney U-test conducted; ζ - single factor ANOVA test validated using Mann-Whitney U-test; η - single factor ANOVA test validated using t-test assuming unequal variance.

Table E.4: Benthic Invertebrate Community Data (Densities Expressed in Number of Organisms per Square Metre) for Mary River Tributary-F Study Areas, August 2017

Taxa	Reference Area					Effluent-Exposed Area				
	1	2	3	4	5	1	2	3	4	5
ROUNDWORMS										
P. Nemata	7	-	-	-	-	-	-	4	-	-
ANNELIDS										
P. Annelida										
WORMS										
Cl. Oligochaeta										
F. Enchytraeidae	4	-	-	4	-	-	-	-	7	4
ARTHROPODS										
P. Arthropoda										
MITES										
Cl. Arachnida										
O. Acarina										
F. Sperchonidae										
Sperchon	-	7	-	7	4	7	-	4	18	-
INSECTS										
Cl. Insecta										
MAYFLIES										
O. Ephemeroptera										
F. Baetidae										
immature	-	-	-	4	-	-	-	-	-	-
TRUE FLIES										
O. Diptera										
MIDGES										
F. Chironomidae										
chironomid pupae	18	4	-	14	14	-	4	4	4	-
S.F. Diamesinae										
Diamesa	75	29	22	86	36	22	50	100	133	97
Pseudokiefferiella	57	-	11	68	36	14	4	-	7	11
S.F. Orthocladiinae										
Chaetocladius	14	-	-	14	-	7	-	4	-	-
Corynoneura	-	-	7	-	-	-	-	-	-	-
Cricotopus/Orthocladius	-	4	-	7	-	-	7	7	32	-
Diplocladius	11	-	4	4	-	7	4	4	7	-
Eukiefferiella	208	104	47	280	100	39	168	247	222	43
Krenosmittia	14	75	7	39	29	32	39	39	14	4
Limnophyes	18	7	-	4	-	4	-	-	-	-
Metriocnemus	-	-	-	7	-	-	-	-	-	-
Parakiefferiella	-	11	-	-	-	-	-	-	-	-
Paraphaenocladius	4	-	-	-	-	-	-	-	-	-
Tokunagaia	11	7	4	-	25	4	4	14	7	-
Tvetenia	-	-	-	-	-	-	4	-	-	-
Vivacricotopus	-	-	-	4	-	-	-	-	-	-
indeterminate	-	-	-	4	-	4	-	-	-	-
F. Empididae										
Clinocera	-	-	-	-	-	4	-	-	7	-
pupae	4	-	-	-	-	-	-	-	-	-
F. Simuliidae										
Gymnopais	161	219	82	480	75	297	462	552	706	685
Prosimulium/Helodon	-	-	-	7	-	-	-	-	-	-
F. Tipulidae										
Tipula	7	7	4	25	11	7	4	36	11	11
Density (No. organisms per m^2)	613	474	188	1,058	330	448	750	1,015	1,175	855
Richness[a]	6	4	3	6	4	5	3	5	6	4
Simpson's Evenness (E)[a]	0.297	0.529	0.689	0.359	0.430	0.379	0.637	0.428	0.338	0.370
Bray-Curtis Index[a]	0.204	0.069	0.378	0.439	0.121	0.291	0.302	0.423	0.481	0.491

[a] Metrics calculated using Family Level (FL) taxonomy.

Table E.5: Supporting Benthic Invertebrate Community Metrics for Mary River Tributary-F Effluent-Exposed and Reference Study Area Replicate Stations, Mary River Project Phase 1 EEM, August 2017

Supportng Metric	Reference Area					Effluent-Exposed Area				
	1	2	3	4	5	1	2	3	4	5
Family Level Taxonomy										
Simpson's Diversity (FL) [a]	0.439	0.528	0.516	0.536	0.418	0.472	0.477	0.533	0.507	0.324
Shannon-Wiener Diversity (FL)[a]	1.108	1.191	1.121	1.251	1.061	1.162	1.001	1.239	1.216	0.818
Lowest Practical Level Taxonomy										
Richness (LPL) [b]	14	10	9	16	8	12	10	11	12	7
Simpson's Evenness (LPL)[b]	0.319	0.339	0.406	0.211	0.626	0.182	0.228	0.246	0.202	0.217
Bray-Curtis Index (LPL) [b]	0.249	0.200	0.385	0.460	0.160	0.312	0.387	0.493	0.557	0.580
Simpson's Diversity (LPL) [b]	0.776	0.705	0.726	0.704	0.800	0.542	0.561	0.631	0.588	0.342
Shannon-Wiener Diversity (LPL)[b]	2.655	2.213	2.332	2.322	2.581	1.918	1.667	1.919	1.849	1.063
Dominant Taxa Groups										
% Chironomidae	70.1%	50.8%	54.3%	50.2%	72.7%	29.7%	37.9%	41.3%	36.3%	18.1%
% Metal Sensitive Chironomidae	24.8%	22.2%	21.3%	18.8%	32.4%	15.6%	12.5%	13.8%	13.2%	13.1%
% Simuliidae	26.3%	46.2%	43.6%	46.0%	22.7%	66.3%	61.6%	54.4%	60.1%	80.1%
% Tipulidae	1.1%	1.5%	2.1%	2.4%	3.3%	1.6%	0.5%	3.5%	0.9%	1.3%
Functional Feeding Groups										
% Collector Gatherers	71.9%	50.0%	54.3%	50.3%	72.7%	29.7%	36.9%	41.0%	34.1%	18.6%
% Filterers	26.3%	46.2%	43.6%	46.0%	22.7%	66.3%	61.6%	54.4%	60.1%	80.1%
% Shredders	1.1%	2.3%	2.1%	3.0%	3.3%	1.6%	1.5%	4.2%	3.7%	1.3%
Habitat Preference Groups										
% Clingers	26.9%	48.5%	43.6%	47.7%	23.9%	68.8%	62.5%	55.5%	64.9%	80.1%
% Sprawlers	70.1%	50.0%	54.3%	48.9%	72.7%	29.7%	36.9%	40.6%	33.5%	18.1%
% Burrowers	2.9%	1.5%	2.1%	3.4%	3.3%	1.6%	0.5%	3.9%	1.5%	1.8%
Dominant Taxa Groups										
Density Chironomidae	430	241	102	531	240	133	284	419	426	155
Density Metal Sensitive Chironomidae	152	105	40	199	107	70	94	140	155	112
Density Simuliidae	161	219	82	487	75	297	462	552	706	685
Density Tipulidae	7	7	4	25	11	7	4	36	11	11
Functional Feeding Groups										
Density Collector Gatherers	441	237	102	532	240	133	277	416	401	159
Density Filterers	161	219	82	487	75	297	462	552	706	685
Density Shredders	7	11	4	32	11	7	11	43	43	11
Habitat Preference Groups										
Density Clingers	165	230	82	505	79	308	469	563	763	685
Density Sprawlers	430	237	102	517	240	133	277	412	394	155
Density Burrowers	18	7	4	36	11	7	4	40	18	15

[a] Metrics calculated using Family Level (FL) taxonomy.

[b] Metrics calculated using Lowest Practical Level (LPL) taxonomy.

