3 June 2016

MOUNT POLLEY MINE TAILINGS STORAGE FACILITY, PERIMETER EMBANKMENT BREACH

Update Report: Post-Event Environmental Impact Assessment Report

Submitted to:
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REPORT

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1.0 INTRODUCTION

On August 4, 2014, the failure of a glacial lacustrine layer beneath the Perimeter Embankment of the Tailings Storage Facility (TSF) at the Mount Polley Mine, British Columbia caused a breach of the embankment and resulted in the release of construction materials, water and tailings from the TSF to Polley Lake, Hazeltine Creek and Quesnel Lake. The BC Ministry of Environment (MoE) issued a Pollution Abatement Order (PAO) with the requirement to initiate monitoring with the end goal of producing a Post-Event Environmental Impact Assessment. The objective of the impact assessment was to provide an assessment of the physical, chemical, and biological impacts of the tailings spill on terrestrial and aquatic environments.

Mount Polley Mining Corporation (MPMC) immediately developed a Rehabilitation and Remediation Strategy (the “Strategy”) framework to guide rehabilitation of terrestrial and aquatic environments (Figure 1). Following this framework, MPMC began work to stabilize and contain the tailings, initiated scientific studies to identify the impacts of the tailings spill on the terrestrial and aquatic environments, and began developing strategies to rehabilitate the terrestrial and aquatic environments impacted. The first edition of the Post-Event Environmental Impact Assessment Report (PEEIAR, MPMC 2015) focused on the findings from studies conducted during the first six to eight months following the tailings spill. Post-event monitoring continued and this edition of the PEEIAR provides an update to the initial findings, with a focus on the findings from the next ten months (from March to December 2015). This edition of the PEEIAR marks completion of Phase 2 of the Strategy; the information collected from both impact assessment reports will feed into the Detailed Site Investigation and Risk Assessment and development of Remediation Options. These reports will focus on identifying the significance of contaminants from the tailings spill to human health and ecological receptors. Uncertainties identified following these investigations will be taken into consideration in MPMC’s Comprehensive Environmental Monitoring Plan (CEMP). The CEMP is required under *Environmental Management Act* Permit 11678 and an assessment of impacts will be provided in the Human Health and Ecological Risk Assessment (HHERA).

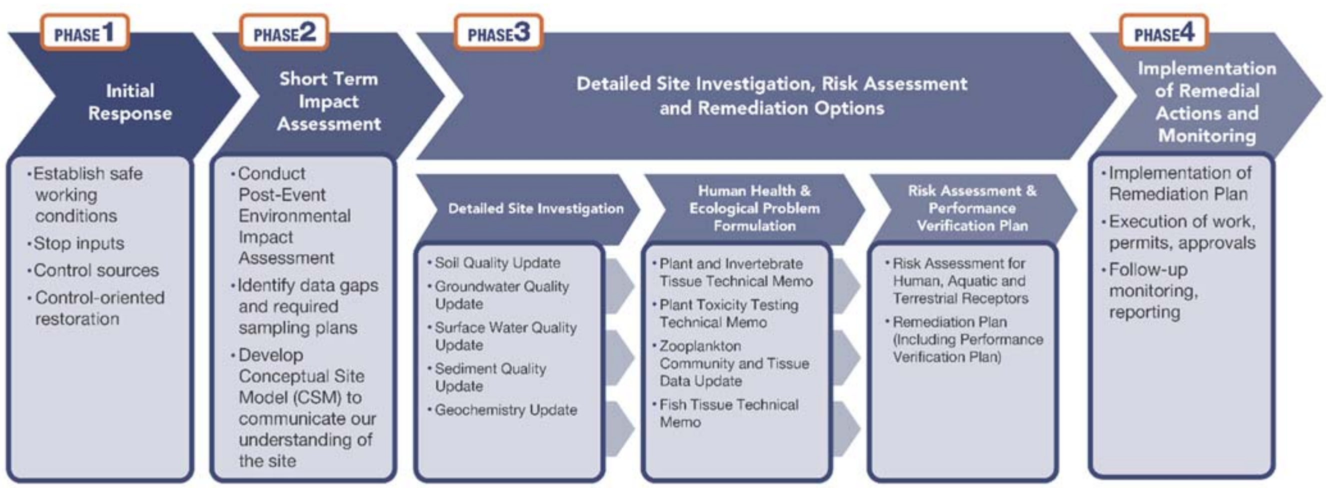


Figure 1: Rehabilitation and Remediation Strategy.

1.1 Organization of this Report

This PEEIAR is a compilation of the scientific studies that have been conducted follow the tailings spill, with particular focus on the findings from the time period between March and December 2015. A comprehensive reporting of the data collected between August 2014 and March 2015 is included in the first version of the PEEIAR (submitted to MoE in June, 2015). Readers are encouraged to review the contents of the June, 2015 report for more detail on the data collected in the first eight months following the spill.

The studies of this PEEIAR update are organized into Technical Appendices based on subject matter. Ahead of the Technical Appendices a summary of findings, by rehabilitation area, is provided (Section 3.0). The rehabilitation areas are shown on Figure 2, below. The information provided in the summary of findings is considered a high level synopsis of the significant findings from the many scientific studies conducted in response to the tailings spill. Readers are encouraged to review the Technical Appendices for detailed methods, results, figures, tables, discussion, conclusions, and references.

In this report, the term parameter of interest (POI) is used to be consistent with terminology commonly used in Environmental Assessments. The terminology, contaminant of potential concern (COPC) is used in work conducted under the CSR. For the purposes of this report, these terms are used interchangeably.

The Technical Appendices include the following scientific studies:

- **Appendix A – Geochemical Characterization**
  - SRK Consulting. *Mount Polley Mine Tailings Dam Failure: Update on Geochemical Characterization of Spilled Tailings*.
- **Appendix B – Soil Quality**
  - Golder Associates Ltd. *Factual Report for Soil Investigation, Hazeltine Creek Floodplain.*
- **Appendix C – Groundwater Quality**
  - Golder Associates Ltd. *Factual Data Report on Groundwater Quality, Hazeltine Creek Floodplain, August 2015*.
- **Appendix D – Surface Water Quality**
  - Golder Associates Ltd. *Mount Polley Surface Water Quality Impact Assessment Update, March to August 2015.*
  - Golder Associates Ltd. *Addendum to Mount Polley Surface Water Quality Impact Assessment Update.*
  - Minnow Environmental Inc. *Results of Diffusive Gradients in Thin Films Device Deployment – August to October 2015*.
- **Appendix E – Sediment Quality**
  - Minnow Environmental Inc. *Sediment Quality Data Report – August 2015 Collections*.

- Minnow Environmental Inc. *Application of the SEM-AVS Method and Selective Extraction Analysis in Evaluating Sediments Collected in the Vicinity of Mount Polley Mine – August 2015.*

- **Appendix F – Aquatic Toxicology**
  - Minnow Environmental Inc. *Investigation of the Influence of Sediment Physical Characteristics on Sediment Toxicity Test Results.*
  - Minnow Environmental Inc. *Summary and Interpretation of Water Toxicity Tests (August to September 2014).*
  - Minnow Environmental Inc. *Summary and Interpretation of Water Toxicity Tests (Nov 2014 to Apr 2015).*
  - Golder Associates Ltd. *Update on Post-event Aquatic Toxicity Testing – March to November 2015.*

- **Appendix G – Lake Productivity and Lower Trophic Tissue Metal Analysis**
  - Minnow Environmental Inc. *Chemical Analysis of Benthic Invertebrates Collected in the Vicinity of the Mount Polley Mine – August 2015*.
  - Golder Associates Ltd. *Quesnel and Polley Lakes 2015 Plankton Update Report.*
  - Golder Associates Ltd. *Mount Polley Mine – Update of Quesnel and Polley Lakes Productivity Assessment.*

- **Appendix H – Fish Tissue Metal Analysis**
  - Golder Associates Ltd. *Summary of Available Fish Tissue Chemistry Data (2014-2015) for Assessment of Potential Changes in Concentrations related to the Mount Polley Tailings Storage Facility Dam Failure*.
  - ALS Environmental. *Summary of Selenium in Tissue Data Verification for Mount Polley Mining Corporation Frypan Gonad Tissue Samples – ALS Work Order L1621080 – ALS Corrective Action Report (CAR) #143968.*

- **Appendix I – Terrestrial Ecosystem Assessment**
  - Golder Associates Ltd. and University of British Columbia. *Terrestrial Ecosystem Assessment of Hazeltine Creek Halo*

- **Appendix J – Terrestrial Plant and Invertebrate Tissue Metal Analysis**
  - Golder Associates Ltd. *Terrestrial Vegetation Data Report*.
  - Golder Associates Ltd. *Terrestrial Invertebrate Tissue Data Report*.

- **Appendix K – Evaluation of the Mercury Biomagnification Potential in Quesnel and Polley Lakes**
  - Golder Associates Ltd. *Review of Mercury Data in Quesnel Lake and Polley Lake.*

2.0 BACKGROUND

As described in the PEEIAR (MPMC 2015), the tailings spill resulted in a complex debris flow extending down Hazeltine Creek to Quesnel Lake, a distance of 9.4 km. The estimated amount of material (water, tailings, and construction materials) released was approximately 25 Mm^3. The majority of the material released was water. The release occurred as a sequence of surges, initially as debris flow scouring out native soil and vegetation, followed by debris floods depositing tailings fines in the floodplain and the surrounding forest.

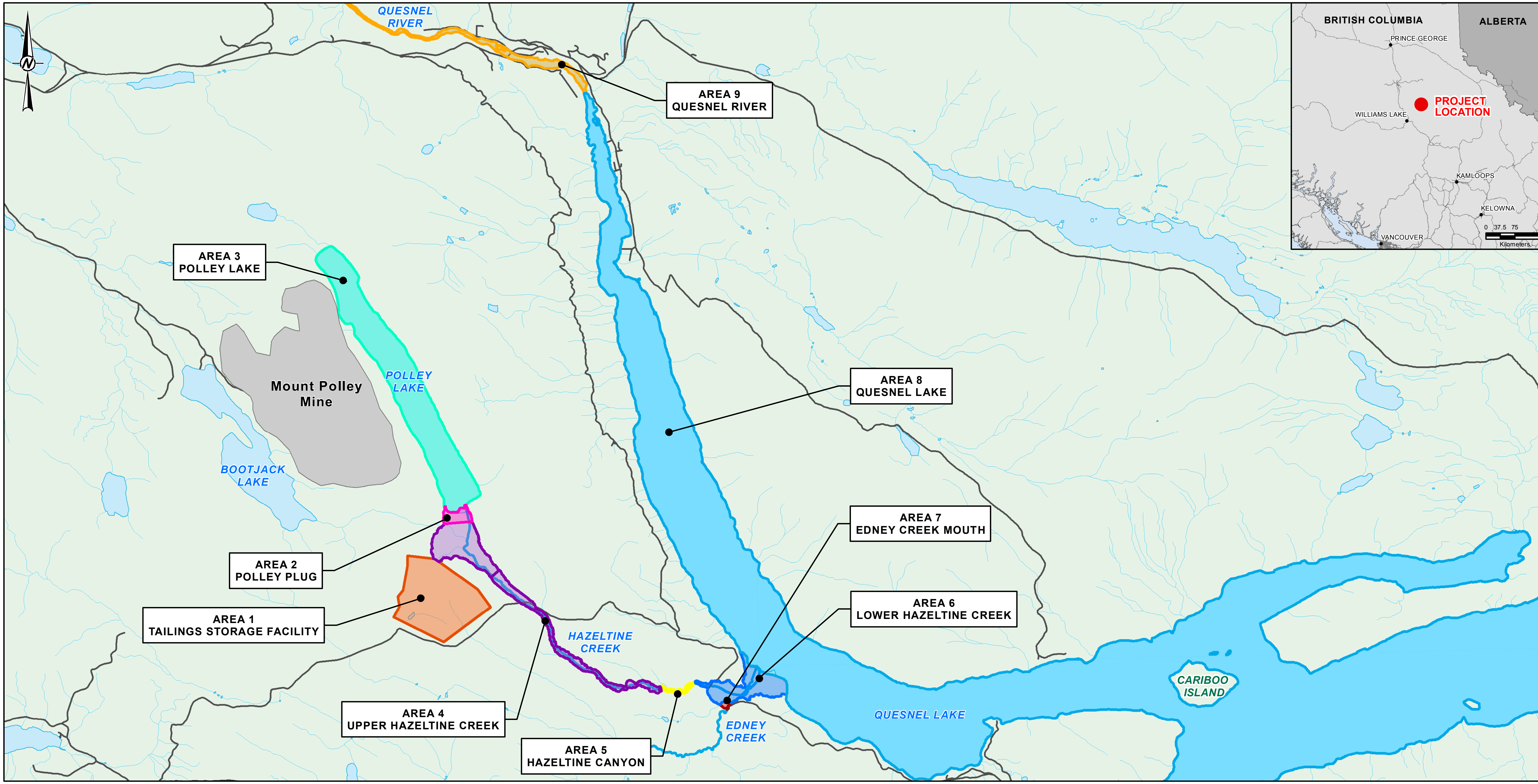
The tailings spill resulted in a thick (~2-3 m) deposit of tailings in the area referred to as the Polley Plug. The debris flow eroded Upper Hazeltine Creek resulting in a wider and deeper channel, which in turn created over steepened, unstable slopes adjacent to the Hazeltine Creek channel. Within the Hazeltine Creek Canyon, the channel was eroded down to bedrock with subsequent deposits of only thin, isolated layers of tailings. Within Lower Hazeltine Creek, the floodplain was eroded, and tailings and native material (mixed tailings) were deposited. The lower reach of Edney Creek was affected by scour and deposition from the debris flow. At the confluence of these two creeks, the Edney Creek channel was scoured resulting in a drop of approximately 2 metres in elevation providing a barrier to the free movement of fish from Quesnel Lake to Edney Creek.

The results of chemistry studies found that the tailings and tailings-eroded native material mixture were low in organic carbon and nutrients and had concentrations of copper and, to a lesser extent, vanadium that exceeded the provincial contaminated site regulation (CSR) standards protective of soil invertebrates and plants. The geochemistry results found that the tailings were not acid-generating and had low leaching potential.

The results of monitoring the biological impacts found that the terrestrial and aquatic communities along Hazeltine Creek were lost immediately following the tailings spill. The sediment-dwelling communities in Polley Lake and in a portion of the West Basin of Quesnel Lake were covered. These effects on the local biological communities were physical and immediate. Toxicology studies using representative aquatic biota and water from Quesnel and Polley Lakes found that the more turbid samples caused an effect on one of the zooplankton test species, but that evidence did not indicate a clear metal-related toxic effect. The 2015 studies of potential toxicity to aquatic organisms from chemical exposure from spill-related related sediments deposited in Quesnel Lake were inconclusive due to the low total organic carbon (TOC) content and/or particle size differences of the tailings soil mixture compared to reference sediment. The PEEIAR assessment of biological effects to terrestrial biota, including the terrestrial riparian forest community, was limited to analysis of soil contaminants and nutrient concentrations, and mapping of areas affected by the tailings. Later studies conducted as part of the risk assessment problem formulation found that there were physical impacts to the terrestrial ecosystem where the tailings deposited on the existing forest floor (referred to as the 'halo') blocked air exchange and led to the loss of standing trees in the 'halo' area along Hazeltine Creek. However, there was no evidence for a metal-related toxic effect on the impacted trees.

3.0 SUMMARY OF FINDINGS BY AREA

To assist in design and implementation of the Rehabilitation and Remediation Strategy, nine areas potentially affected by the tailings spill were identified (Figure 2). This was done because the different areas of impact have different characteristics, different potential for impact and different study needs. The first edition of the PEEIAR found that conditions along the length of Hazeltine Creek were similar, thus Areas 4 through 7 are treated as a single area. Area 1, the TSF, was excluded as this area is part of the operating mine.