Table E.6: Benthic Invertebrate Community Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Study Areas Calculated for EEM Metrics Calculated at Lowest Practical Level Taxonomy and Relative Abundance of Dominant Taxa, FFG and HPG

Metric	Two-Sample Comparison					Summary Statistics						
	Significant Difference Among Areas?	Trans-formation	Test	p-value	Magnitude of Difference [a] (No. of SD)	Area	Median	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Richness (LPL Taxa)	NO	$\log_{10}$	ANOVA	0.6633	~	Reference	10	11.4	3.4	1.5	8.0	16.0
						Effluent-Exposed	11	10.4	2.1	0.9	7.0	12.0
Simpson's Evenness LPL	YES	$\log_{10}$	ANOVA	0.0238	-1.1	Reference	0.339	0.380	0.154	0.069	0.211	0.626
						Effluent-Exposed	0.217	0.215	0.024	0.011	0.182	0.246
Bray-Curtis Index (LPL)	YES	$\log_{10}$	ANOVA	0.0525	1.4	Reference	0.249	0.291	0.127	0.057	0.160	0.460
						Effluent-Exposed	0.493	0.466	0.114	0.051	0.312	0.580
Chironomidae (% of community)	YES	none	ANOVA	0.0029	-2.5	Reference	54.3	59.6	10.9	4.9	50.2	72.7
						Effluent-Exposed	36.3	32.7	9.2	4.1	18.1	41.3
Metal-Sensitive Chironomidae (%)	YES	$\log_{10}$	ANOVA	<0.001	-2.0	Reference	22.2	23.9	5.2	2.3	18.8	32.4
						Effluent-Exposed	13.2	13.6	1.2	0.5	12.5	15.6
Simuliidae (% of community)	YES	none	ANOVA	0.0035	2.4	Reference	43.6	37.0	11.5	5.1	22.7	46.2
						Effluent-Exposed	61.6	64.5	9.7	4.3	54.4	80.1
Collector-gatherers (% of community)	YES	none	ANOVA	0.0025	-2.4	Reference	54.3	59.8	11.5	5.1	50.0	72.7
						Effluent-Exposed	34.1	32.1	8.6	3.8	18.6	41.0
Filterers (% of community)	YES	none	ANOVA	0.0035	2.4	Reference	43.6	37.0	11.5	5.1	22.7	46.2
						Effluent-Exposed	61.6	64.5	9.7	4.3	54.4	80.1
Clingers (% of community)	YES	none	ANOVA	0.0029	2.4	Reference	43.6	38.1	11.8	5.3	23.9	48.5
						Effluent-Exposed	64.9	66.4	9.1	4.1	55.5	80.1
Sprawlers (% of community)	YES	none	ANOVA	0.0026	-1.8	Reference	54.3	59.2	11.4	5.1	48.9	72.7
						Effluent-Exposed	33.5	31.8	8.6	3.9	18.1	40.6

[a] Magnitude calculated by comparing the difference between the reference area and effluent-exposed area means divided by the reference area standard deviation.

Highlighted values indicates significant difference between study areas based on a p-value less than 0.10.

Table E.7: Benthic Invertebrate Community Statistical Comparison Results between Mary River Tributary-F Effluent-Exposed and Reference Study Areas Upon Removal of Simuliidae from the Data Set

Metric	Two-Sample Comparison					Summary Statistics					
	Significant Difference Among Areas?	Trans-formation	Test	p-value	Magnitude of Difference [a] (No. of SD)	Area	Mean	Standard Deviation	Standard Error	Minimum	Maximum
Density	NO	none	ANOVA	0.8590	~	Reference	327.8	183.3	82.0	106.0	571.0
						Effluent-Exposed	308.2	153.3	68.6	151.0	469.0
Richness (FL Taxa)	NO	none	ANOVA	1.0000	~	Reference	3.6	1.3	0.6	2.0	5.0
						Effluent-Exposed	3.6	1.1	0.5	2.0	5.0
Simpson's Evenness FL	NO	none	ANOVA	0.9209	~	Reference	0.348	0.131	0.058	0.221	0.540
						Effluent-Exposed	0.356	0.105	0.047	0.242	0.514
Bray-Curtis Index (FL)	NO	none	ANOVA	0.8490	~	Reference	0.223	0.202	0.090	0.006	0.414
						Effluent-Exposed	0.242	0.088	0.039	0.093	0.304
Richness (LPL Taxa)	NO	none	ANOVA	0.6454	~	Reference	10.2	3.1	1.4	7.0	14.0
						Effluent-Exposed	9.4	2.1	0.9	6.0	11.0
Simpson's Evenness LPL	NO	none	ANOVA	0.7570	~	Reference	0.389	0.143	0.064	0.231	0.577
						Effluent-Exposed	0.362	0.121	0.054	0.275	0.551
Bray-Curtis Index (LPL)	NO	none	ANOVA	0.2641	~	Reference	0.303	0.155	0.069	0.063	0.428
						Effluent-Exposed	0.401	0.096	0.043	0.273	0.498
Chironomidae (% of community)	NO	none	ANOVA	0.1760	~	Reference	94.6	1.2	0.5	93.0	96.2
						Effluent-Exposed	91.8	4.0	1.8	88.1	98.6
Metal-Sensitive Chironomidae (%)	NO	none	ANOVA	0.5999	~	Reference	37.9	3.7	1.7	33.6	42.0
						Effluent-Exposed	41.6	15.0	6.7	30.2	65.9
Collector-gatherers (% of community)	YES	none	ANOVA	0.0829	-2.1	Reference	94.8	2.0	0.9	92.9	97.6
						Effluent-Exposed	90.6	4.3	1.9	85.5	96.2
Filterers (% of community)	NO	none	ANOVA	1.0000	~	Reference	0.0	0.0	0.0	0.0	0.0
						Effluent-Exposed	0.0	0.0	0.0	0.0	0.0
Clingers (% of community)	NO	none	ANOVA	0.2503	~	Reference	2.0	1.7	0.8	0.0	4.3
						Effluent-Exposed	4.8	4.9	2.2	0.0	12.2
Sprawlers (% of community)	NO	none	ANOVA	0.1019	~	Reference	93.8	2.2	1.0	90.5	96.2
						Effluent-Exposed	89.7	4.5	2.0	84.0	96.2

[a] Magnitude calculated by comparing the difference between the reference area and effluent-exposed area means divided by the reference area standard deviation.

Highlighted values indicates significant difference between study areas based on a p-value less than 0.10.

Data Quality Review

APPENDIX E BENTHIC DATA QUALITY REVIEW

E.1 Introduction

Quality Assurance/Quality Control (QA/QC) implemented for the Mary River Project Phase 1 EEM included a Data Quality Review (DQR) of the benthic invertebrate community data to provide an evaluation of how well laboratory data quality compared to prescribed goals (i.e., Data Quality Objectives [DQO]) established *a priori*. This DQR report provides a comparison of target data quality to actual data quality, subsequently discussing the consequences of any failures to meet DQO. By completing this step, the quality of the data for the program can be effectively evaluated and demonstrated.

E.2 Quality Control Measures and DQO

During laboratory processing, all benthic invertebrate community sample material was examined in its entirety (i.e., no sub-sampling was conducted; Table E-DQR.2) and therefore only one type of QC was applied in the laboratory for the benthic invertebrate community study component:

- **Organism Recovery Check.** Organism recovery checks for benthic invertebrate community samples involve the re-processing of previously sorted material from a randomly selected sample to determine the number of invertebrates that were not recovered during the original sample processing. The reprocessing is conducted on a minimum of 10% of the samples submitted for the study by an analyst not involved during the original processing so as to reduce any bias. This check allows the determination of accuracy through assessment of recovery efficiency. The DQO for organism recovery checks was ≥90%.

E.3 Benthic Invertebrate Community Sample DQA Results

Organism recovery for the two benthic invertebrate community samples evaluated was high, averaging 99% (Table E-DQR.1) and meeting the sorting efficiency DQO of ≥ 90% recovery. Therefore, the benthic invertebrate community sample recovery was considered acceptable. Overall, the benthic invertebrate community sample data were of acceptable quality, meeting the established accuracy (percent recovery) QC criteria.