LEGEND

REMEDIATION AREA
- 1 - TAILINGS STORAGE FACILITY
- 2 - POLLEY PLUG
- 3 - POLLEY LAKE
- 4 - UPPER HAZELTINE CREEK
- 5 - HAZELTINE CANYON
- 6 - LOWER HAZELTINE CREEK
- 7 - EDNEY CREEK MOUTH
- 8 - QUESNEL LAKE
- 9 - QUESNEL RIVER

- MOUNT POLLEY MINE SITE
- ROAD
- WATERCOURSE
- WATERBODY

0 2 4
1:80000 KILOMETRES

REFERENCES
1. WATERCOURSE, LAKE, ROAD, CITY AND PROVINCE DATA OBTAINED FROM CANVEC © DEPARTMENT OF NATURAL RESOURCES CANADA. ALL RIGHTS RESERVED.
2. PROJECTION: NAD 1983 UTM ZONE 10

CLIENT
IMPERIAL METALS
MOUNT POLLEY MINING CORPORATION

PROJECT
DETAILED SITE INVESTIGATION AND HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

CONSULTANT

Golder Associates

YYYY-MM-DD	2016-01-25
DESIGNED	AA
PREPARED	RH
REVIEWED	AB
APPROVED	TAM

TITLE
MOUNT POLLEY TAILINGS DAM FAILURE - REMEDIATION AREAS

PROJECT NO.	CONTROL	REV.	FIGURE
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3.1 Polley Lake (and Plug)

3.1.1 Physical

Polley Lake is a long (6.17 km), narrow (0.65 km) lake situated adjacent to the Mount Polley Mine within a watershed area of 17.1 km^2. The estimated hydraulic residence time of the lake is approximately 16.2 years (MPMC 2015 Appendix F). Polley Lake had a mean depth of 18 m and maximum depths of 35 m in the south basin and 33 m in the north basin. The main inflow to the lake is from the Frypan Lake sub-watershed situated to the northwest. Polley Lake is a dimictic lake that mixes from the surface to the lake bottom twice each year. Thermal stratification occurs in summer; a thermocline typically forms at a depth between 5 and 15 m (Minnow 2014). Hypoxic conditions (low oxygen) generally occur at depths greater than 20 m, with dissolved oxygen (DO) concentrations less than 5 mg/L (Minnow 2014). Trophic status of the lake changed from oligotrophic/mesotrophic prior to mine development (1995/1996) to mesotrophic/eutrophic in 2012 (Minnow 2014).

Water and tailings released during the spill were deposited directly into Polley Lake. The sediment investigation indicated that tailings were heterogeneously deposited throughout Polley Lake (MPMC 2015 Appendix E). A thick deposit of tailings and other debris (known as the Plug), blocked water from flowing out of Polley Lake and into Hazeltine Creek. In addition, the wetland area that existed before the tailings spill at the outlet of Polley Lake, was inundated with tailings that have remained saturated due to the high water table associated with the lake. Reconstruction of the Hazeltine Creek channel has restored the connection to Polley Lake, and a weir installed just downstream of the lake outlet controls the volume of water flowing out of Polley Lake.

Immediately following the event, the water level in Polley Lake increased by approximately 1.7 m and turbidity was increased in the deeper waters of the lake (below the thermocline). In mid-October 2014, lake turnover occurred causing mixing of shallow and deep water in the lake; during that period turbidity and DO were uniform throughout the water column. In mid-November 2014, turbidity and DO concentrations in the lake returned to pre-event conditions and have remained consistent since (Appendix D).

3.1.2 Chemical

3.1.2.1 Surface Water Quality Update

Water quality data collected from Polley Lake by MPMC has been evaluated to assess temporal trends of POIs since the tailings spill through December 2015 (Appendix D). The water quality assessment was based on comparison of water chemistry to BC water quality guidelines (WQG), reference data, and baseline data. Immediately following the tailings spill, concentrations of copper and molybdenum were measured at concentrations greater than the BC WQGs for protection of aquatic life (MPMC 2015 Appendix F). Concentrations of those POIs in Polley Lake have been below BC WQGs throughout 2015. With respect to nutrients, total phosphorus concentrations were somewhat elevated in deep water immediately following the event, but have been within the range observed in Polley Lake prior to the event since fall turnover in November 2014. Based on the evaluation of 2015 water quality data, no POIs in surface water remain above WQGs in Polley Lake.

Metals concentrations in Polley Lake surface water will continue to be monitored as part of MPMC's routine monitoring program.

3.1.2.1.1 Free Metals in Surface Water

Between August and October 2015, Minnow deployed diffusive gradients in thin films (DGT) passive sampling devices in the south basin of Polley Lake (near-field location) to measure the amount of free and weakly complexed metals in water near the sediment-water interface (Appendix D). Labile metals are the fraction of metals that are considered to be potentially bioavailable (i.e., that can be readily transported across biological membranes of aquatic organisms). The DGT device simulates the biological membrane of an aquatic organism. Calculated concentrations of free metals in water (based on accumulation by the DGT device) were compared to concentrations of total and dissolved metals in concurrent water samples, reference concentrations from Bootjack Lake, and BC WQGs.

In Polley Lake, copper and molybdenum were measured by the DGT devices at concentrations greater than in Bootjack Lake, but lower than the BC WQGs (Figure 3). It is acknowledged that the WQGs were not derived with DGT data, so the comparison was made for information purposes only. In comparison to total and dissolved (filtered) concentrations, the DGT-labile concentrations of copper in water near the bottom of Polley Lake were lower. The ‘dissolved’ concentrations are measured by filtering water through a 0.45 um filter. The DGT results suggest that the free and weakly complexed fraction of these metals is lower than indicated by the filtered water samples referred to as dissolved metals in routine analysis.

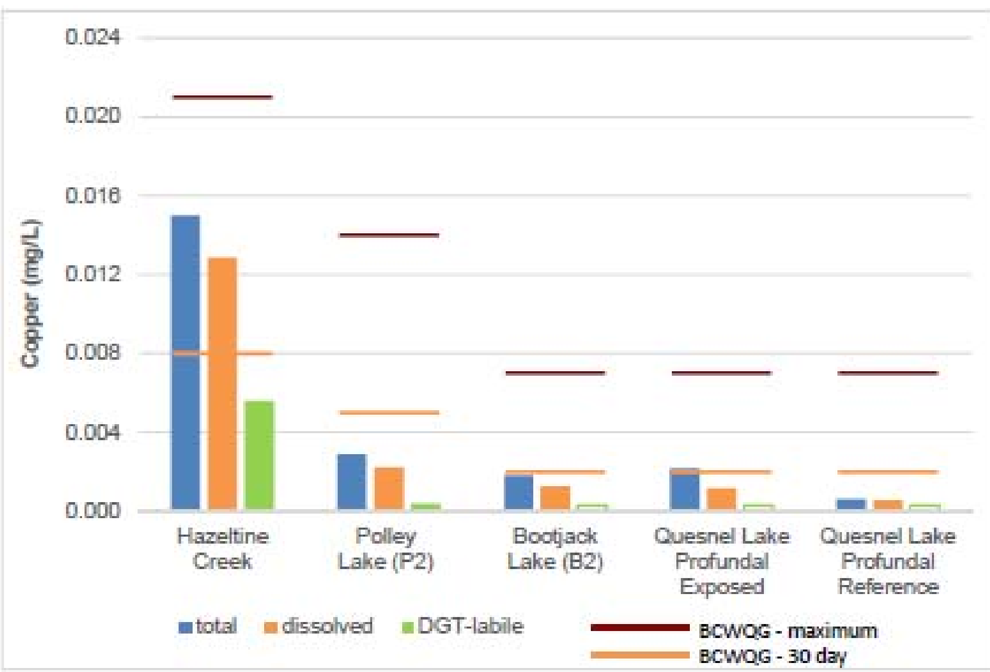


Figure 3: Total (T), Dissolved (D) and DGT-labile Concentrations of Copper in Water

Note: The open bars denote results that were less than detection limits.

3.1.2.2 Sediment Quality Update

Sediment quality data collected from Polley Lake by Minnow Environmental Inc. (Minnow) has been evaluated to assess changes in sediment chemistry since the tailings spill occurred (Appendix E, MPMC 2015 Appendix E). Unlike water quality, concentrations of metals in the tailings-influenced sediment are not expected to have changed substantially between sampling events in 2014 and 2015. A total of 21 sediment samples have been collected by Minnow in Polley Lake following the tailings spill. The sediment quality assessment was based on comparison of sediment chemistry to BC sediment quality guidelines (SQG), reference data and baseline data (i.e., data collected prior to the tailings spill). Baseline sediment data from Polley Lake indicated that concentrations of metals were naturally-elevated in the lake prior to the tailings spill (MPMC 2015 Appendix E).

In 2014, sediment was collected from deep and mid-depth locations throughout the lake. The 2014 chemistry data indicated that arsenic (at deep stations), copper (at mid-depth and deep stations) and iron (at mid-depth stations) were elevated in comparison to guidelines and reference/baseline concentrations. The deep station in the south basin of Polley Lake was considered to be representative of the worst case and sampled in 2015. The 2015 chemistry data indicated that arsenic and copper remained elevated in comparison to standards and reference/baseline concentrations (Appendix E). Iron was not elevated in comparison to reference/baseline at the deep station; however, the concentrations of iron at the deep station were similar between 2014 and 2015, thus the same could be assumed for the mid-depth stations where iron was elevated in 2014. Based on the evaluation of 2014 and 2015 sediment quality data, arsenic, copper and iron were identified as POIs in Polley Lake.

3.1.2.3 Evaluation of Mercury Biomagnification Potential

COPCs related to the tailings spill were identified for surface water (Appendix D, MPMC 2015 Appendix F), soil (Appendix B, MPMC 2015 Appendix D), and sediment (Appendix E, MPMC 2015 Appendix E). Although mercury was not identified as a COPC based on measured concentrations in these media, mercury has been identified as a stakeholder concern due to questions regarding possible methylation and subsequent biomagnification into the aquatic food web via a “reservoir effect” in Polley Lake that could potentially occur as a result of the TSF breach and the introduction of organic debris into the lakes.

The reservoir effect refers to a phenomenon of enhanced mercury mobilization sometimes observed in newly-formed reservoirs. Reservoir formation often involves flooding soils and vegetation, thus providing a new source of nutrients and organic material for bacteria that can methylate and de-methylate mercury in the flooded environment (Ullrich et al. 2001). Bacterial decomposition of this new organic material can increase the natural rate of formation of methylmercury. Methylmercury is a positively charged ion that readily binds to sulfur-based amino acids such as cysteine (Newman 2009).

Once attached to amino acids, methylmercury can be incorporated into proteins and transferred to higher trophic levels. Bacteria that methylate inorganic mercury are consumed by invertebrates, which are consumed by fish, leading to increased concentrations of methylmercury in fish tissues (CCME 2000). Stakeholder concern related to mercury is connected to the hypothesis that the deposited mixture of tailings and native organic material created conditions that promote the methylation of mercury, as occurs in a reservoir.

Golder reviewed the conditions that favour the methylation of mercury to assess whether these conditions could occur in Polley Lake and reviewed the existing monitoring data to examine if there is evidence of increased mercury concentrations as a result of the tailings spill.

3.1.2.3.1 Factors Influencing Methylation of Mercury

Azimuth (2010, 2012, and 2015) summarized environmental factors that influence mercury methylation. As outlined in Sections 4.3 to 4.5 of Azimuth (2012), key parameters that influence methylation potential are residence time, trophic status, temperature, DO, pH, dissolved organic carbon, total suspended solids, sulphate, sediment grain size, and total organic carbon in sediment. The correlation of these parameters with mercury methylation (i.e., positive or negative) is summarized in Table 3-1.

Table 3-1: Summary of Parameters and their Correlation with Mercury Methylation (Azimuth 2012) and Current (Post-event) Conditions of these Parameters in Polley Lake

Parameter	Correlation	Conditions that Favour Methylation	Polley Lake	Source for Polley Lake data
Residence time	Positive	Longer residence time	16.2 years, more likely	1
Trophic status	Positive	Highly productive systems	Moderate to high productivity; classified as mesotrophic/eutrophic, more likely	1
Water – Temperature	Positive	Warmer temperatures (weakly related)	Temperature < 10℃ at depths greater than 15 m, less likely	2
Water - Dissolved Oxygen	Negative	Low oxygen conditions	Concentrations < 5 mg/L at depths greater than 10 m, more likely	2
Water – pH	Negative	Slightly acidic waters (pH <6.5)	Median pH = 8.1, less likely	3
Water - dissolved organic carbon	Positive	Concentrations > 5 mg/L	Mean concentration = 6.2 mg/L, more likely	3
Water - total suspended solids	Positive	Higher concentrations (as transport media for mercury)	Below detection limit of 3 mg/L in most samples (n= 54); 4 samples had detected concentrations that ranged from 3.1 to 5.4 mg/L, less likely	3
Water - sulphate	Positive	Higher concentrations over environmentally relevant range (5-30 mg/L)	Mean concentration = 44.3 mg/L, more likely	3
Sediment - grain size	Negative	Fine grain sediment[5]	Predominantly silt in the <63 µm fraction, more likely	4
Sediment - total organic carbon	Positive	Higher	Mean total organic carbon ≤ 7.7% in the <63 µm fraction, more likely	4

Abbreviations*: < = less than; ≤ = less than or equal to; > = greater than; ~ = approximately; ℃ = degrees Celsius; m = metres; mg/L = milligrams per litre; µm = micrometres; % = percent.*

Sources*:*
[1] Minnow (2014).
[2] Depth profiles presented in MPMC (2015 Appendix H).
[3] Appendix D. Values calculated using all Quesnel Lake samples or all Polley Lake samples collected in 2015.
[4] Appendix E. Based on mean particle size or mean total organic carbon at exposed locations sampled in 2014 and 2015.
[5] Condition that favours mercury methylation is described in Azimuth (2012).

In Polley Lake, some parameters indicate that mercury methylation would not be favoured (i.e., temperature, pH, and total suspended solids), whereas other parameters indicate that mercury methylation could be favoured (i.e., trophic status, DO, sulphate, and sediment characteristics). For the latter set of parameters, these conditions appear to be unrelated to the tailings spill because, with the exception of sulphate[1], pre-event and post-event conditions are comparable. Prior to the tailings spill, Polley Lake was classified as a mesotrophic/eutrophic lake with hypoxic conditions (i.e., dissolved oxygen concentrations less than 5 mg/L) generally occurring at depths greater than 20 metres (MPMC 2015 Appendix F). Pre-event sediment grain size (predominantly silt; MPMC 2015 Appendix E) and total organic carbon in sediment (mean in deep areas = 18.2%, mean in mid-depth areas = 8.4%; MPMC 2015 Appendix E) were also similar to conditions shown in Table 3-1. Overall, based on the key parameters identified in Sections 4.3 to 4.5 of Azimuth (2012) and the data presented in Table 3-1, the potential for the tailings spill to increase mercury methylation in Polley Lake is considered low.

3.1.2.3.2 Review of Existing Monitoring Data for Mercury

Water Chemistry

Water chemistry data collected between August 2014 and July 2015 are reported in Appendix D. During this time total aqueous mercury concentrations in Polley Lake samples have been below the reported detection limits of 50 ng/L (August 2014 samples), 10 ng/L (September 2014 samples), or 5 ng/L (2015 samples). Because mercury data are sparse and total aqueous mercury concentrations were below the reported detection limit in all samples, interpretation of aqueous mercury trends is limited.

In Appendix D, detection limits for samples with no detected mercury were compared to the BC water quality guideline (BC MoE 2001) of 10 ng/L, based on the assumption that the percent methylmercury in Polley Lake is 1%. Because the percent methylmercury in Polley Lake has not been measured, the aqueous mercury data cannot be directly compared to the BC water quality guideline. However, comparison to the CCME (2003) water quality guideline for inorganic mercury (26 ng/L) suggests that the potential for mercury effects is low. In water samples collected from September 2014 (i.e., detection limit of 10 ng/L) to July 2015 (i.e., a detection limit of 5 ng/L), aqueous mercury concentrations were lower than the CCME (2003) water quality guideline for inorganic mercury.

Although the above comparisons to the CCME (2003) water quality guidelines suggest that the potential for mercury effects is low, the CCME (2003) derivation document states that the water quality guidelines may not fully protect higher trophic level fish. Therefore, sediment, zooplankton tissue chemistry, and fish tissue chemistry data collected from Polley Lake were also reviewed to assess spatial and temporal trends in mercury concentrations.

Sediment Mercury Chemistry

Sediment chemistry data are reported in MPMC (2015 Appendix E) and Appendix E. Sampling in Polley Lake was conducted in 2014 at two depths: mid-depth (approximately 20 metres deep) and deep basins (approximately 29 meters deep). Sampling of both the mid-depth and deep basins were done in two areas, one located on the south side and the other on the north side of Polley Lake. Mercury concentrations were measured in the <2 mm

[1] Mean pre-event sulphate concentration was 20 mg/L (MPMC 2015 Appendix F).

fraction (deep basin samples) and the <63 µm fraction (mid-depth and deep basin samples). In 2015, sampling of the deep basin on the south side of Polley Lake was conducted and concentrations were measured for the <63 µm fraction. The deep basins had been historically sampled as a part of baseline studies for Mount Polley Mine and are summarized in MPMC (2015 Appendix E). Bootjack Lake served as a reference for Polley Lake.

In 2014 and 2015, sediment mercury concentrations in Polley Lake were lower than concentrations in Bootjack Lake (i.e., the reference lake), lower than the BC sediment quality guideline, and lower than the mean historic baseline concentration (pre-mine operation) in Polley Lake. With respect to temporal comparisons, mercury concentrations in sediment were similar in 2014 and 2015 (Appendix E).

Mercury in Zooplankton Tissue

Zooplankton tissue chemistry collected in 2015 from Polley Lake is reported in Appendix G. Tissue samples were collected in four months (May, July, August, and September) from two stations in Polley Lake; P1 (northern end of Polley Lake) and P2 (southern end of Polley Lake, closer to the outlet of Hazeltine Creek). No baseline or reference data were available for comparison.

Zooplankton mercury concentrations were similar between sampling stations (P1 and P2) in Polley Lake in 2015, with the exception of the September 2015 sampling event when P1 was higher than P2. August and September mercury tissue concentrations were higher at both stations compared to mercury concentrations in May and July. Tissue mercury concentrations in all Polley Lake samples were lower than or similar to those measured in the Quesnel Lake reference stations. Zooplankton was not sampled in 2015 in the Polley Lake reference site, Bootjack Lake.

The zooplankton data are considered preliminary at this time. Further assessment of zooplankton conditions is included in the CEMP.

Fish Tissue - Mercury

Fish tissue chemistry collected in 2014 and 2015 from Polley Lake is reported in Appendix G. Tissue chemistry comparisons were conducted spatially (i.e., exposure versus reference areas) and temporally (i.e., 2014 versus 2015 data) for site, species, and tissue type, where data were available.

In 2014 and 2015, mercury concentrations in all fish species collected from Polley Lake were either lower than or similar to concentrations in fish collected from reference locations. With respect to temporal comparisons, mercury concentrations in fish were similar in 2014 and 2015. These results are consistent with the lack of spatial and/or temporal trends observed in water chemistry, sediment chemistry, and zooplankton tissue chemistry.

This review of the available data suggests that increased mobilization of mercury in the aquatic food chain in Polley Lake as a result of the tailings spill is unlikely. There are uncertainties related to this evaluation, including that there may be additional key parameters currently unknown that influence mercury methylation. Also, the percent aqueous methylmercury in Polley Lake has not been measured but was assumed to be 1%. In order to reduce uncertainty regarding future conditions, monitoring mercury concentrations in fish tissue has been included in the CEMP. However, indications to date are that methylation and increased mobilization of mercury in Polley Lake is unlikely.

3.1.3 Biological

3.1.3.1 Sediment Toxicity

MPMC conducted a post-event toxicity testing program between August and October 2014 (MPMC 2015 Appendix E), in which surface sediment samples collected from Polley Lake were tested using a series of standard laboratory tests using sensitive invertebrate test species. The program provided an important evaluation of the bioavailability and toxicity of POIs as they are observed in site-specific samples, as well as changes to physical conditions of the sediment that may affect the capacity of sediment to support sediment dwelling organisms. The laboratory testing provided a direct measure of biological effect to individual organisms under site-relevant conditions.

The results of the 2014 post-event toxicity testing indicated no instances of significantly reduced survival or growth of either *Hyalella* or *Chironomus* test species in Polley Lake sediments relative to concurrent laboratory controls and reference samples from Bootjack Lake. One exception was a modest reduction in survival of *Chironomus dilutus* at the mid-depth area close to the south end of the lake. Further toxicity testing of Polley Lake sediment was not conducted in 2015.

3.1.3.2 Benthic Invertebrate Tissue Metal Analysis

Benthic invertebrate biomass and tissue metal analysis is provided in Appendix G. The approximate biomass of benthic invertebrates retrieved from the south basin of Polley Lake was much lower than the biomass collected from the corresponding reference area in Bootjack Lake (exposed area mean <0.17 g/m2 wet weight; reference area mean >0.85 g/m2 wet weight). Samples collected from Polley Lake and Bootjack Lake were composed mainly of chironomids (midge larvae) and oligochaetes.

Mean concentrations of copper, manganese, molybdenum, selenium, tin, and titanium in benthic invertebrates from Polley Lake were more variable and were significantly higher than those in the corresponding reference area (Table 3-2). Principal Components Analysis (PCA) supported these observations.

For all these metals, except selenium, concentrations were lower in benthic invertebrates compared to sediment concentrations in Polley Lake and Bootjack Lake, indicating accumulation factors of less than 1. For selenium, the concentrations in benthic invertebrates appeared to be about twice the concentration in sediment, indicating that the benthic invertebrates in Polley Lake may be accumulating selenium. The benthic invertebrates analyzed in this study were not depurated prior to analysis, so some of the metal content may be related to sediment in gut. MPMC are conducting further investigation into concentrations of selenium in biota in Polley Lake, as well as initiating further investigations into the fate and transport of selenium in Polley Lake and the significance of these measurements to benthic invertebrates and lake productivity.

Table 3-2: Summary whole benthic invertebrate and sediment chemistry results from lake sampling areas in Polley Lake, 2015

Parameter		Units	Polley Lake									
			Reference					Exposed				
			Bootjack Lake (BOL-B2)					Polley Lake (POL-P2)				
			Benthic Invertebrate Tissue		Sediment		BSAF [2]	Benthic Invertebrate Tissue		Sediment		BSAF [2]
			Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE	
Parameters of Interest (POIs)	Arsenic	mg/kg	0.76	0.44	7.72	1.65	0.10	2.36	2.90	14.0	0.95	0.17
	Copper	mg/kg	16.7	4.4	382	59.3	0.04	**97.4**	84.0	823	57.2	0.12
	Iron	mg/kg	1,114	701	30,067	7,512	0.04	3,793	4,115	29,760	2,270	0.13
	Manganese	mg/kg	25.4	8.2	3,327	1,207	0.01	**585**	635	2,574	787	0.23
	Nickel	mg/kg	0.42	0.05	33.3	3.25	0.01	3.09	2.77	22.0	3.64	0.14
	Zinc	mg/kg	68.2	14.0	82.8	9.4	0.82	61.0	29.2	86.4	6.5	0.71
Indicator Parameters (IPs)	Barium	mg/kg	16.8	15.3	289	46.8	0.06	50.1	50.8	329	22.2	0.15
	Calcium	mg/kg	1,055	350	8,417	1,571	0.13	3,706	3,050	24,500	4,099	0.15
	Cobalt	mg/kg	0.23	0.09	13.3	1.65	0.02	2.47	2.61	23.1	2.66	0.11
	Molybdenum	mg/kg	0.49	0.21	4.32	1.22	0.11	**2.74**	3.04	10.1	1.56	0.27
	Phosphorus	mg/kg	7,902	129	2,537	2,182	3.12	7,250	4,167	1,200	86	6.04
	Selenium	mg/kg	2.31	0.56	2.75	0.40	0.84	**7.31**	2.82	4.43	1.07	1.65
	Silver	mg/kg	0.029	0.005	0.377	0.031	0.08	0.051	0.041	0.348	0.013	0.15
	Sodium	mg/kg	5,642	487	900	418	6.27	4,424	3,681	1,828	127	2.42
	Strontium	mg/kg	5.38	1.89	99.4	14.5	0.05	38.0	36.7	289	18.7	0.13
	Tin	mg/kg	0.038	0.016	0.697	0.183	0.06	**0.225**	0.236	2.10	0.199	0.11
	Titanium	mg/kg	6.86	1.93	461	157	0.01	**224**	264	1,832	238	0.12
	Vanadium	mg/kg	1.34	0.43	80.3	10.5	0.02	20.9	25.1	115	7.5	0.18

Notes:
1. Summary statistics were calculated using method detection limit (MDL) values if data were below the MDL. Means are shown with a < symbol if all data used in their calculation were < MDL. If MDLs were variable, means were reported as < the maximum MDL.
2. BSAF = Biota Sediment Accumulation Factor; [Mean concentration of analyte in benthic tissue (mg/kg dw)] / [Mean concentration of analyte in sediment (mg/kg dw)]
***Bold** font indicates mean analyte concentration in benthic invertebrates was significantly higher than in the associated reference area , p < 0.05 (using a non-parametric Mann-Whitney U test).*

3.1.3.3 Benthic Invertebrate Community

Analysis of the benthic invertebrate community in Polley Lake has been conducted by Minnow to assess the initial impacts of the tailings spill and track recovery. The benthic invertebrate community assessment was based on comparison of community metrics (e.g., diversity, richness, evenness) to reference (Bootjack Lake) and baseline data. Sampling in 2014 at mid-depth locations in Polley Lake and at the deep location in the north basin indicated density (individuals per m^2) and richness of invertebrates were lower in comparison to reference (Bootjack Lake), but were consistent with baseline sampling at those locations in Polley Lake. Sampling at the deep location in the south basin of Polley Lake in 2014 yielded no benthic invertebrates, indicating the benthic community was entirely covered by tailings. A follow up analysis of the benthic invertebrate community was conducted during the fall of 2015. The data report was not available for this Update Report, but will be included in the Risk Assessment and CEMP reports.

3.1.3.4 Surface Water Toxicity Testing

MPMC has conducted a post-event toxicity testing program since the tailings spill occurred, in which surface water samples collected from Polley Lake were tested using a series of standard laboratory tests using sensitive plant, invertebrate, and fish test species. The program provides an important evaluation of the potential bioavailability and toxicity of POIs as they are observed in site-specific samples. The laboratory testing provides a direct measure of biological effect to individual organisms under site-relevant conditions, and includes sensitive test species representing primary producers, primary consumers, and secondary consumers.

The results of post-event toxicity testing conducted between August 2014 and February 2015 (MPMC 2015 Appendix F) and follow-up post-event toxicity testing conducted between March and November 2015 (Appendix F) indicate that the water quality in Polley Lake did not adversely affect aquatic health. The results of toxicity testing conducted between January and November 2015 are presented in Table 3-3.

Table 3-3: Summary of Surface Water Toxicity Testing in Polley Lake (January to December 2015)

Test	Sample ID	Date	T. Cu (mg/L)	D. Cu (mg/L)	LC50 (% v/v)	IC25 (% v/v)	IC50 (% v/v)
7-d fathead minnow survival and growth	P2-Surface	06 Jan 2015	0.0024	0.0021	>100	>100	>100
	P2-Surface	14 Apr 2015	0.0025	0.0019	>100	>100	>100
7-d Rainbow Trout swim-up survival and growth	P2-Surface	06 Jan 2015	0.0024	0.0021	>100	>100	>100
	P2-Surface	14 Apr 2015	0.0025	0.0019	>100	>100	>100
	P2-Surface	25 Aug 2015	0.0033	0.0029	>100	>100	>100
	P2-Surface	12 Nov 2015	0.0036	0.0024	>100	>100	>100
7- to 8-d *C. dubia* survival and reproduction	P2-Surface	06 Jan 2015	0.0024	0.0021	>100	>100	>100
	P2-Surface	14 Apr 2015	0.0025	0.0019	>100	>100	>100
	P2-Surface	25 Aug 2015	0.0033	0.0029	>100	>100	>100
	P2-Surface	11 Nov 2015	0.0036	0.0024	>100	>100	>100

Notes: Effect concentration expressed on a volume/volume basis. LC50 = Lethal concentration causing 50% mortality. IC25/IC50 = Non-lethal concentration causing 25% or 50% reduction in growth or reproduction. Total and dissolved copper (T. Cu and D. Cu) concentrations for January to August samples are provided in Appendix B; concentrations for September to November samples are MPMC unpublished data.

3.1.3.5 Plankton Community and Tissue Metal Analysis

Sampling of plankton was conducted at two stations in Polley Lake monthly between May and September 2015 (during the open water period; Appendix G). Plankton was not sampled in Polley Lake in 2014. Plankton was also not collected from a reference lake for Polley Lake. Therefore, these data were considered to provide a preliminary indication of plankton biomass and tissue metal concentrations that can be built on in future sampling events.

- Spatial and temporal trends in phytoplankton biomass (as chlorophyll *a*) and zooplankton abundance throughout the open water period of 2015 were qualitatively examined by plotting the data.
- Trophic status of Polley Lake was classified as ranging from oligotrophic to mesotrophic based on nutrients, Secchi depth, and chlorophyll *a* concentrations measured during the 2015 period.
- Total zooplankton abundance in Polley Lake increased from May to June followed by a decline in abundance from June to August. In September, P1 had an increase in zooplankton abundance where P2 had a slight decline from August. No biomass calculations were made so it is unknown whether zooplankton biomass follows a similar seasonal pattern compared to abundance.
- Similar community composition was observed at the two stations in Polley Lake. Copepod nauplii made up the greatest proportion of total zooplankton abundance in Polley Lake between May and July whereas cyclopoid copepods were generally dominant in August and September. Cladocerans, rotifers, and calanoid copepods were generally present in smaller numbers at both stations through the open water period.
- Zooplankton tissue concentrations of arsenic, copper, mercury, and selenium were generally similar between sampling stations (P1 and P2) in Polley Lake in 2015 with the exception of the September sampling event when P1 was consistently higher than P2 for arsenic, copper, mercury, and selenium.

- Tissue concentrations of arsenic, copper, mercury, and selenium displayed an increasing trend from May to September at P1. This trend was not observed in aqueous concentrations of these parameters with the exception of copper, which also exhibited a slight increase in aqueous concentrations at both sampling locations. See Figures 4a to 4d, below.
- Zooplankton tissue selenium concentrations were at or above the BC interim dietary guideline for tissue consumption by fish (BC MoE 2014) at both stations during the sampling events in Polley Lake in 2015, as shown in Figure 4d. MPMC are continuing to monitor the zooplankton tissue selenium concentration in Polley Lake and compare results to Bootjack Lake, the reference location to determine if there are trends in concentrations over time.

The available data did not allow for evaluation of changes between 2014 and 2015 or assessment of natural variability.