Table E-DQR.1: Organism Recovery Rates for Benthic Invertebrate Community Samples

Station	Number of Organisms Recovered (initial sort)	Number of Organisms in Re-sort	Percent Recovery
MRTF-REF-1	171	171	100.0%
MRTF-EXP-4	326	328	99.4%
		Average % Recovery	99.7%

Table E-DQR.2: Sample Fractions Sorted for Benthic Invertebrate Community Samples

Station	Fraction Sorted (500 um)
MRTF-REF1	Whole
MRTF-REF2	Whole
MRTF-REF3	Whole
MRTF-REF4	Whole
MRTF-REF5	Whole
MRTF-EXP1	Whole
MRTF-EXP2	Whole
MRTF-EXP3	Whole
MRTF-EXP4	Whole
MRTF-EXP5	Whole

QA/QC Notes

Pupae were not counted toward total number of taxa unless they were the sole representative of their taxa group.
Immatures were not counted toward total number of taxa unless they were the sole representative of their taxa group.

APPENDIX F

FISH POPULATION SURVEY DATA

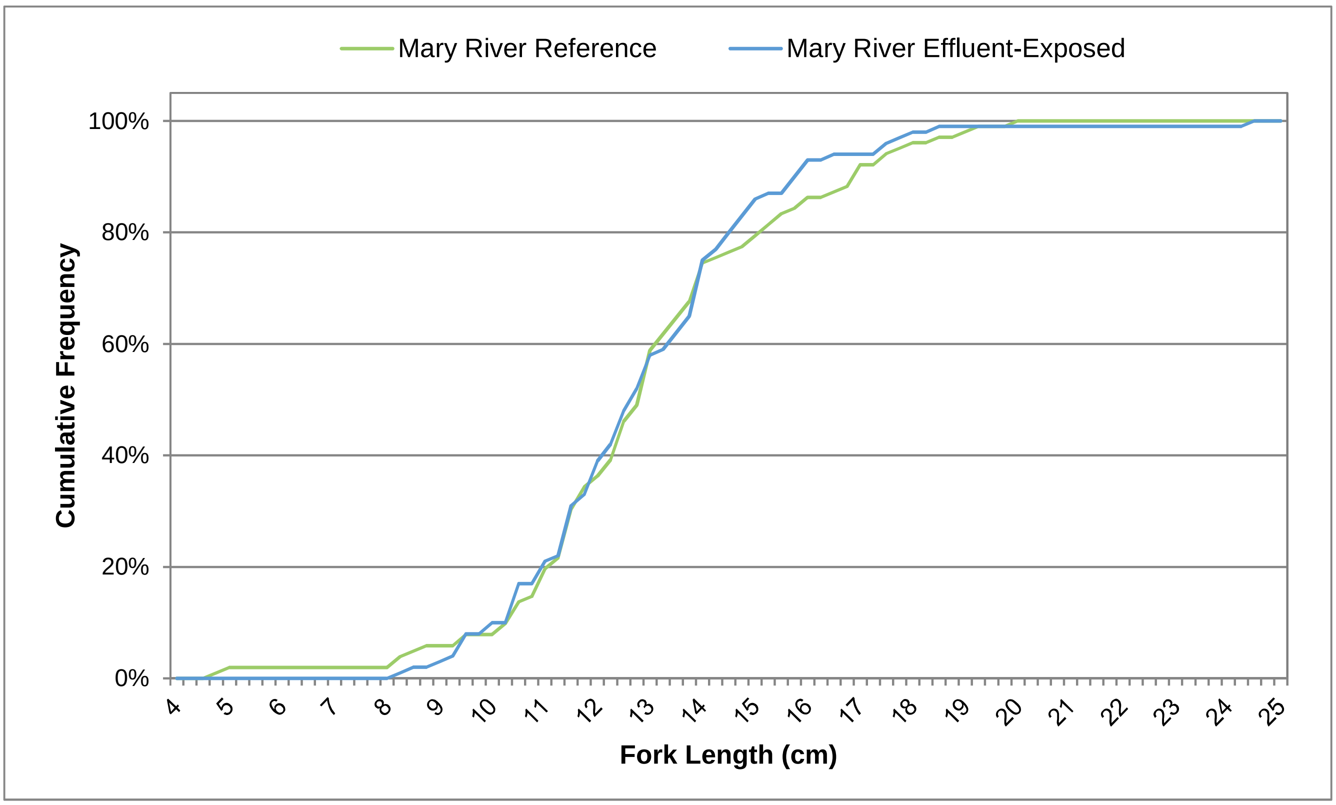
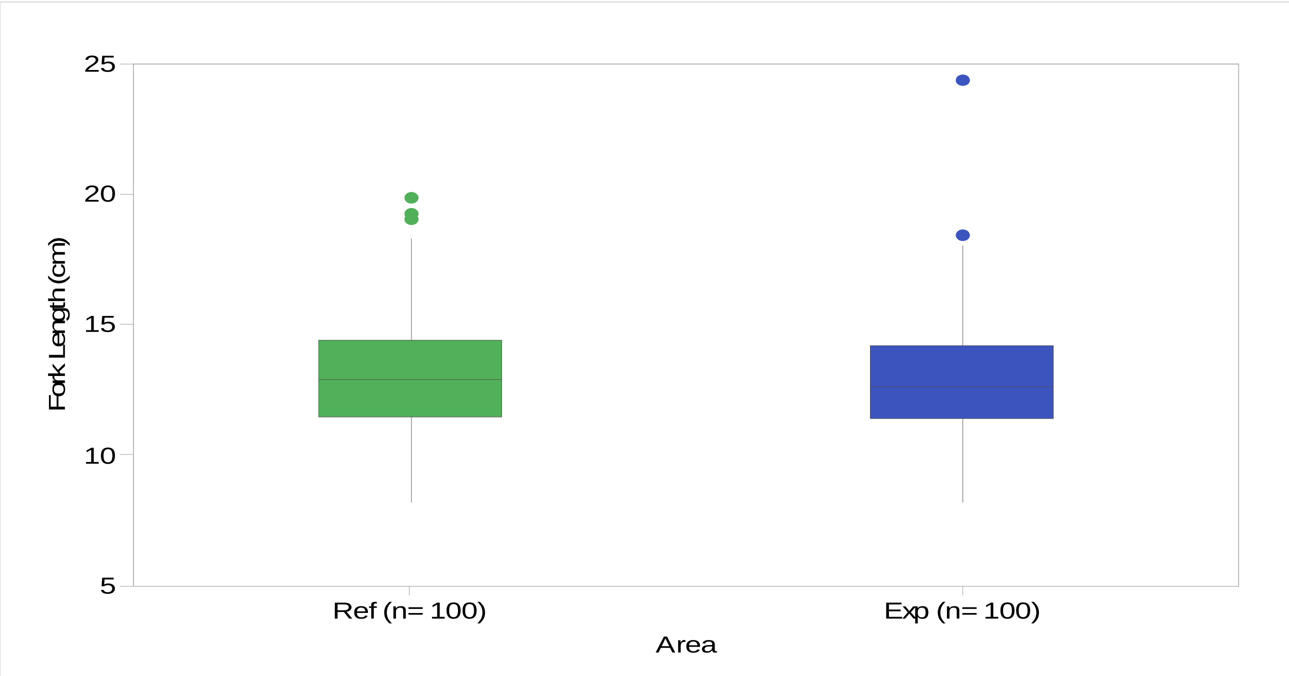