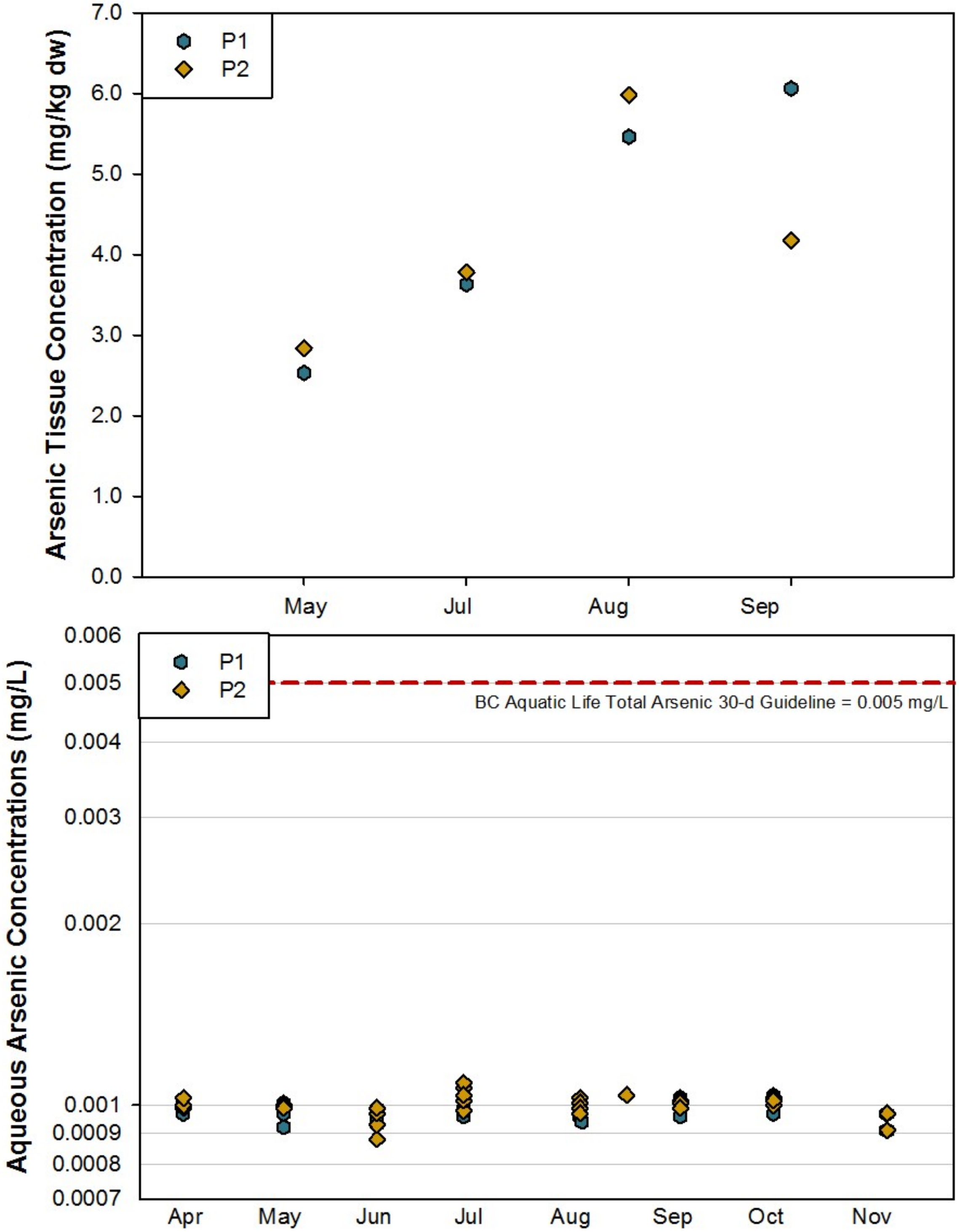
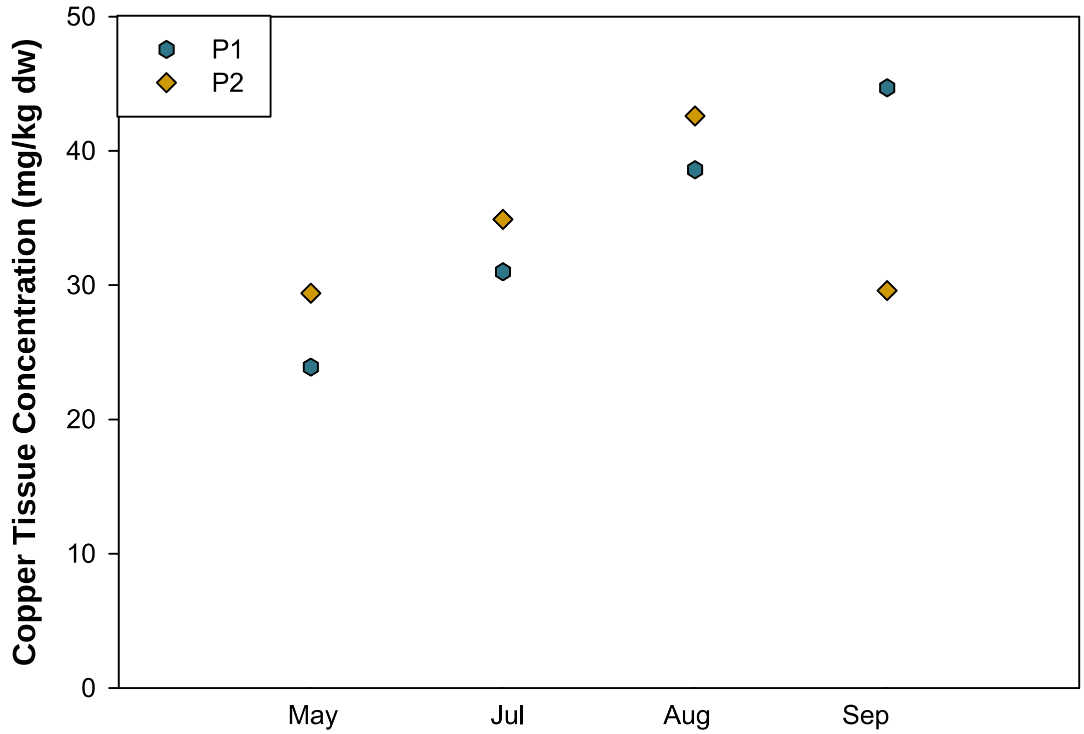


Figure 4a: Concentrations of Arsenic Measured in Zooplankton Tissue (top) and Surface Water (bottom) Collected from Polley Lake, 2015.



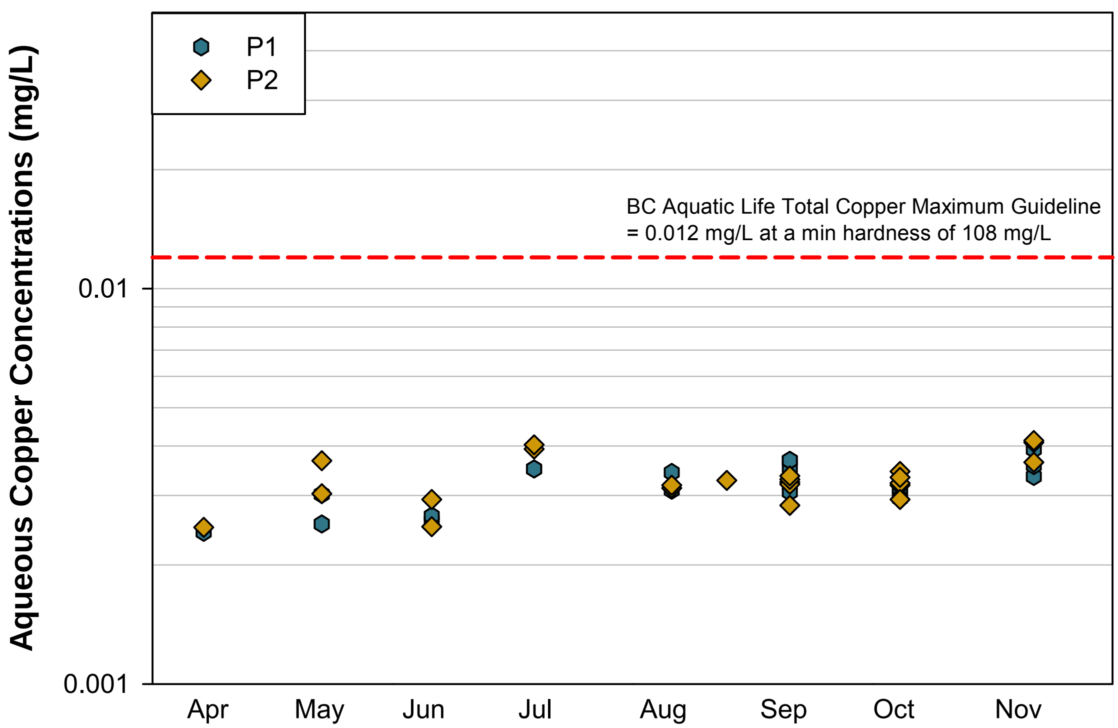


Figure 4b: Concentrations of Copper Measured in Zooplankton Tissue (top) and Surface Water (bottom) Collected from Polley Lake, 2015.

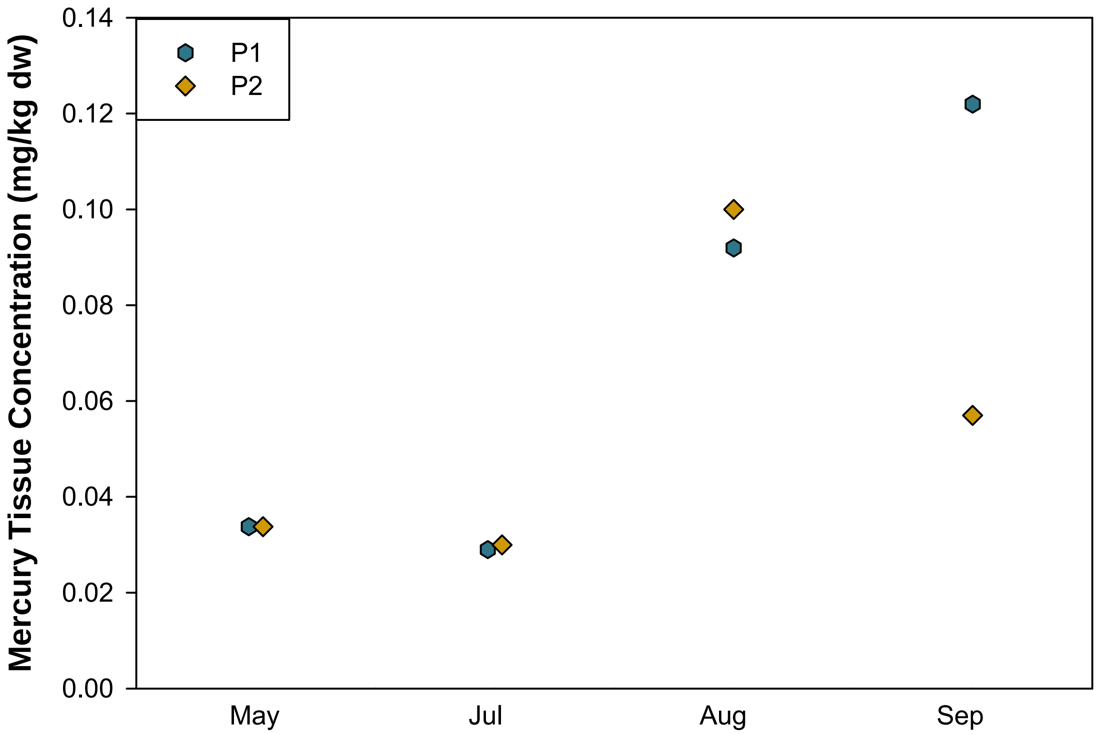


Figure 4c-Concentrations of Mercury Measured in Zooplankton Tissue Collected from Polley Lake, 2015.

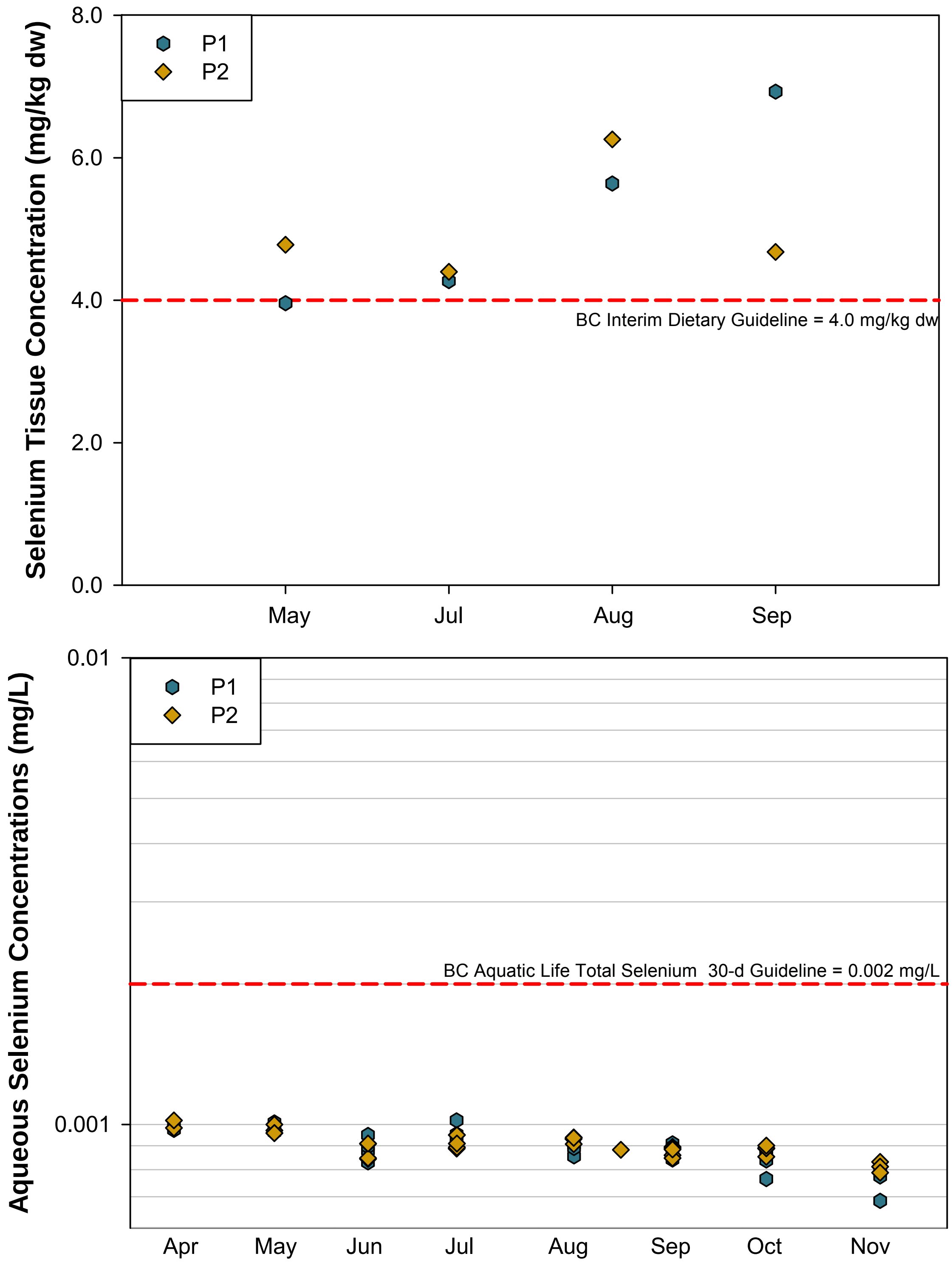


Figure 4d: Concentrations of Selenium Measured in Zooplankton Tissue (top) and Surface Water (bottom) Collected from Polley Lake, 2015.

3.1.3.6 Fish Productivity

The primary effect of the event on the Rainbow Trout of Polley Lake was the disruption to rearing habitat in Hazeltine Creek and the potential loss of a year-class of Rainbow Trout and the blockage of access to Hazeltine Creek for spawning in 2015 and 2016 (Appendix G). Post-event toxicity testing indicated that Polley Lake water did not affect survival or growth of fish, survival or growth of daphnid zooplankton, or growth of plant test species. Rainbow Trout and Longnose Sucker length and weight data suggest that feeding efficiency was not affected. A summary of Rainbow Trout tissue metal concentrations and potential impacts on fish productivity is discussed below.

3.1.3.7 Fish Tissue Metal Analysis

Multiple stakeholders collected fish tissue samples following the release of tailings. Golder consolidated the data from these multiple sources into a single dataset to facilitate data review. The details of the methods for review are provided in Appendix H, Fish Tissue. As discussed in detail in Appendix H, there are several limitations to this data set and this evaluation is considered to be preliminary at this time. See discussion of selenium data below. Additional monitoring to investigate these selenium concentrations will be conducted, as required.

3.1.3.7.1 Comparison to Tissue Guidelines

Tissue guidelines are available for arsenic, mercury and selenium (See Appendix H). The proportion of samples above tissue guidelines is reported by species (including all species for which data are available) and tissue type. The primary comparison for arsenic and mercury is for muscle tissue because this sample type is the most frequently consumed portion of the fish. However, liver and kidney may be consumed by some populations, and therefore, Golder has conservatively retained those comparisons in this data summary. General observations regarding the number of exceedances of these guideline values are as follows.

- There were no arsenic guideline exceedances observed for Polley Lake fish.
- There were no mercury guideline exceedances observed for Polley Lake fish.
- Some selenium guideline exceedances were observed for Polley Lake fish. These guideline exceedances are considered to be suspect at this time. In particular, the selenium tissue results for Frypan Creek-Polley Lake Rainbow Trout are unusually high for the ovary tissue in comparison to the muscle tissue. The data are also considered somewhat suspect as the selenium concentrations in surface water have been below the water quality guideline for the protection of fish and egg productivity.
- Given the unexpected and unusual tissue data, further investigation regarding data quality is currently underway. In the meantime, the selenium concentrations in fish tissue from Frypan Creek-Polley Lake are considered to be suspect.

These exceedances are outlined in Table 3-4 for human health protection and Table 3-5 for environmental protection.

Table 3-4: Summary of Selenium Tissue Exceedances for the Protection of Human Health in Polley Lake. These data should be interpreted with caution as data quality concerns are investigated further

Guideline	Year	Species	Location	Number and Type
Low Fish Intake (75 mg/kg dw) Recreational Fishers	2014	Rainbow Trout	Polley Lake (exposure)	3 of 15 liver
	2015	Rainbow Trout	Polley Lake (exposure)	3 of 8 liver
Moderate Fish Intake (14.5 mg/kg dw) General Population	2014	Rainbow Trout	Polley Lake (exposure)	14 of 15 liver
	2015	Rainbow Trout	Polley Lake (exposure)	8 of 8 ovary, 8 of 8 kidney, 8 of 8 liver
High Fish Intake (7.3 mg/kg dw) First Nation Subsistence	2014	Longnose Sucker	Polley Lake (exposure)	3 of 16 whole body
		Rainbow Trout	Polley Lake (exposure)	1 of 2 ovary, 14 of 15 liver
	2015	Rainbow Trout	Polley Lake (exposure)	8 of 8 ovary, 8 of 8 kidney, 8 of 8 liver
	2016	Rainbow trout	Polley Lake (exposure)	3 of 8 ovary

Table 3-5: Summary of Selenium Tissue Exceedances for Environmental Protection in Polley Lake

Year	Species	Location	Number and Type
2014	Longnose Sucker	Polley Lake (exposure)	1 of 1 muscle
	Rainbow Trout	Polley Lake (exposure)	1 of 15 muscle and 1 of 2 ovary
	Longnose Sucker	Polley Lake (exposure)	16 of 16 whole-body
	Rainbow Trout	Polley Lake (exposure)	1 of 3 whole-body
	Rainbow Trout	Polley Lake (exposure)	5 of 8 muscle and 8 of 8 ovary
2016	Rainbow Trout	Polley Lake (exposure)	3 of 8 ovary

3.1.3.7.2 Risk Assessment and Toxicological Context

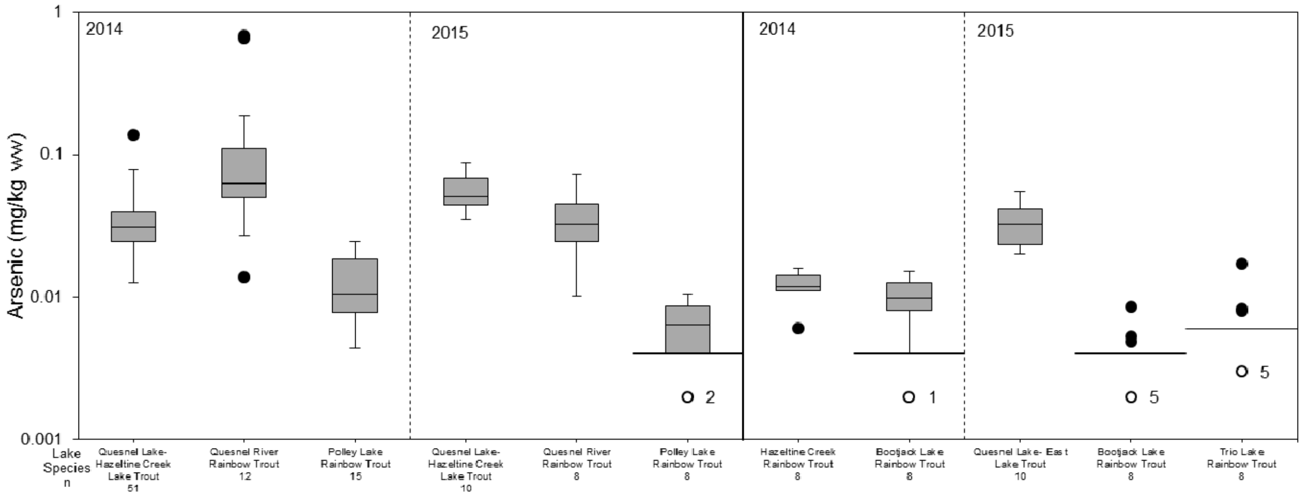
Fish tissue chemistry data were reviewed in further detail for selected combinations of metals and fish species and/or sample types to provide early context for how the data will be integrated into the HHERA. Fish tissue chemistry data would typically be used to develop a realistic, worst-case exposure estimate for each receptor being evaluated. This receptor-specific evaluation means that different parts of the fish tissue chemistry data set would be used for each receptor, depending on a variety of factors such as fish ecology, variability in the data, and the strength of association between the chemistry data and the underlying assessment endpoint. Ultimately, fish tissue can be used as part of the following three measurement endpoints:

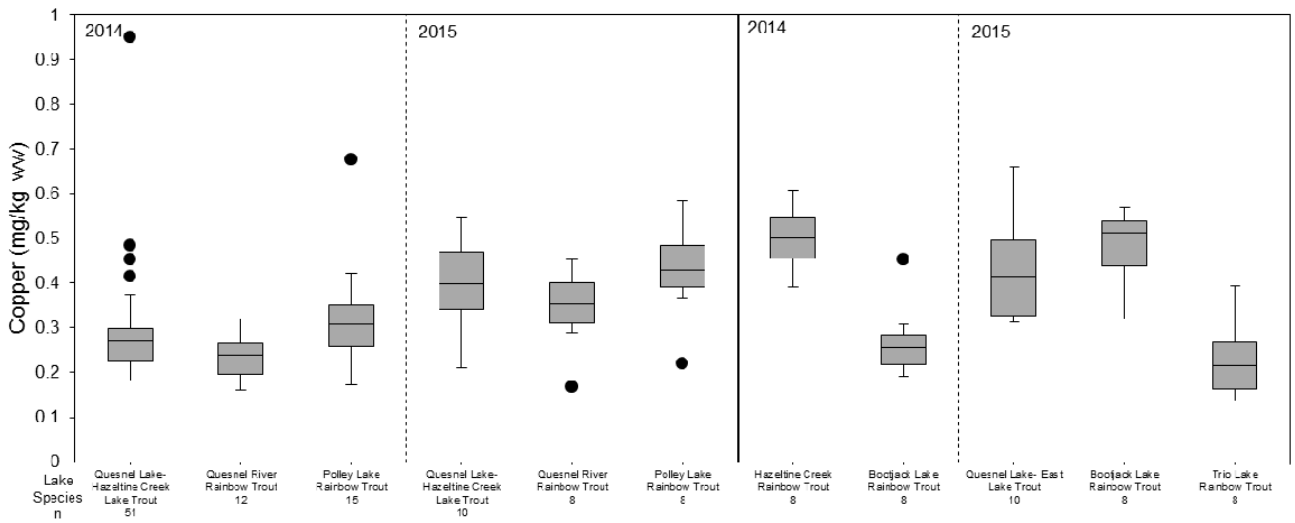
- Consumption of fish by humans --- Increased metals concentrations in muscle samples from large bodied fish caught for recreation or sustenance can contribute to risks to human receptors. Further input is needed from the Williams Lake Indian Band and Soda Creek First Nation regarding appropriate fish tissue to consider for local consumption.
- Bioaccumulation by fish – Increased accumulation of metals in fish tissue can cause adverse effects to the fish themselves.
- Consumption of fish by ecological receptors – Increased metals concentrations in whole-body samples from smaller fish can contribute to risks to piscivorous fish and wildlife. Increased metals concentrations in muscle or organ samples can also contribute to increased risk to higher trophic level wildlife such as bears or raptors which might preferentially feed on these parts of this fish instead of consuming the whole body.

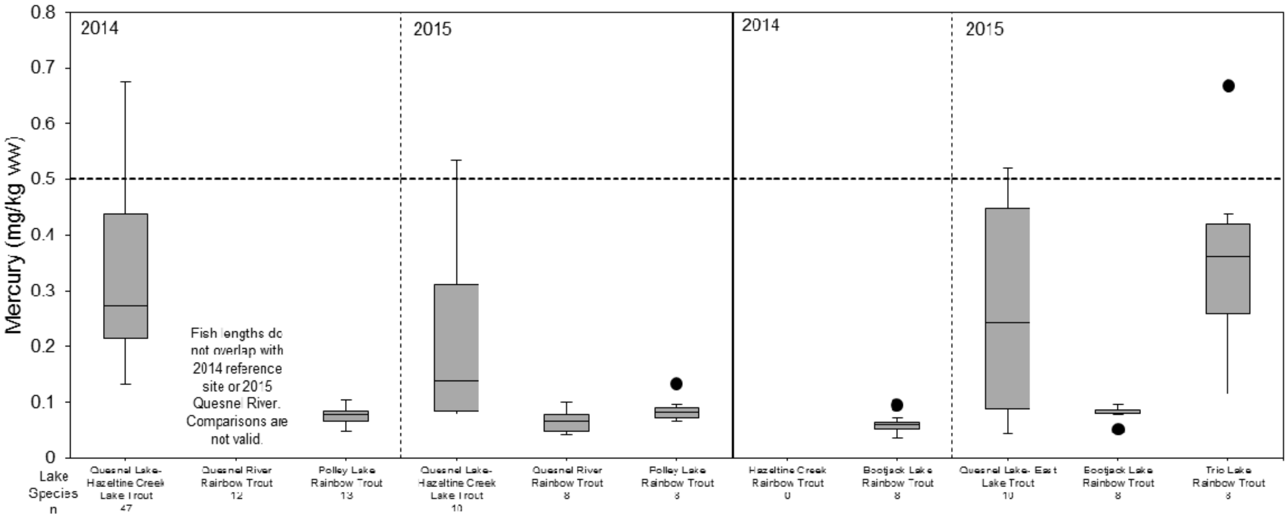
For Polley Lake, Rainbow Trout are an isolated population. A fence prevents them from moving into Hazeltine Creek while restoration work, including the addition of habitat improvements, continues for Hazeltine Creek. Therefore, Rainbow Trout are representative of conditions of Polley Lake. Rainbow Trout are also consumed by humans and wildlife, so they fulfill all three objectives. Rainbow Trout data from Polley Lake were compared to Bootjack Lake and Trio Lake for reference purposes.

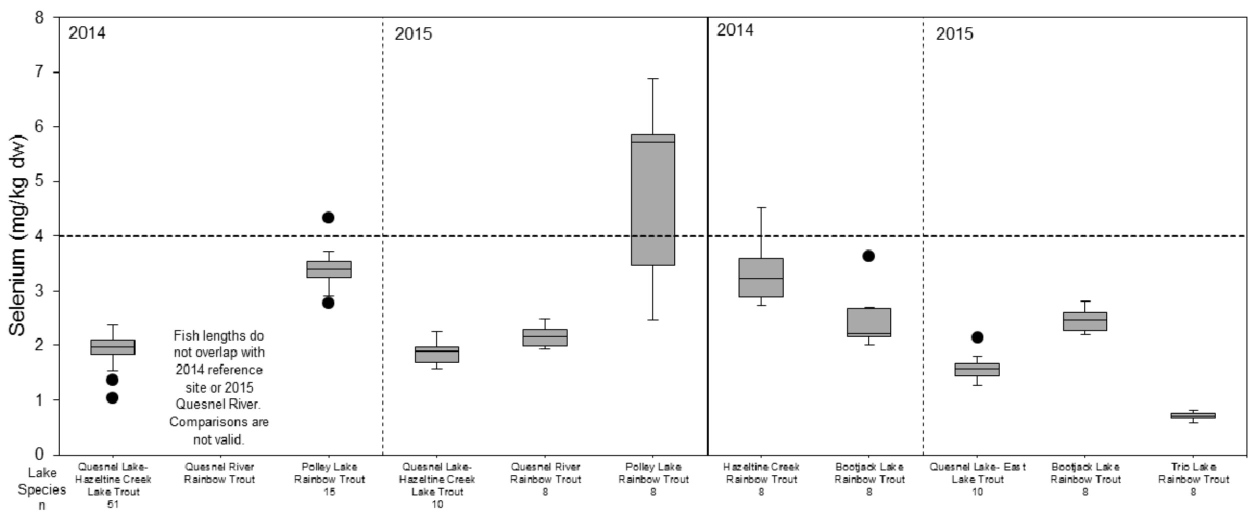
Consumption of Fish by Humans

Figure 5 (below) provides a summary of the box plots for specific metals in the muscle samples from large-bodied fish species. As described above, Lake Trout, Rainbow Trout, and juvenile Sockeye Salmon were identified as a reasonable surrogate for the preliminary consideration of this pathway. Individual box plots with pair-wise comparisons for different sites, species, and years are provided in Appendix I, Attachment 2.


Arsenic (mg/kg ww)
1
0.1
0.01
0.001
2014
2015
2014
2015
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout 51
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Hazeltine Creek Rainbow Trout 8
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8
2
1
5
5


Copper (mg/kg ww)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2014
2015
2014
2015
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout 51
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Hazeltine Creek Rainbow Trout 8
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8


Mercury (mg/kg ww)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference site or 2015 Quesnel River. Comparisons are not valid.
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout 47
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 13
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Hazeltine Creek Rainbow Trout 0
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8


Selenium (mg/kg dw)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference site or 2015 Quesnel River. Comparisons are not valid.
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout 51
Quesnel River Rainbow Trout
Polley Lake Rainbow Trout 15
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Hazeltine Creek Rainbow Trout 8
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8

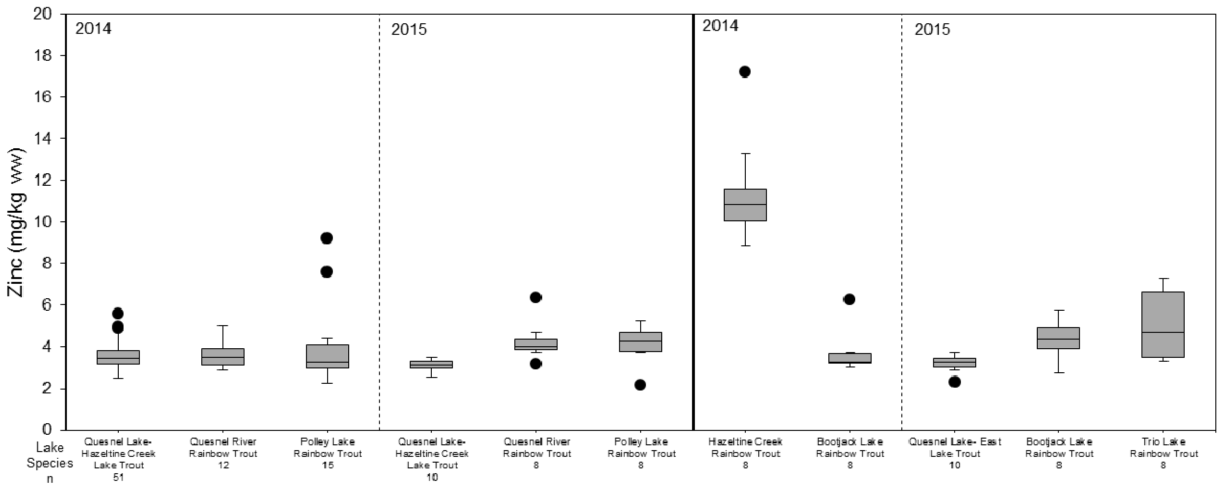


Figure 5: Summary of Available Muscle Chemistry Data for Select Fish Species and Sampling Sites (2014, 2015).

Note: Cadmium and vanadium are not presented because most values were below detection limit with the exception of four samples for cadmium, and one sample for vanadium. Box plots are censored at the detection limit (DL = solid horizontal line). Concentrations below the DL are plotted as an open symbol at half the DL. Extreme values are plotted as individual values. mg/kg ww = milligrams per kilogram wet weight; mg/kg dw = milligrams per kilogram dry weight; n = sample size; dashed vertical lines (- - -) indicate the separation of years; solid vertical lines (−) indicate the separation of exposure and reference; dashed horizontal lines (- - -) indicate guidelines from CFIA (mercury) or BC MoE (selenium).