Figure F.1: Cumulative Length-frequency Distributions for Arctic Charr Captured at Mary River Project Phase 1 EEM Effluent-Exposed and Reference Study Areas, August 2017



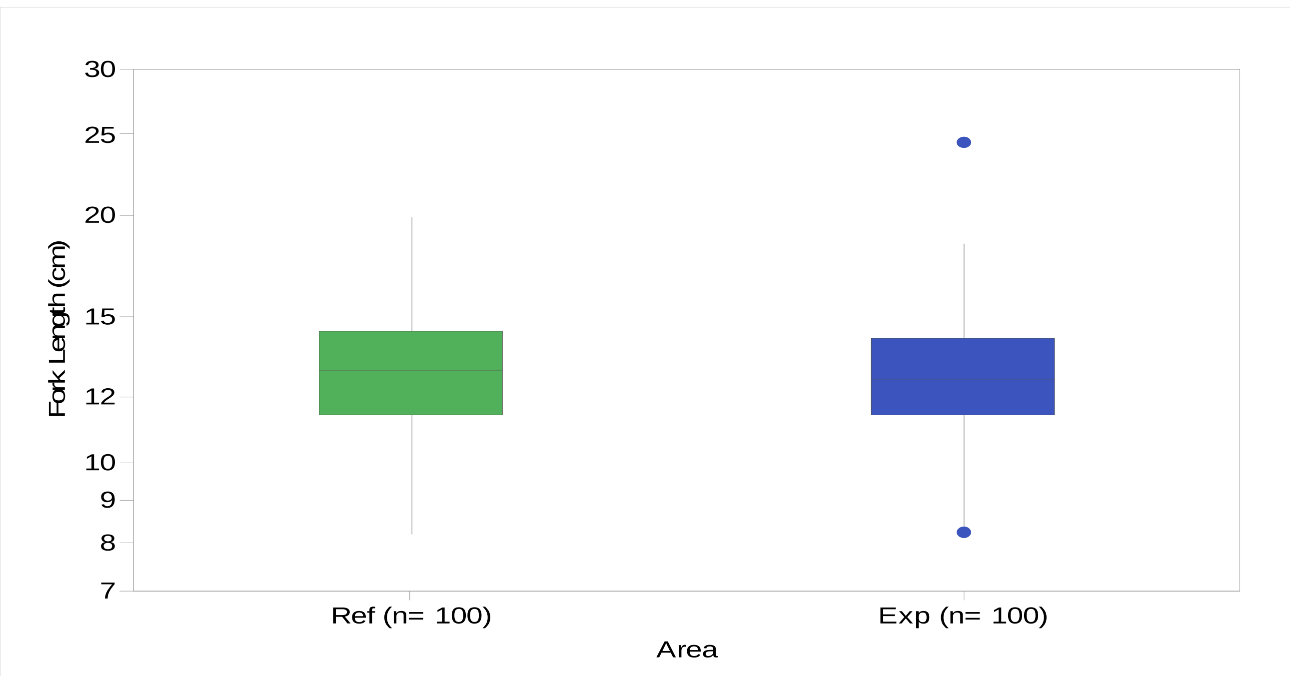
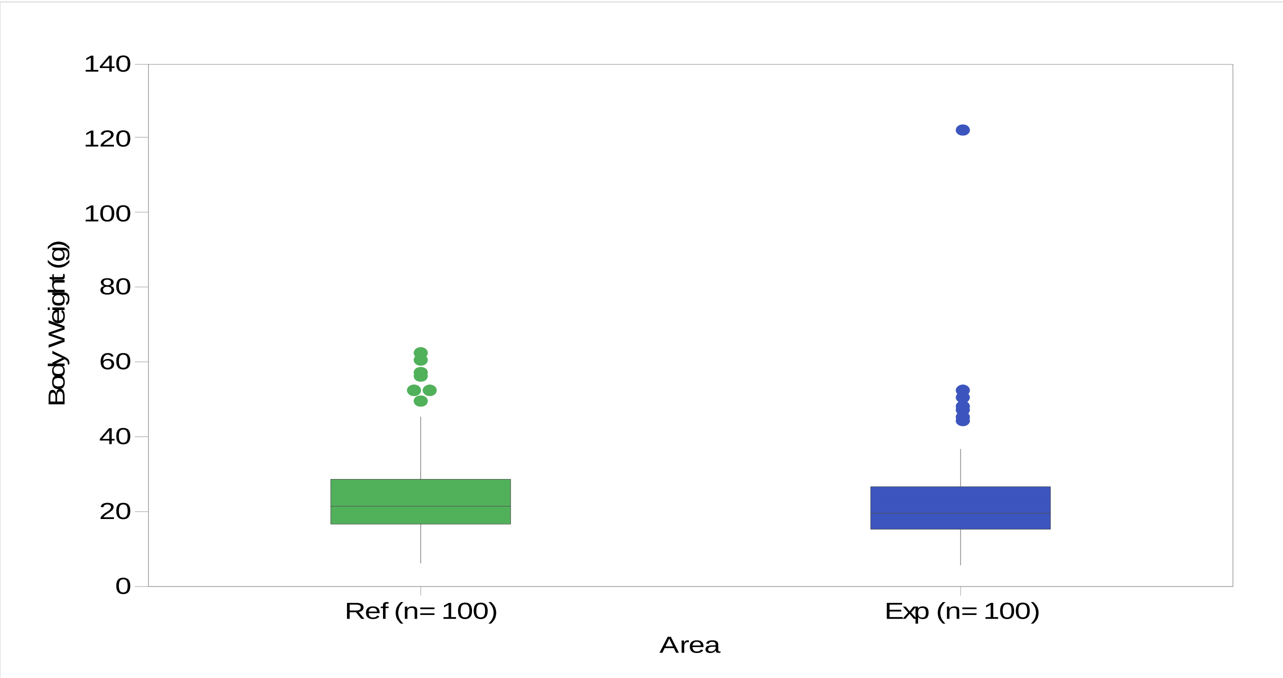


Figure F.2: Boxplot of Fork Length by Area with Unscaled and $\log_{10}$-scaled Axes for Arctic Charr Collected at Mary River Project Phase 1 EEM Effluent-Exposed (Exp) and Reference (Ref) Study Areas, August 2017

Note: Statistical analyses were conducted on $\log_{10}$-transformed data so boxplots are also displayed on the $\log_{10}$ scale to show the data distributions used for statistical comparisons