The purpose of Figure 5 is to highlight whether there are obvious changes in metal accumulation between reference and exposed sites, or between years that would indicate that there has been a change in tissue concentrations. In brief, results are summarized as follows:

- Arsenic concentrations in muscle samples were variable among reference and the exposed sites. Samples from Polley Lake Rainbow Trout appeared to be similar to Bootjack and Trio Lake Rainbow Trout, as well as Rainbow Trout collected from Hazeltine Creek prior to the release of tailings. All measured concentrations were less than the Canadian Food Inspection Agency (CFIA) preliminary tissue guideline.
- Copper concentrations in muscle samples were similar between Polley Lake and Bootjack Lake.
- Mercury concentrations in muscle samples appeared to be similar between exposed sites and reference sites.
- Selenium concentrations in Rainbow Trout muscle collected in 2015 from Frypan Creek (tributary to Polley Lake) were frequently higher than the tissue guideline for environmental protection, and appear to be elevated relative to the applicable references sites (i.e., Bootjack Lake, Trio Lake). The selenium concentrations measured in Frypan Creek Rainbow Trout muscle did not exceed the screening value for First Nation subsistence fish consumers. Readers are reminded that these selenium data are considered to be anomalous and are undergoing further quality checks (see below). Selenium concentrations in Polley Lake Rainbow Trout muscle appear similar to those observed in Hazeltine Creek Rainbow Trout, which were collected prior to the release of tailings.

- Zinc concentrations in muscle tissue appeared to be generally consistent between exposed and reference sites, and were also lower than the median concentrations measured in Hazeltine Creek Rainbow Trout, which were collected prior to the release of tailings.
- The selenium concentrations in Frypan Creek-Polley Lake Rainbow Trout ovary tissue exceeded thresholds for productivity and are higher than what would be expected based on the muscle tissue data. Selenium concentrations in Rainbow Trout ovary tissue collected from Polley Lake (Frypan Creek) in 2015 showed a substantial increase relative to ovary concentrations in Rainbow Trout collected from Hazeltine Creek or Bootjack Lake in 2014 (Figure 6). A similar increase was noted in Rainbow Trout kidney and muscle samples (Figure 5) for the same individual fish. These concentrations were considered potentially anomalous based on the magnitude of the increase and the lack of a similar magnitude of increase in water or fish dietary concentrations. The anomalous data was contained in a single certificate of analysis, and therefore, the analytical laboratory was requested to provide further validation. A summary of the validation conducted to date is included in Appendix H. The concentrations measured in Rainbow Trout ovary tissue were lower in 2016, though concentrations ranged above and below the guidelines for protection of productivity in fish and birds, and the guideline for subsistence consumers of fish. MPMC are conducting additional studies of selenium concentrations in Polley Lake biota and are seeking feedback from the Williams Lake and Soda Creek First Nations regarding current or traditional consumption of Rainbow Trout and other fish tissues.

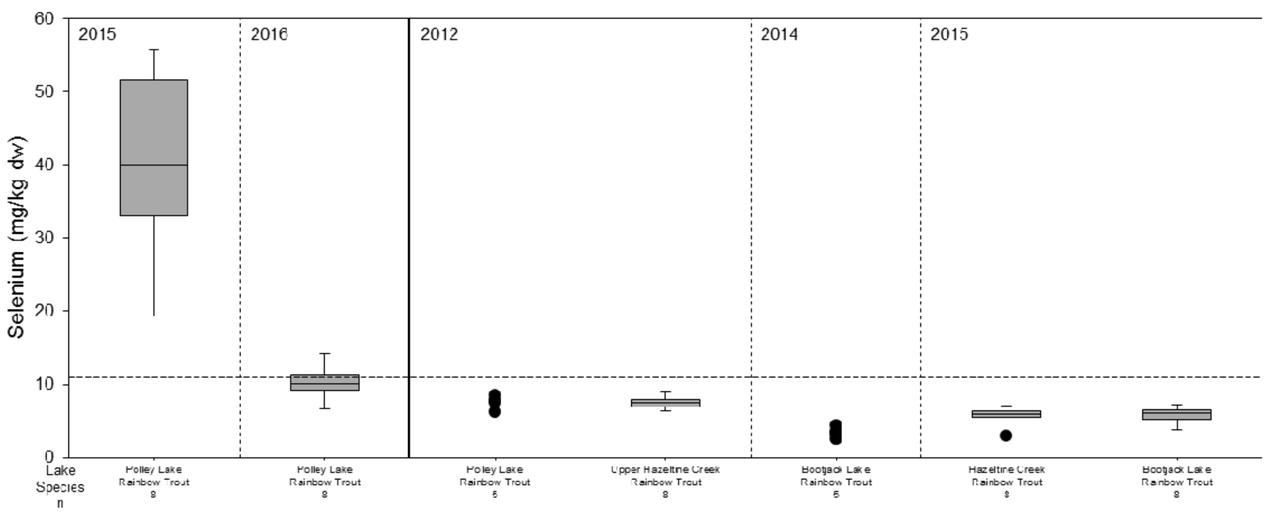


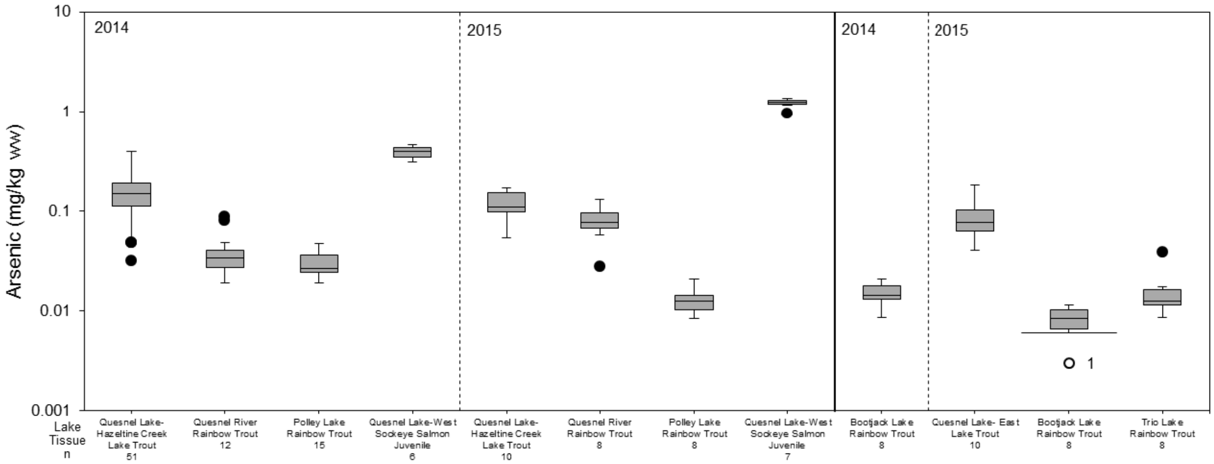
Figure 6: Summary of Available Ovary Chemistry Data for Rainbow Trout from Relevant Sampling Sites.

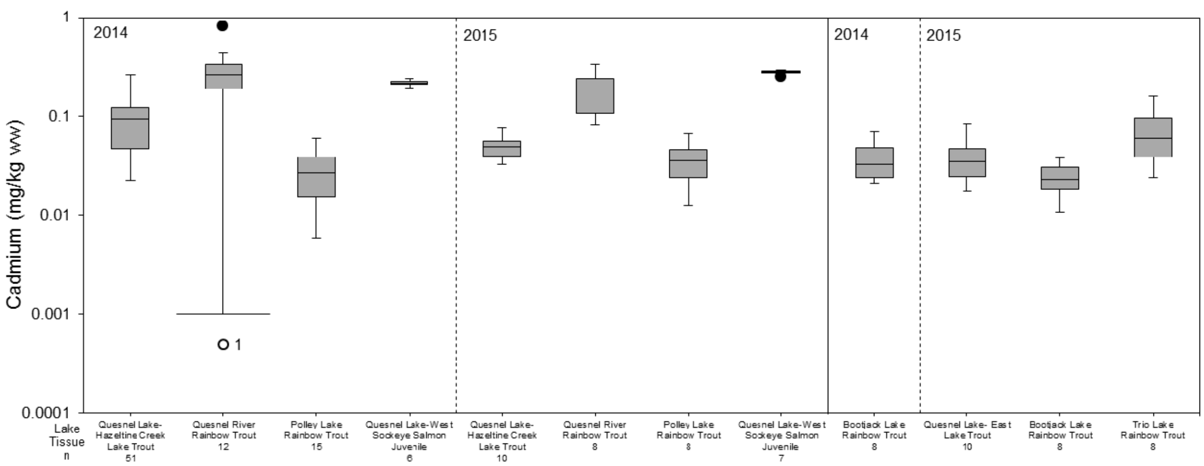
Note: Boxplots are censored at the detection limit (DL = solid horizontal line). Concentrations below the DL are plotted as an open symbol at half the DL. Extreme values are plotted as individual values. mg/kg ww = milligrams per kilogram wet weight; mg/kg dw = milligrams per kilogram dry weight; n = sample size; dashed vertical lines (- - -) indicate the separation of years; solid vertical lines (−) indicate the separation of exposure and reference; dashed horizontal lines (- - -) indicate guidelines from CFIA or BCMoE.

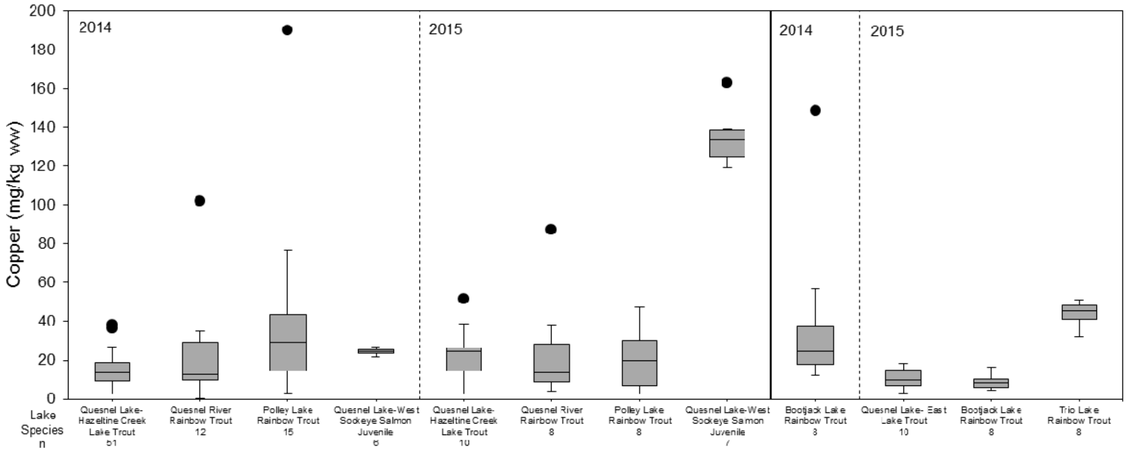
Bioaccumulation by Fish

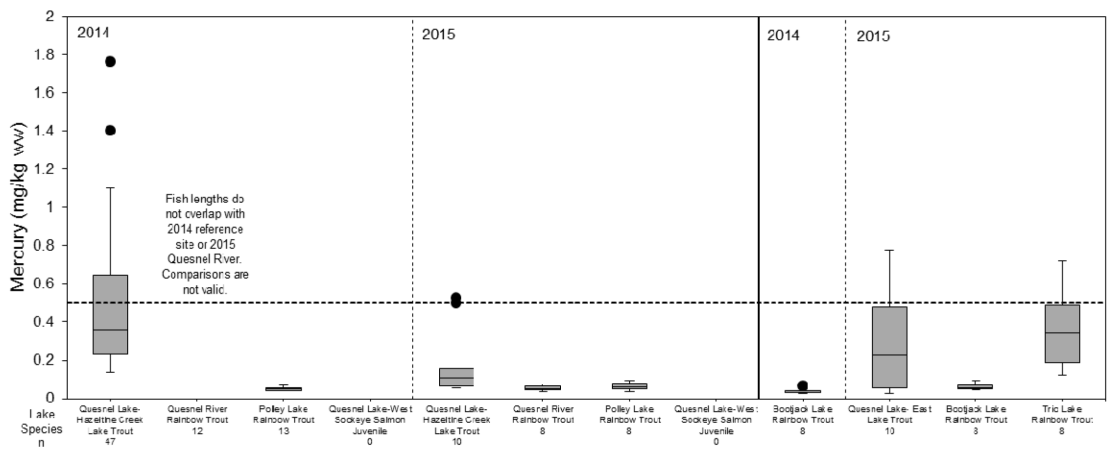
Figure 7 (liver), below, provides summaries of the available fish tissue chemistry data for liver samples presented as censored box plots for the specific metals identified. Individual censored box plots showing comparisons of exposure and reference sites, species, and years are provided in Appendix H, Attachment 2. The purpose of the five summary figures presented herein is to highlight changes in metal concentrations between reference and exposed sites, or between years in tissues that have been associated with metal accumulation. In brief, results are summarized as follows:

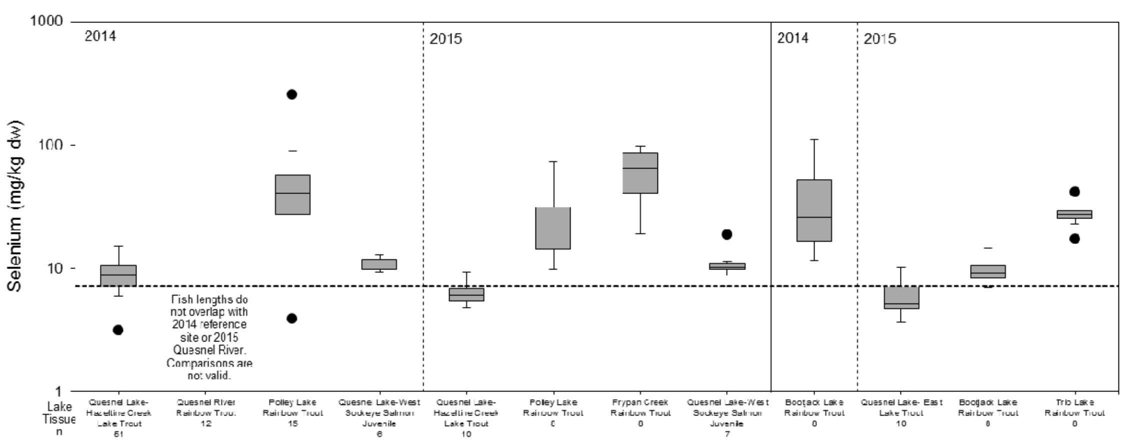
- For arsenic, copper, and zinc, liver (Figure 7) and kidney concentrations were generally consistent between the Polley Lake compared to Bootjack and Trio Lakes.
- Mercury concentrations in fish liver were consistently low for both Polley Lake and Bootjack Lake.
- Concentrations of vanadium may have been higher in Polley Lake Rainbow Trout liver in 2015 compared to reference, which were generally below the detection limit.
- Selenium concentrations in the liver samples collected from Rainbow Trout in Polley Lake, Frypan Creek and Bootjack Lake in 2014 appeared to be greater than Bootjack samples collected in 2015. The concentrations of selenium in liver samples appeared to decrease in Bootjack Lake between 2014 and 2015 (Figure 7). As noted above, additional data quality confirmation is on-going to confirm the 2015 Polley Lake Rainbow Trout data.