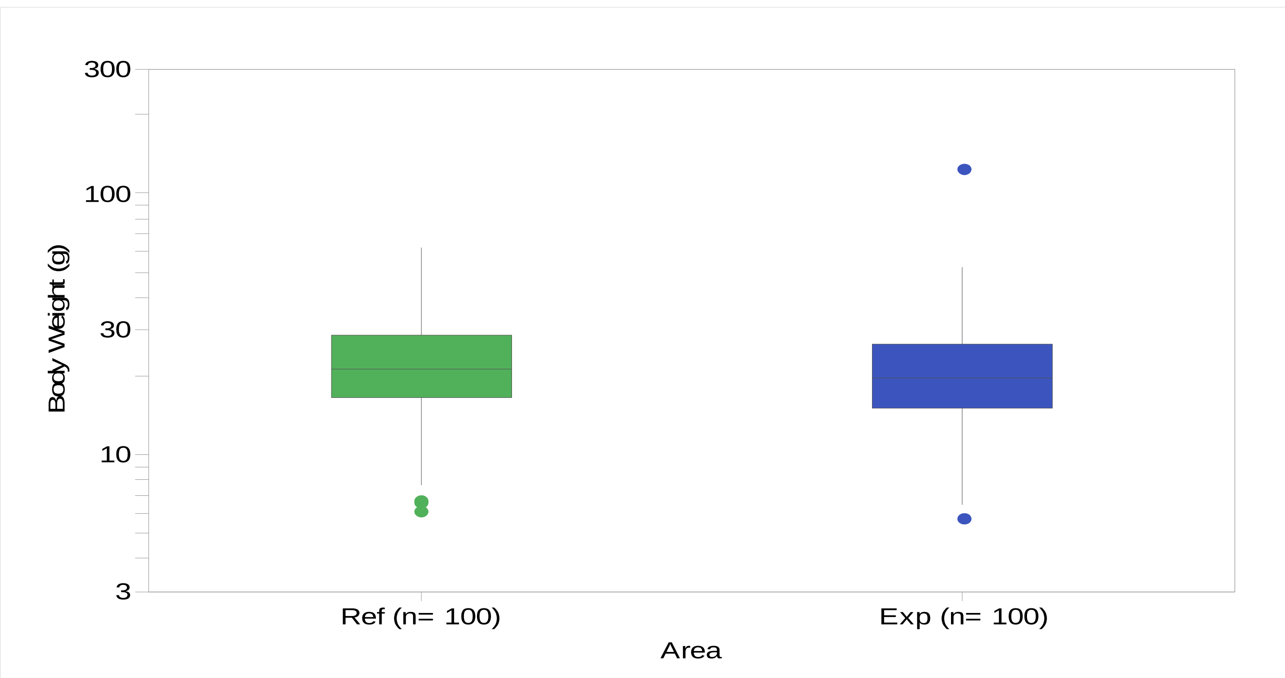


Figure F.3: Boxplot of Body Weight by Area with Unscaled and $\log_{10}$-scaled Axes for Arctic Charr Collected at Mary River Project Phase 1 EEM Effluent-Exposed (Exp) and Reference (Ref) Study Areas, August 2017

Note: Statistical analyses were conducted on $\log_{10}$-transformed data so boxplots are also displayed on the $\log_{10}$ scale to show the data distributions used for statistical comparisons

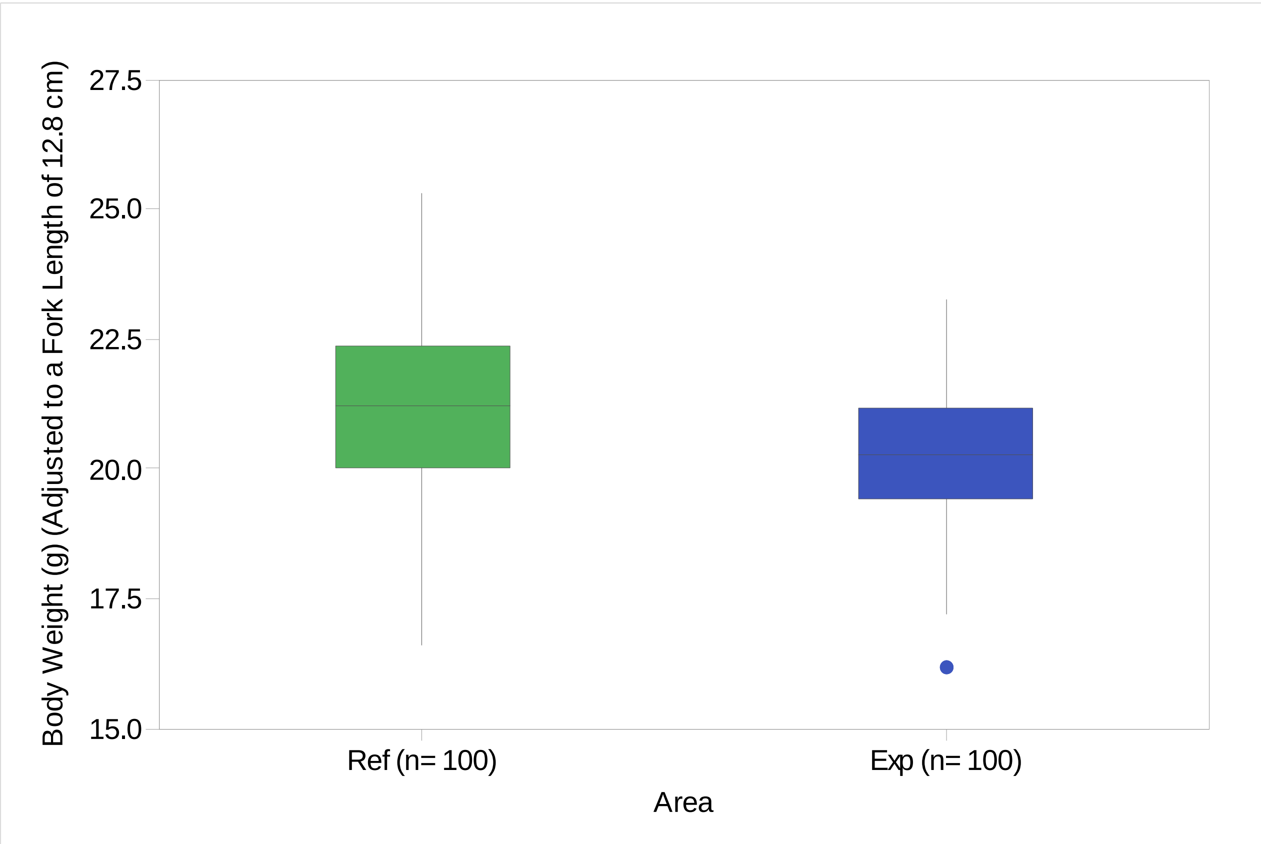


Figure F.4: **Boxplot of Body Weight (Adjusted to a Fork Length of 12.8 cm Based on the Parallel Slope ANCOVA Model) by Area for Arctic Charr Collected from Mary River Project Phase 1 EEM Effluent-Exposed (Exp) and Reference (Ref) Fish Population Survey Study Areas, August 2017**

Table F.1: Electrofishing Catch Record for the Mary River Project Phase 1 EEM, August 2017

Watercourse	Station ID	Date	Location			Effort (seconds)	Fish Species				Total (all species)	
			Coordinates		Station Length (m)		Arctic Charr		Ninespine Stickleback			
			Latitude	Longitude			Catch	CPUE	Catch	CPUE	Total Catch	CPUE
Mary River Tributary-F	MRTF-EXP-F1	26-Aug-17	71 20 10.212	79 10 54.129	167	1,254	0	0.00	0	0.00	0	0.00
	MRTF-EXP-F2	26-Aug-17	71 20 11.857	79 10 56.262	193	730	0	0.00	0	0.00	0	0.00
	MRTF-EXP-F3	26-Aug-17	71 18 38.276	79 11 49.646	55	355	0	0.00	0	0.00	0	0.00
	MRTF-EXP-F4	26-Aug-17	71 18 45.579	79 11 50.276	125	866	0	0.00	0	0.00	0	0.00
	MRTF-EXP-F5	26-Aug-17	71 19 09.571	79 11 23.362	138	952	0	0.00	0	0.00	0	0.00
					Total	**4,157**	**0**	**0.00**	**0**	**0.00**	**0**	**0.00**
Mary River Effluent-Exposed	MR-EXP-F1	27-Aug-17	71 17 57.136	79 15 43.125	129	2,086	40	1.15	0	0.00	40	1.15
	MR-EXP-F2	27-Aug-17	71 18 01.379	79 15 30.567	55	481	7	0.87	0	0.00	7	0.87
	MR-EXP-F3	27-Aug-17	71 18 02.390	79 15 17.695	133	1,093	26	1.43	0	0.00	26	1.43
	MR-EXP-F4	27-Aug-17	71 18 03.265	79 15 11.074	71	927	27	1.75	0	0.00	27	1.75
					Total	**4,587**	**100**	**1.30**	**0**	**0.00**	**100**	**1.30**
Mary River Reference	MR-REF-F1	28-Aug-17	71 15 22.745	79 24 34.144	159	1,754	27	0.92	0	0.00	27	0.92
	MR-REF-F2	28-Aug-17	71 15 25.935	79 24 25.750	331	2,794	22	0.47	2	0.04	24	0.52
	MR-REF-F3	28-Aug-17	71 15 23.139	79 24 38.731	218	3,792	56	0.89	1	0.02	57	0.90
					Total	**8,340**	**105**	**0.76**	**3**	**0.02**	**108**	**0.78**

Note: Catch-per-unit-effort (CPUE) represents the number of fish captured per electrofishing minute.

Table F.2: **Arctic Charr Measurements from Fish Captured at the Mary River Reference Area by Electrofishing, Mary River Project Phase 1 EEM, August 2017**

Specimen ID	Fork Length (cm)	Total Length (cm)	Body Weight (g)	Age (years)	Fulton's Condition Factor (K)
MRR-AC-01	14.5	15.7	29.707	-	0.974
MRR-AC-02	12.4	13.4	20.865	-	1.094
MRR-AC-03	15.9	17.3	40	-	0.995
MRR-AC-04	12.9	14.0	17.009	-	0.792
MRR-AC-05	19.8	21.5	62	-	0.799
MRR-AC-06	15.9	17.2	37	-	0.920
MRR-AC-07	12.5	13.6	19.920	-	1.020
MRR-AC-08	12.7	13.7	20.811	-	1.016
MRR-AC-09	13.1	14.2	26.242	-	1.167
MRR-AC-10	13.6	14.6	26.714	-	1.062
MRR-AC-11	13.8	14.9	24.405	-	0.929
MRR-AC-12	10.3	11.0	11.707	-	1.071
MRR-AC-13	13.9	15.0	25.934	-	0.966
MRR-AC-14	12.4	13.4	22.428	-	1.176
MRR-AC-15	11.5	12.4	16.697	-	1.098
MRR-AC-16	15.0	16.2	31.273	-	0.927
MRR-AC-17	12.8	14.0	21.380	-	1.019
MRR-AC-18	10.5	11.3	11.128	-	0.961
MRR-AC-19	9.3	10.0	8.654	-	1.076
MRR-AC-20	10.9	11.7	13.423	-	1.037
MRR-AC-21	11.4	12.3	17.076	-	1.153
MRR-AC-22	13.5	14.6	22.042	-	0.896
MRR-AC-23	11.7	12.7	18.479	-	1.154
MRR-AC-24	12.2	13.2	16.414	-	0.904
MRR-AC-25	11.5	12.6	17.321	-	1.139
MRR-AC-26	10.9	11.6	13.475	-	1.041
MRR-AC-27	11.3	12.2	15.022	-	1.041
MRR-AC-28	13.1	14.1	23.621	-	1.051
MRR-AC-29	12.9	14.0	20.777	-	0.968
MRR-AC-30	19.0	20.6	57	-	0.831
MRR-AC-31	11.1	12.0	14.529	-	1.062
MRR-AC-32	15.2	16.5	30.388	-	0.865
MRR-AC-33	16.9	18.4	45	-	0.932
MRR-AC-34	19.2	20.8	60	-	0.848
MRR-AC-35	11.7	12.8	15.888	-	0.992
MRR-AC-36	13.0	14.2	23.379	-	1.064
MRR-AC-37	13.8	14.8	27.605	-	1.050
MRR-AC-38	13.8	14.9	26.785	-	1.019
MRR-AC-39	14.6	15.7	26.954	-	0.866
MRR-AC-40	11.8	12.7	18.854	-	1.148
MRR-AC-41	10.4	11.2	12.919	2	1.148
MRR-AC-42	11.6	12.5	16.920	-	1.084
MRR-AC-43	12.3	13.2	18.558	-	0.997
MRR-AC-44	11.5	12.6	18.175	-	1.195
MRR-AC-45	11.4	12.4	16.587	-	1.120
MRR-AC-46	13.9	15.0	28.827	-	1.073
MRR-AC-47	11.2	12.0	13.942	-	0.992
MRR-AC-48	8.2	8.8	6.579	-	1.193
MRR-AC-49	13.0	14.0	22.087	-	1.005
MRR-AC-50	11.5	12.3	16.566	-	1.089
MRR-AC-51	12.2	13.2	17.889	-	0.985
MRR-AC-52	13.9	15.0	28.129	-	1.047
MRR-AC-53	10.9	11.9	14.052	-	1.085
MRR-AC-54	15.5	16.8	29.487	-	0.792
MRR-AC-55	15.5	16.9	36.551	-	0.982
MRR-AC-56	12.2	13.1	21.402	-	1.179
MRR-AC-57	12.6	13.6	19.925	-	0.996
MRR-AC-58	13.0	14.0	22.926	-	1.044
MRR-AC-59	15.0	16.5	30.585	-	0.906

Table F.2: Arctic Charr Measurements from Fish Captured at the Mary River Reference Area by Electrofishing, Mary River Project Phase 1 EEM, August 2017

Specimen ID		Fork Length (cm)	Total Length (cm)	Body Weight (g)	Age (years)	Fulton's Condition Factor (K)
MRR-AC-60		11.3	12.1	15.386	-	1.066
MRR-AC-61		12.4	13.4	22.403	-	1.175
MRR-AC-62		15.6	16.9	32.972	-	0.869
MRR-AC-63		13.0	13.9	20.955	-	0.954
MRR-AC-64		12.5	13.5	23.753	-	1.216
MRR-AC-65		13.1	14.1	27.020	-	1.202
MRR-AC-66		11.6	12.5	16.457	-	1.054
MRR-AC-67		18.3	19.8	56	-	0.914
MRR-AC-68		8.2	8.8	6.518	-	1.182
MRR-AC-69		16.3	17.7	36.480	-	0.842
MRR-AC-70		13.0	14.0	20.302	-	0.924
MRR-AC-71		10.2	11.0	12.626	-	1.190
MRR-AC-72		13.0	14.1	23.922	-	1.089
MRR-AC-73		13.7	14.8	25.515	-	0.992
MRR-AC-74		17.3	18.6	49	-	0.946
MRR-AC-75		12.4	13.3	18.645	-	0.978
MRR-AC-76		13.3	14.3	21.957	-	0.933
MRR-AC-77		13.3	14.4	22.383	-	0.951
MRR-AC-78		12.9	13.9	20.245	-	0.943
MRR-AC-79		10.4	11.2	13.070	-	1.162
MRR-AC-80		17.8	19.4	52	-	0.922
MRR-AC-81		12.0	13.0	20.633	-	1.194
MRR-AC-82		12.6	13.6	19.636	-	0.982
MRR-AC-83		17.6	19.0	45	-	0.825
MRR-AC-84		16.8	18.0	37	-	0.780
MRR-AC-85		17.4	18.9	52	-	0.987
MRR-AC-86		15.2	16.5	30.117	-	0.858
MRR-AC-87		16.7	18.1	35	-	0.751
MRR-AC-88		13.8	14.8	23.499	-	0.894
MRR-AC-89		16.8	18.5	42	-	0.886
MRR-AC-90		10.9	11.6	14.225	-	1.098
MRR-AC-91		11.0	11.8	15.461	-	1.162
MRR-AC-92		11.4	12.2	16.260	2	1.098
MRR-AC-93		10.1	10.8	10.986	2	1.066
MRR-AC-94		8.6	9.2	7.659	1	1.204
MRR-AC-95		9.5	10.2	9.949	2	1.160
MRR-AC-96		16.8	18.3	44	4	0.928
MRR-AC-97		14.1	15.3	28.108	3	1.003
MRR-AC-98		13.6	14.6	22.804	3	0.907
MRR-AC-99		10.6	11.3	11.906	2	1.000
MRR-AC-100		8.3	8.7	5.963	1	1.043
Overall Catch Summary	**total number**	**100**	**100**	**100**	**10**	**100**
	average	**13.1**	**14.2**	**24.198**	**2.2**	**1.014**
	median	**12.9**	**14.0**	**21.391**	**2.0**	**1.011**
	standard deviation	**2.5**	**2.7**	**12.116**	**0.9**	**0.114**
	standard error	**0.2**	**0.3**	**1.212**	**0.3**	**0.011**
	minimum	**8.2**	**8.7**	**5.963**	**1**	**0.751**
	maximum	**19.8**	**21.5**	**62.000**	**4**	**1.216**