Arsenic (mg/kg ww)
10
1
0.1
0.01
0.001
2014
2015
2014
2015
1
Lake
Tissue
n
Quesnel Lake-Hazeltine Creek Lake Trout 51
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-West Sockeye Salmon Juvenile 6
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Quesnel Lake-West Sockeye Salmon Juvenile 7
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8


Cadmium (mg/kg ww)
1
0.1
0.01
0.001
0.0001
2014
2015
2014
2015
1
Lake
Tissue
n
Quesnel Lake-Hazeltine Creek Lake Trout 51
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-West Sockeye Salmon Juvenile 6
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Quesnel Lake-West Sockeye Salmon Juvenile 7
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8


Copper (mg/kg ww)
2014
2015
2014
2015
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-West Sockeye Salmon Juvenile
Quesnel Lake-Hazeltine Creek Lake Trout
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Quesnel Lake-West Sockeye Salmon Juvenile
Bootjack Lake Rainbow Trout
Quesnel Lake- East Lake Trout
Bootjack Lake Rainbow Trout 8
Trio Lake Rainbow Trout 8


Mercury (mg/kg ww)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference site or 2015 Quesnel River. Comparisons are not valid.
Lake
Species
n
Quesnel Lake-Hazeltine Creek Lake Trout 47
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 13
Quesnel Lake-West Sockeye Salmon Juvenile 0
Quesnel Lake-Hazeltine Creek Lake Trout 10
Quesnel River Rainbow Trout 8
Polley Lake Rainbow Trout 8
Quesnel Lake-West Sockeye Salmon Juvenile 0
Bootjack Lake Rainbow Trout 8
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout
Trio Lake Rainbow Trout 8


Selenium (mg/kg dw)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference site or 2015 Quesnel River. Comparisons are not valid.
Lake
Tissue
n
Quesnel Lake-Hazeltine Creek Lake Trout
Quesnel River Rainbow Trout 12
Polley Lake Rainbow Trout 15
Quesnel Lake-West Sockeye Salmon Juvenile
Quesnel Lake-Hazeltine Creek Lake Trout 10
Polley Lake Rainbow Trout
Frypan Creek Rainbow Trout
Quesnel Lake-West Sockeye Salmon Juvenile 7
Bootjack Lake Rainbow Trout
Quesnel Lake- East Lake Trout 10
Bootjack Lake Rainbow Trout
Trio Lake Rainbow Trout

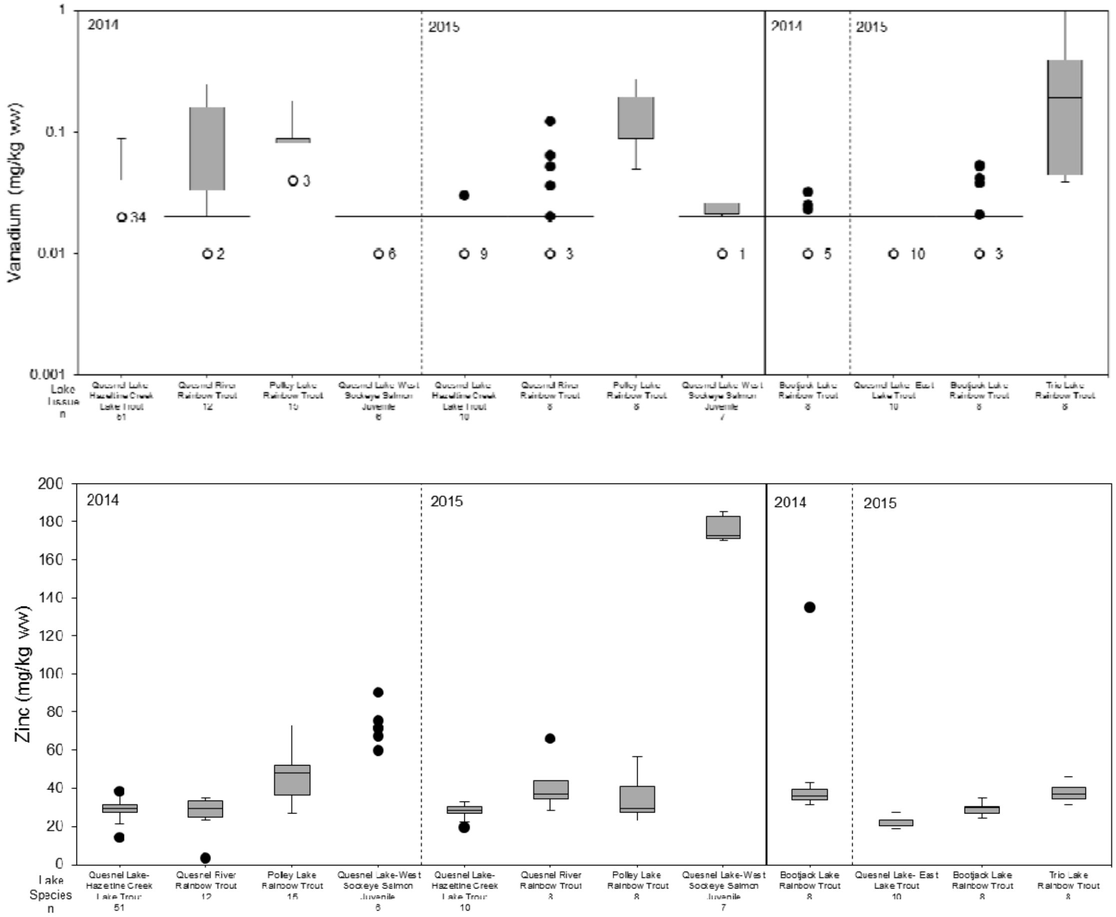


Figure 7: Summary of Available Liver Chemistry Data for Select Fish Species and Sampling Sites (2014, 2015).

Box plots are censored at the detection limit (DL = solid horizontal line). Concentrations below the DL are plotted as an open symbol at half the DL. Extreme values are plotted as individual values. mg/kg ww = milligrams per kilogram wet weight; mg/kg dw = milligrams per kilogram dry weight; n = sample size; dashed vertical lines (- - -) indicate the separation of years; solid vertical lines (−) indicate the separation of exposure and reference; dashed horizontal lines (- - -) indicate guidelines from CFIA (mercury) or BC MoE (selenium).

Consumption by Piscivores

The fish assemblage in Polley Lake is limited. Whole body fish samples were not collected.

3.2 Hazeltine and Edney Creeks

3.2.1 Physical

Hazeltine Creek flows from Polley Lake to the West Basin of Quesnel Lake, a distance of approximately 9.2 km. Prior to the tailings spill, Hazeltine Creek flowed into Edney Creek just upstream of the discharge to Quesnel Lake. Edney Creek drains the watershed south of the Mount Polley Mine, and is understood to be a larger drainage than Hazeltine Creek and to provide more significant fish habitat as pertains to fish communities migrating to and from Quesnel Lake.

Water and tailings released during the spill created a debris flow that eroded material along the Hazeltine Creek channel and surrounding area (referred to as the floodplain). The debris flow formed a wider and deeper channel along the entire length of Hazeltine Creek by removing sediments from the channel, and native soil and forest from the floodplain. The floodplain accounts for 57% (136 ha) of the total terrestrial area affected by the debris flow. An additional 100 hectares of forest surrounding the floodplain (referred to as the halo) was inundated by tailings and remobilized sediment and the forest floor was buried to varying depths. Figure 8 shows the extent of erosion and tailings inundation in Lower Hazeltine Creek.

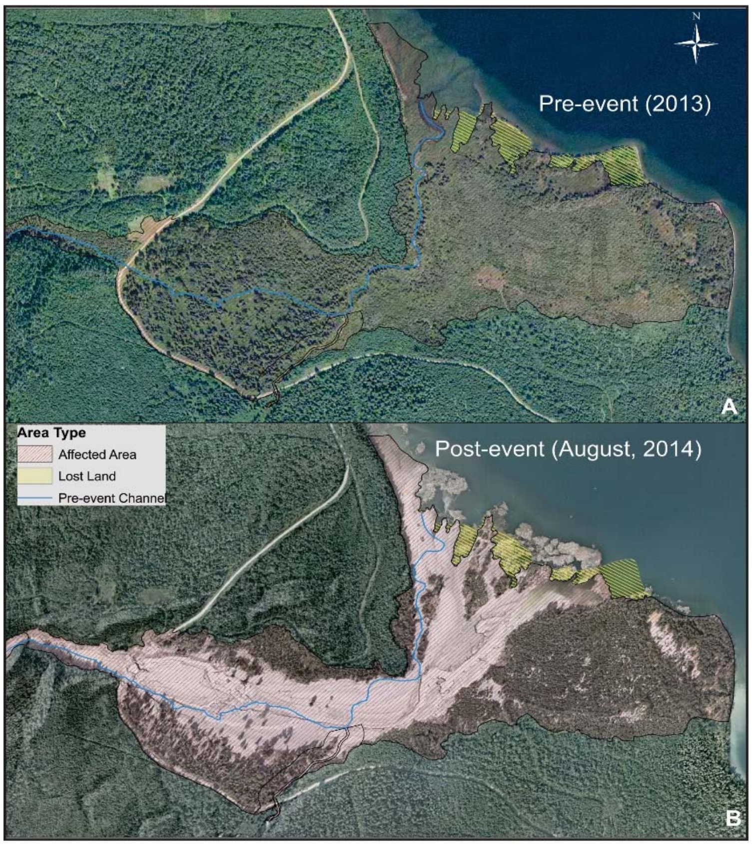


Figure 8: Pre-event and post-event view of Hazeltine Creek delta.

The lower portion of Edney Creek was also eroded away by the debris flow and fish passage into upper Edney Creek was cut off. Early rehabilitation efforts were able to restore the connection between Edney Creek and Quesnel Lake, and isolate Edney Creek from continuous impact by tailings deposited along Hazeltine Creek. While the lower portion of Edney Creek was impacted by the physical effects of the debris flow, Edney Creek water quality is determined by a watershed that was not influenced by the event and thus impacts on Edney Creek water quality were not assessed. As such, analyses of impacts to people, and terrestrial and aquatic wildlife are focused on conditions along Hazeltine Creek.

The Hazeltine Creek corridor (inclusive of the channel, floodplain, and halo) includes both terrestrial and aquatic habitats that have been impacted by the tailings spill. The impacts to these habitats and the communities within each are discussed separately below.

Terrestrial Habitat

Within the floodplain, the physical impact of the tailings spill included uprooting and transport of trees and other forest biota down the Hazeltine Creek corridor, leaving the floodplain largely absent of original vegetation. The force of the debris flow diminished at the edges of the floodplain, such that the trees in the "halo" zone were not uprooted, but the forest floor was covered by a layer of tailings and left absent of understory vegetation. The nature of the physical impact within the halo zone was less obvious than within the floodplain. The deposition of tailings and water within the halo filled the pores in the forest floor and mineral soil, blocking exchange of oxygen (O_2) and carbon dioxide (CO_2) involved in root and microbial metabolism and respiration. Many trees in the halo area appeared moribund in the spring and early summer of 2015, likely because the depth, fine texture, and saturation of the tailings created anaerobic conditions in the rooting zone. Under anoxic conditions, anaerobic and facultative soil microbes can use alternative electron acceptors such as sulfate, nitrate, ferric iron, manganese oxide, and carbon dioxide to produce energy. Field observations of an anaerobic ('rotten egg') odour, supported by quantitative measures (refer to Appendix I), in holes excavated in the tailings indicated at least some microbes were using sulfate as an alternative electron acceptor to oxygen. By contrast, the obligate aerobic tree roots, mycorrhizal fungal symbionts, and associated soil food web invertebrate organisms had died in the anoxic soils. These organisms require approximately 5% oxygen and use oxygen as their electron acceptor.

The pattern of tree mortality observed within the halo zone indicated tree death was caused by the anaerobic environment of the tree roots and not metal toxicity. Primarily, the foliage of trees was observed to have died uniformly through the crown, suggestive of sudden death caused by oxygen starvation to tree roots. The dying trees observed in July 2015, were reportedly still green until May 2015, after which the foliage rapidly turned brown. It is likely the tree roots had started to die immediately when the tailings inundated the floodplain, but foliage did not turn brown until the following spring after the winter dormancy had broken. As soils warmed in the spring of 2015, the foliage would have transpired while dead roots were incapable of acquiring and transporting water to the crown via the xylem. The browning of the foliage hence occurred rapidly in spring, over a period of approximately 1 to 2 months. Further summary of the impacts to the forest community within the halo area is provided in Appendix I.

Aquatic Habitat

Like within the floodplain, the sediments and aquatic community associated with Hazeltine Creek were scoured during the debris flow and transported downstream. As the debris flow receded, the remaining creek channel was composed of exposed and eroding underlying native materials and tailings, with turbid waters flowing into Quesnel Lake. After providing for safe worker access and controlling the residual source inputs from the TSF, construction began on an armoured creek channel capable of resisting erosion and providing for future fish habitat. Pockets of tailings and tailings dam materials were removed from the footprint of the constructed channel and from the footprint of any fill materials placed in the floodplain. A significant interim feature of sediment control during these works was treatment of the entirety of Hazeltine Creek flow in two sequential sediment ponds located in the lower

Hazeltine Creek floodplain. The sediment ponds provided beneficial suspended solids removal. Construction of the armoured Hazeltine Creek channel was completed in May 2015. Further work is planned to add habitat features for aquatic life along the length of the channel.

Prior to and during construction, turbidity concentrations in Hazeltine Creek were elevated above the short and long-term BC WQGs. Clear-flow conditions ensued upon completion of the channel construction. A progressive decline in turbidity levels continued throughout 2015 with levels measured closer to BC WQGs by the end of the year. Turbidity and total suspended solids remain POIs as they can be elevated above BC WQGs during occasionally turbid flow events when the creek is subject to erosion (See Appendix D). Fish access to Hazeltine Creek is currently blocked until construction is complete and appropriate habitat has been established.

3.2.2 Chemical

3.2.2.1 Soil Quality Update

Soil quality data collected from along Hazeltine Creek by SNC and Golder has been evaluated to characterize the chemical and physical composition of the deposited tailings. The soil quality assessment was based on comparison of soil chemistry to Contaminated Sites Regulation (CSR) standards and reference data. Copper and vanadium were found to exceed the most conservative applicable CSR standards and were greater than reference concentrations. The soil quality assessment found that metals concentrations between the two types of tailings observed (grey fine grained and red-black sand) were not significantly different. With regards to nutrients, average nutrient concentrations were up to 12 times less and concentrations of TOC were up to 34 times less in tailings compared to reference and native soil (Appendix B).

Based on the evaluation of 2014 and 2015 soil quality data, copper and vanadium were identified as POIs in tailings deposited along Hazeltine Creek. The bioavailability of these metals to terrestrial life has been assessed further, as discussed below.

3.2.2.2 Groundwater Quality Update

Limited groundwater quality data collected in the summer of 2015 from along Hazeltine Creek by Golder has been evaluated to provide field confirmation of the geochemistry findings that the tailings have a low potential for leaching of metals. Further investigation is planned for the summer of 2016 to confirm the potential for dissolved metal transport from the tailings to shallow groundwater that would largely discharge to Hazeltine Creek.

The groundwater quality assessment was based on comparison of groundwater chemistry to CSR standards and reference data. No exceedances of standards were observed in groundwater samples collected in 2015 and the average concentrations of metals in groundwater samples from along the creek were similar to reference concentrations (Appendix C). Based on the evaluation of 2015 groundwater quality data, no POIs were retained.

The additional groundwater investigation to be conducted in 2016 has been broadened in response to stakeholder concerns, and includes characterization of the hydrogeological regime near Hazeltine Creek.

3.2.2.3 Surface Water Quality Update

Water quality data collected from Hazeltine Creek by MPMC has been evaluated to assess temporal trends of POIs since the tailings spill through December 2015 (Appendix D). The water quality assessment was based on comparison of water chemistry to BC WQGs, reference data, and baseline data. Baseline water quality data indicates that concentrations of copper were naturally-elevated in Hazeltine Creek prior to the tailings spill. The water quality assessment identified exceedances of total metal WQGs in Hazeltine Creek in the first half of 2015, mainly during turbid flow periods typically associated with elevated concentrations of particulate matter. Clear-flow conditions ensued upon completion of channel construction, and typically resulted in lower concentrations of particulate matter and subsequently lower concentrations of total forms of metals.

The majority of metals identified as POIs in the first half of 2015 decreased to concentrations below guideline levels by mid-summer and remained stable through December 2015, with a few noted exceptions (e.g., beryllium, chromium, and cobalt in Hazeltine Creek at the Horsefly-Likely Forest Service Road (the “Ditch Road”) bridge). By December 2015, only total and dissolved copper consistently exceeded BC WQGs for the protection of aquatic life. Copper therefore remains the primary POI in Hazeltine Creek based on the 2015 data. When the creek is subject to erosion (primarily runoff and high flow events) resulting in turbid flow events, some other metals may also exceed guidelines. The water quality data from June through December 2015 is considered representative of post creek construction conditions within Hazeltine Creek. The immediate impacts of the tailings spill to Polley Lake and the creek, as well as impacts during construction of the creek channel, had subsided during this period.