Table F.3: Arctic Charr Measurements from Fish Captured at the Mary River Effluent-Exposed Area by Electrofishing, Mary River Project Phase 1 EEM, August 2017

Specimen ID	Fork Length (cm)	Total Length (cm)	Body Weight (g)	Age (years)	Fulton's Condition Factor (K)
MRE-AC-01	12.6	13.7	19.174	-	0.959
MRE-AC-02	12.4	13.4	16.362	-	0.858
MRE-AC-03	14.4	15.5	25.868	-	0.866
MRE-AC-04	13.0	13.9	18.810	-	0.856
MRE-AC-05	10.9	11.7	13.933	-	1.076
MRE-AC-06	11.9	12.7	16.775	-	0.995
MRE-AC-07	11.3	12.3	15.096	-	1.046
MRE-AC-08	10.5	11.5	10.572	-	0.913
MRE-AC-09	15.7	17.2	35.921	-	0.928
MRE-AC-10	10.0	10.8	10.311	-	1.031
MRE-AC-11	10.4	11.1	11.483	-	1.021
MRE-AC-12	12.6	13.9	17.439	-	0.872
MRE-AC-13	11.0	11.9	14.160	-	1.064
MRE-AC-14	13.1	14.3	21.184	-	0.942
MRE-AC-15	11.4	12.3	15.075	-	1.018
MRE-AC-16	15.7	17.0	33.560	-	0.867
MRE-AC-17	13.7	14.8	23.778	-	0.925
MRE-AC-18	11.5	12.5	14.966	-	0.984
MRE-AC-19	12.3	13.2	16.097	-	0.865
MRE-AC-20	14.7	15.9	30.004	-	0.945
MRE-AC-21	13.8	14.6	24.608	-	0.936
MRE-AC-22	9.9	10.6	10.375	-	1.069
MRE-AC-23	13.8	15.1	25.628	-	0.975
MRE-AC-24	14.9	16.2	34.875	-	1.054
MRE-AC-25	14.0	15.2	23.108	-	0.842
MRE-AC-26	17.7	19.2	50	-	0.902
MRE-AC-27	18.0	19.5	45	-	0.772
MRE-AC-28	12.2	13.2	19.444	-	1.071
MRE-AC-29	13.8	14.9	24.217	-	0.921
MRE-AC-30	13.0	14.0	20.587	-	0.937
MRE-AC-31	11.8	12.9	16.323	-	0.993
MRE-AC-32	12.3	13.3	19.558	-	1.051
MRE-AC-33	11.5	12.5	13.621	-	0.896
MRE-AC-34	8.3	8.9	6.450	-	1.128
MRE-AC-35	12.3	13.3	16.185	-	0.870
MRE-AC-36	16.4	17.9	44	-	0.998
MRE-AC-37	11.0	11.9	13.349	-	1.003
MRE-AC-38	11.7	12.5	15.999	-	0.999
MRE-AC-39	10.9	11.8	14.006	-	1.082
MRE-AC-40	9.4	10.1	7.783	-	0.937
MRE-AC-41	15.2	16.5	35.126	-	1.000
MRE-AC-42	13.5	14.6	25.016	-	1.017
MRE-AC-43	12.3	13.5	20.696	-	1.112
MRE-AC-44	14.8	16.0	28.649	-	0.884
MRE-AC-45	14.0	15.2	24.043	-	0.876
MRE-AC-46	10.5	11.3	11.822	-	1.021
MRE-AC-47	10.3	11.1	10.947	-	1.002
MRE-AC-48	13.8	14.9	22.302	-	0.849
MRE-AC-49	14.0	15.4	28.457	-	1.037
MRE-AC-50	16.0	17.4	36.283	-	0.886
MRE-AC-51	14.7	15.9	33.098	-	1.042
MRE-AC-52	15.8	17.2	36.468	-	0.925
MRE-AC-53	9.3	9.8	7.393	-	0.919
MRE-AC-54	13.9	14.7	26.469	-	0.986
MRE-AC-55	15.0	16.3	33.729	-	0.999
MRE-AC-56	11.2	12.1	15.798	-	1.124
MRE-AC-57	12.9	14.1	21.952	-	1.023
MRE-AC-58	12.1	13.1	18.452	-	1.042
MRE-AC-59	11.5	12.3	13.467	-	0.885

Table F.3: Arctic Charr Measurements from Fish Captured at the Mary River Effluent-Exposed Area by Electrofishing, Mary River Project Phase 1 EEM, August 2017

Specimen ID		Fork Length (cm)	Total Length (cm)	Body Weight (g)	Age (years)	Fulton's Condition Factor (K)
MRE-AC-60		18.4	19.9	47	-	0.754
MRE-AC-61		8.2	8.7	5.649	1	1.025
MRE-AC-62		13.4	14.4	24.484	-	1.018
MRE-AC-63		13.7	15.0	23.966	-	0.932
MRE-AC-64		15.9	16.9	34.709	-	0.863
MRE-AC-65		11.7	12.7	15.638	-	0.976
MRE-AC-66		9.0	9.5	7.509	-	1.030
MRE-AC-67		9.3	10.0	7.918	-	0.984
MRE-AC-68		14.2	15.3	25.522	-	0.891
MRE-AC-69		24.3	26.2	122	-	0.850
MRE-AC-70		10.4	11.2	12.021	-	1.069
MRE-AC-71		11.3	12.5	14.909	-	1.033
MRE-AC-72		12.6	13.3	16.920	-	0.846
MRE-AC-73		12.6	13.6	18.579	3	0.929
MRE-AC-74		14.2	15.5	29.376	-	1.026
MRE-AC-75		9.5	10.3	8.864	-	1.034
MRE-AC-76		13.6	14.5	22.717	-	0.903
MRE-AC-77		12.8	13.9	20.361	-	0.971
MRE-AC-78		11.9	12.9	16.975	-	1.007
MRE-AC-79		11.5	12.6	16.252	-	1.069
MRE-AC-80		12.9	14.0	21.412	-	0.997
MRE-AC-81		13.9	15.0	25.734	-	0.958
MRE-AC-82		14.6	15.8	30.065	-	0.966
MRE-AC-83		12.1	13.0	17.180	-	0.970
MRE-AC-84		17.4	18.9	48	-	0.911
MRE-AC-85		12.8	13.8	19.908	-	0.949
MRE-AC-86		13.5	14.6	24.067	-	0.978
MRE-AC-87		10.5	11.3	12.084	-	1.044
MRE-AC-88		15.6	16.9	36.058	-	0.950
MRE-AC-89		12.0	13.1	17.858	-	1.033
MRE-AC-90		12.0	12.8	13.647	3	0.790
MRE-AC-91		10.5	11.2	11.712	2	1.012
MRE-AC-92		9.1	10.0	8.578	2	1.138
MRE-AC-93		11.4	21.3	15.316	2	1.034
MRE-AC-94		17.3	18.7	52	4	1.004
MRE-AC-95		14.3	15.4	28.430	3	0.972
MRE-AC-96		13.9	15.0	24.611	3	0.916
MRE-AC-97		14.4	15.6	28.965	4	0.970
MRE-AC-98		11.5	12.5	16.483	-	1.084
MRE-AC-99		11.8	12.7	16.841	-	1.025
MRE-AC-100		12.4	13.4	20.578	-	1.079
Overall Catch Summary	**total number**	**100**	**100**	**100**	**10**	**100**
	average	**12.9**	**14.0**	**22.567**	**2.7**	**0.971**
	median	**12.6**	**13.8**	**19.501**	**3.0**	**0.981**
	standard deviation	**2.4**	**2.8**	**14.264**	**0.9**	**0.081**
	standard error	**0.2**	**0.3**	**1.426**	**0.3**	**0.008**
	minimum	**8.2**	**8.7**	**5.649**	**1**	**0.754**
	maximum	**24.3**	**26.2**	**122.000**	**4**	**1.138**

Table F.4: Non-Lethal Endpoint Statistical Comparison Results for Arctic Charr Collected from Mary River Effluent-Exposed (Exp) and Reference (Ref) Study Areas, Mary River Project Phase 1 EEM, August 2017

Indicator	Endpoint	Variables		Sample Size		Test	ANCOVA Statistics			Summary Statistics			Test *P*-value (Area)	Magnitude of Difference (%)[a]	Estimated Minimum Detectable Difference (% Relative to Reference) with α=β=0.1	
		Response	Covariate	Ref Area	Exp Area		Interaction Model / Interaction P-value	Parallel Slope Model / Covariate P-value	Covariate Value for Comparisons	Statistic	Ref Area	Exp Area			Decrease	Increase
Survival/ Recruitment	Length Frequency Distribution All Fish	Fork Length (cm)	n/a	102	100	K-S	-	-	-	-	-	-	0.936	-	-	-
	Length Frequency Distribution Non-YOY only	Fork Length (cm)	n/a	100	100	K-S	-	-	-	-	-	-	0.906	-	-	-
Body Size	Fork Length (Non-YOY)	$\log_{10}$[Fork Length (cm)]	n/a	100	100	t-test	-	-	-	Geometric Mean	12.9	12.7	0.523	-1.6	-7.4	8.0
	Body Weight (Non-YOY)	$\log_{10}$[Body Weight (g)]	n/a	100	100	t-test	-	-	-	Geometric Mean	21.6	19.7	0.200	-8.7	-19	23
Energy Storage	Condition (Non-YOY)	$\log_{10}$[Body Weight (g)]	$\log_{10}$[Fork Length (cm)]	100	100	ANCOVA	0.001[b]	<0.001	12.8	Adjusted Mean	21.1	20.1	<0.001	-4.5	-2.3	2.3

(shaded box) = P-value < 0.05 for ANCOVA interaction and covariate terms and P-value < 0.1 for overall test for area

[a] For ANCOVA: Calculated as the difference in adjusted mean between areas (effluent-exposed minus reference), expressed as a percentage of the reference area mean

[b] The R^2 of the interaction model was 0.9766 and the R^2 of the parallel slope model was 0.9753 (difference of 0.13%) so the ANCOVA proceeded under the assumption that the slopes are practically parallel, as per Environment Canada (2012) guidance.

Table F.5: Estimated Minimum Sample Sizes to Detect Various Effect Sizes for Arctic Charr Health Endpoints between Mary River Reference and Effluent-Exposed Areas Based on the Observed Variability in the Phase 1 EEM Study, 2017

Indicator	Endpoint	Variables		Sample Size		Model	S[a]	Minimum Sample Size to Detect an Effect Size (% Increase [i] or Decrease [d] Relative to Reference) with α=β=0.1							
		Response	Covariate	Ref	Exp			i=5%	i=10%	i=20%	i=25%	i=30%	i=40%	i=50%	i=100%
								d=5%	d=9%	d=17%	d=20%	d=23%	d=29%	d=33%	d=50%
Body Size	Fork Length	$\log_{10}$[Fork Length (cm)]	n/a	100	100	t-test	0.0803	247	66	19	13	10	6	5	3
	Body Weight	$\log_{10}$[Body Weight (g)]	n/a	100	100	t-test	0.2161	1,782	468	129	86	63	39	27	10
Energy Storage	Condition	$\log_{10}$[Body Weight (g)]	$\log_{10}$[Fork Length (cm)]	100	100	ANCOVA	0.0342	46	13	5	4	3	3	2	2

[a] Pooled standard deviation of the residuals.

Data Quality Review

APPENDIX F FISH SURVEY DATA QUALITY REVIEW

F.1 Introduction

Quality Assurance/Quality Control (QA/QC) implemented for the Mary River Project Phase 1 EEM included a Data Quality Review (DQR) of the fish population survey tissue collection data to provide an evaluation of how well laboratory data quality compared to prescribed goals (i.e., Data Quality Objectives [DQO]) established *a priori*. This DQR report provides a comparison of target data quality to actual data quality, subsequently discussing the consequences of any failures to meet DQO. By completing this step, the quality of the data for the program can be effectively evaluated and demonstrated.

F.2 Quality Control Measures and DQO

A single type of QC was applied in the laboratory for the fish population survey component of the Mary River Project Phase 1 EEM:

- **Aging Precision Check**. An aging precision check involves the reprocessing of previously aged structure to ensure that the initial age determination was accurate. Aging precision checks are completed on a minimum of 10% fish age structure samples, randomly selected from the project, that had been previously subject to age determination. Using the same structure originally subject to age determination, the sample is re-evaluated by an independent analyst not involved during the original age determination to reduce any bias. The DQO for the aging precision check was ±1 year of the original age determination.

F.3 Fish Population Survey Tissue Sample DQA Results

Aging precision checks were conducted on 10 of the 20 arctic charr (*Salvelinus alpinus*) samples submitted to AEE Tech Services Inc. (La Salle, MB). Age estimates for all arctic charr met the DQO of ±1 year when separately assessed by a second, independent professional (Table F-DQR.1). Therefore, the fish population survey fish age precision was considered acceptable. Overall, the fish population survey fish age data were of acceptable quality, meeting the established QC precision criterion.

Table F-DQR.1: Laboratory Fish Aging Precision Check Results for Arctic Charr Sampled for the Mary River Project Phase 1 EEM, August 2017

Sample Identification	Structure Type	Age Assigned by Primary Ager (KM)	Age Assigned by QA Manager (MM)	Difference (years)
MRE-AC-73	Otolith	3	3	0
MRE-AC-91	Otolith	2	2	0
MRE-AC-93	Otolith	2	2	0
MRE-AC-95	Otolith	3	3	0
MRE-AC-97	Otolith	4	4	0
MRR-AC-92	Otolith	2	2	0
MRR-AC-94	Otolith	1	1	0
MRR-AC-96	Otolith	4	4	0
MRR-AC-98	Otolith	3	3	0
MRR-AC-100	Otolith	1	1	0

Indicates independent age determination was outside of the DQO of ±1 year of age.