Discharge of treated effluent to Hazeltine Creek, as authorized by BC MoE in the amendment to Permit 11678 (November 29, 2015), was initiated on December 1, 2015. Concomitant with the initiation of the authorized discharge, selenium concentrations increased at two stations in Hazeltine Creek located close to and downstream from the discharge location. The most sensitive receptors to selenium are egg laying vertebrates. Although these receptors have been either excluded (fish) or are limited in number (aquatic feeding birds), selenium was also monitored as a POI in Hazeltine Creek. Concentrations of selenium in water appear to have decreased in the first quarter of 2016 by 1 to 2 times compared to the concentrations reported in December 2015 following the initial discharge of treated effluent to the creek.

Metals concentrations in Hazeltine Creek surface water will continue to be monitored as part of MPMC’s routine monitoring program.

Free Metals in Surface Water

Between August and October 2015, Minnow deployed diffusive gradients in thin films (DGT) passive sampling devices in pools within the Hazeltine Creek canyon to measure the amount of free and weakly complexed metals from water near the sediment-water interface (Appendix D). Calculated concentrations of free metals in water (based on accumulation by the DGT device) were compared to concentrations of total and dissolved metals in concurrent water samples, and BC WQGs. Further background discussion of the DGT data is provided in the Polley Lake section above.

In Hazeltine Creek, copper was measured by the DGT devices at concentrations greater than other waterbodies, but lower than the applicable BC WQGs (Figure 3 above; Appendix D). It is acknowledged that the WQG were not developed based on DGT data so the comparison was made for information purposes only. In comparison to total and dissolved (filtered) concentrations, the DGT-labile concentrations of copper in water in Hazeltine Creek were lower.

3.2.2.4 Sediment Quality Update

Sediment quality data collected by Minnow from Hazeltine Creek has been evaluated to assess changes in sediment chemistry since the tailings spill occurred and following reconstruction of the creek channel (Appendix E). The sediment quality assessment was based on comparison of sediment chemistry to BC sediment quality guidelines (SQG), reference data, and baseline data. Baseline sediment data indicates that concentrations of metals were naturally-elevated in Hazeltine Creek prior to the tailings spill.

In 2014 prior to reconstruction of the creek channel, sediment was collected from locations in the upper, mid, and lower sections of the creek. The 2014 chemistry data indicated that copper and iron were elevated in comparison to guidelines and reference/baseline concentrations. Reconstruction of Hazeltine Creek included removal of tailings and laying of clean rock. Two sedimentation ponds were installed at the end of the creek, just upstream of Quesnel Lake, to contain particulate material that entered the creek during construction activities or through erosion from upland areas. In 2015 following reconstruction of the creek, sediment within the sedimentation pond was collected to represent sediment that might be present within the creek. The 2015 chemistry data indicated that copper and iron were elevated in comparison to standards and reference/baseline concentrations. Arsenic concentrations were higher in 2015 than in 2014. Based on the evaluation of 2015 sediment quality data, arsenic, copper, and iron remain POIs in Hazeltine Creek. Mercury and selenium have been added as POIs due to stakeholder concerns.

3.2.2.5 Geochemistry

Geochemistry investigations conducted by SRK Consulting (SRK) have continued since the release of the PEEIAR to geochemically characterize tailings material released during the tailings spill (Appendix A, MPMC 2015 Appendix C). The investigations have included tests to determine the potential for acid generation (acid-base accounting), as well as assessment of tailings composition, mineralogy, and leaching under subaerial (humidity cell and column tests) and subaqueous (sequential extractions) conditions.

Preliminary investigations (MPMC 2015 Appendix C) found that when compared to average concentrations in similar rock types, the only enriched elements in the tailings were copper and selenium. Only a portion (approximately 33%) of the copper is associated with sulphide, with the remainder (approximately 67%) associated with silicate minerals. This non-sulphide fraction is relatively insoluble and would have a low potential for leaching under both subaerial and subaqueous conditions. The sulphide fraction would also have low potential for leaching under subaerial conditions because the tailings were determined to be neutral or slightly alkaline with negligible potential to cause acid rock drainage (ARD). The ARD potential is negligible owing to low sulphur content and high buffering potential from calcite in the tailings. The portion of non-sulphide selenium is lower than copper (approximately 13%), and potential for leaching is also expected to be low for selenium.

Updated results provided by SRK (Appendix A) corroborate the initial findings. Results of kinetic leaching reported for 32 weeks of the 40 week long tests (humidity cells and column tests) indicate leaching rates have reduced over time and at 32 weeks showed a progressive decrease, which is likely to continue to the end of the tests. Based on the information from the geochemical tests to date the following conclusions can be drawn with respect to the potential for leaching from the tailings deposited along Hazeltine Creek under subaerial conditions:

- The results indicate that a significant amount of copper (up to 66%) is associated with the non-sulphide portion (likely chlorite) of the tailings and is considered to be non-reactive. This is based on previous studies and the results provided in this report that required acidic conditions to leach copper associated with the non-sulphide fraction.
- Kinetic testing confirmed that leaching considerations are under neutral to alkaline conditions and continue to support the previous assessment that ARD is not expected in these materials. Based on 32 weeks of testing, leaching rates are beginning to stabilize and general downward trends are expected to continue as the testing progresses. Variability in leaching rates is also being established and water contact chemistry predictions (i.e. geochemical source terms) should be possible after 40 weeks of testing.
- For any tailings materials with water flow paths longer than half a metre, mineral solubility controls for copper are expected. Longer flow paths in the fine grained materials may also be conducive to lower rates of oxygen diffusion and therefore conditions that support selenium reduction to its more insoluble forms such as selenite and elemental selenium.
- Testing is on-going and the current assessment of tailings reactivity and leaching rates will be updated once testing passes 40 weeks.

3.2.3 Biological

3.2.3.1 Terrestrial Ecosystem Assessment

As discussed above, in the summer of 2015, a study was conducted to describe and quantify the differences in terrestrial habitat quality between the halo and reference/background areas (Appendix I). Secondarily, the study was conducted to determine the cause of mortality for trees in the halo area. The study considered forest floor and mineral soil properties, forest stand attributes (e.g., tree species composition, site index, height, age, basal area, stems per hectare, and stand structure), vegetation attributes (e.g., species cover, richness, and diversity), evidence of wildlife use, and wildlife attributes (e.g., snag density and size, and coarse woody debris cover and diameter).

The results of the study indicated that roots of trees within the halo were in a state of decay and were visibly disappearing from the soil horizons. Abundance and richness of the plant community were significantly lower in the halo than reference. Over forty plant species were either eliminated or reduced by over 80% in the halo compared to reference. Species gained in the halo plots tended to be “weedy” species, characteristic of disturbed areas (e.g., fireweed, dandelion, great mullein, hawksweed, white clover). Species lost tended to be characteristic of mature forests (e.g., wild ginger, rattlesnake plantain, one-side wintergreen). Cover of all plant layers were also significantly reduced due to the decline of the trees and burial of the plant community.

As discussed in the summary of physical impacts, the results available from the field program indicate that the pattern of tree mortality in the halo was caused by the anaerobic conditions in the tree rooting zone created by the deposit of fine, saturated tailings material over the forest floor. This deposit immediately blocked soil pores and reduced oxygen reaching the roots of the trees. Water trapped within the fine particles created a perched water table that continued to restrict oxygen reaching the roots. Health of the soil and microbial community also declined in response to the restricting layer of water or deposited material.

Further work is being conducted to determine if metals concentrations in soil and tailings will inhibit re-establishment of the forest community.

3.2.3.2 Terrestrial Plant and Soil Invertebrate Tissue Metals Analysis

Sampling of edible plants (berries, spruce, willow, and rye grass) and soil invertebrates (ants, beetles, worms, and slugs) was conducted in 2015 within the terrestrial area impacted by the tailings spill (i.e., Hazeltine Creek floodplain and halo) (Appendix J). The purpose of the program was to evaluate whether concentrations of soil POIs had increased in plants or soil invertebrates as a result of the tailings deposition. Plant and invertebrate sample results were compared to reference sample results and baseline data (plants only) to determine if tissue concentrations of POIs were increased and to evaluate the potential exposure to higher trophic level receptors. Each tissue sample was collected with a co-located soil sample to calculate tissue:soil ratios (i.e., bioaccumulation factors [BAFs]).

Concentrations of several metals were occasionally found to be greater in plant or invertebrate samples from the floodplain or halo in comparison to reference or baseline. BAFs calculated for copper and vanadium (POIs in soil) were below one indicating there is no relationship between copper or vanadium concentrations in soil and plants or soil and invertebrates.

A limitation of these datasets were the small number of samples, particularly for soil invertebrates. Additional sampling of plants and soil invertebrates along Hazeltine Creek will be conducted in 2016.

3.2.3.3 Surface Water Toxicity Testing

Toxicity testing was conducted on water samples collected in Hazeltine Creek prior to and following the December 1, 2015 discharge of treated mine effluent to Hazeltine Creek (authorized by BC MoE in the amendment to Permit 11678 dated November 29, 2015). Surface water samples from Hazeltine Creek were tested using a series of standard laboratory tests using sensitive invertebrate and fish test species. Neither short-term nor long-term exposure to Hazeltine Creek water, collected before or after the start of discharging treated water, resulted in adverse effects to aquatic life. The results of toxicity testing conducted between November and December 2015 are presented in Table 3-6. No toxicity was observed for any of the tests conducted, indicating that the creek water was not toxic to sensitive fish and invertebrate species tested during sensitive life stages.

Table 3-6: Summary of Surface Water Toxicity Testing in Hazeltine Creek (November to December 2015)

Test	Sample ID	Date	T. Cu (mg/L)	D. Cu (mg/L)	LC50 (% v/v)	IC25 (% v/v)	IC50 (% v/v)
96-h Rainbow Trout LC50	HAC-12	02 Nov 2015	-	-	>100	-	-
48-h *D. magna* LC50	HAC-12	02 Nov 2015	-	-	>100	-	-
7-d Rainbow Trout swim-up survival and growth	HAC-12	30 Dec 2015	0.013	0.01	>100	>100	>100
	HAC-12	12 Nov 2015	0.0099	0.0077	>100	>100	>100
7- to 8-d *C. dubia* survival and reproduction	HAC-12	30 Dec 2015	0.0099	0.0077	>100	>100	>100

Notes: Effect concentration expressed on a volume/volume basis. LC50 = Lethal concentration causing 50% mortality. IC25/IC50 = Non-lethal concentration causing 25% or 50% reduction in growth or reproduction. Total and dissolved copper (T. Cu and D. Cu) concentrations for November and December samples are MPMC unpublished data.

3.2.3.4 Sediment Toxicity

Additional testing, including sediment bioassays, community, and benthic invertebrate tissue samples were not conducted in 2015 as the creek was under construction and was not considered to be fish habitat.

3.2.3.5 Benthic Invertebrate Tissue Metals Analysis

Benthic invertebrate samples collected from upper Hazeltine Creek were dominated by a high abundance of black fly larvae, while a more diverse benthic invertebrate assemblage, composed mainly of caddisflies and mayflies, was evident at the lower Hazeltine Creek sampling area. Benthic invertebrate samples collected from Edney Creek were composed of a diverse mix of organisms, including mayflies, stoneflies and caddisflies.

The mean concentrations of several metals were significantly higher in benthic invertebrates from both upper and lower sampling areas of Hazeltine Creek than those in the corresponding reference area (Edney Creek; Table 3-7; Appendix G). PCA results confirmed the distinction between the two exposed areas and reference (Appendix G).

Table 3-7: Summary whole benthic invertebrate and water chemistry (dissolved metals) results from creek and river sampling areas in the vicinity of the Mount Polley Mine, 2015[1]

	Parameter	Units	Hazeltine Creek																								
			Reference					Pre-event (2010)										Exposed (2015)									
			Edney Creek (EDC-1)					Upper Hazeltine (W7)					Lower Hazeltine (W11)					Upper Hazeltine (HAC-U)					Lower Hazeltine (HAC-D)				
			Benthic Invertebrate Tissue		Water		BCF [2]	Benthic Invertebrate Tissue		Water		BCF [2]	Benthic Invertebrate Tissue		Water [3]		BCF [2]	Benthic Invertebrate Tissue		Water		BCF [2]	Benthic Invertebrate Tissue		Water		BCF [2]
			Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE	
Parameters of Interest (POIs)	Arsenic	mg/kg	1.47	0.43	0.00054	0.00016	2,710	2.62	1.07	0.00042	0.00032	6,323	3.94	2.64	0.00051	-	7,729	2.56	0.20	0.00090	0.00008	2,842	2.29	0.46	0.00117	0.00009	1,957
	Copper	mg/kg	15.9	3.0	0.0050	0.0015	3,198	49.8	5.2	0.0021	0.0003	24,000	26.2	7.8	0.0028	-	9,432	176	13.2	0.014	0.005	12,215	204	56.0	0.034	0.008	6,054
	Iron	mg/kg	384	453	0.15	0.04	2,573	-	-	<0.03	0	-	-	-	0.094	-	-	6,502	2,902	0.079	0.046	82,144	7,720	4,103	0.243	0.227	31,749
	Manganese	mg/kg	73.8	43.2	0.0060	0.0022	12,385	2,018	275	0.0043	0.0105	468,757	1,146	477	0.0036	-	321,120	590	66.2	0.46	0.34	1,271	204	27.5	0.17	0.07	1,169
	Nickel	mg/kg	0.42	0.23	0.0011	0.0001	382	13.54	8.18	<0.0005	0	27,088	26.8	31.1	0.00070	-	38,334	8.44	2.46	0.00094	0.00038	9,016	3.14	1.01	0.0016	0.0005	1,941
	Zinc	mg/kg	74.9	5.8	<0.003	0	24,953	220	27.5	<0.001	0	219,800	101	13.5	0.0010	-	100,740	91.9	10.8	0.0034	0.0008	27,091	110	8.4	0.0033	0.0004	33,887
Indicator Parameters (IPs)	Barium	mg/kg	6.7	2.8	0.014	0.006	478	65.0	14.4	0.0079	0.0067	8,262	69.5	33.0	0.0102	-	6,818	97.9	26.0	0.031	0.009	3,118	69.8	13.7	0.032	0.004	2,200
	Calcium	mg/kg	1,477	555	22.1	7.6	67	4,276	5,999	36.1	12.7	118	2,568	1,186	21.8	-	118	7,416	2,017	62.5	14.2	119	4,202	1,300	42.5	3.4	99.0
	Cobalt	mg/kg	0.19	0.12	0.00011	0.00001	1,825	2.51	0.70	<0.0001	0	25,120	3.47	2.24	<0.0001	-	34,660	4.22	1.10	0.00064	0.00045	6,602	3.95	2.21	0.00038	0.00016	10,272
	Molybdenum	mg/kg	5.01	2.11	0.0013	0.0012	3,790	4.08	0.80	0.0020	0.0013	2,018	5.14	2.88	0.00094	-	5,481	1.47	0.25	0.012	0.001	123	1.26	0.27	0.0084	0.0014	150
	Phosphorus	mg/kg	7,408	804	0.0084	0.0014	878,419	-	-	-	-	-	-	-	-	-	-	3,940	1,341	0.0080	0.0048	492,500	2,914	993	0.0082	0.0018	354,910
	Selenium	mg/kg	1.51	0.84	0.00033	0.00011	4,519	10.9	0.82	0.001	0	10,900	3.51	0.24	<0.001	-	3,508	4.91	0.79	0.00083	0.00016	5,921	2.72	0.26	0.00090	0.00011	3,019
	Silver	mg/kg	0.023	0.022	<0.00001	0	2,259	-	-	<0.00001	0	-	-	-	<0.00001	-	-	0.080	0.024	0.000015	0.000008	5,308	0.126	0.068	0.000013	0.000002	9,787
	Sodium	mg/kg	1,972	179	3.83	1.99	514	-	-	4.50	3.81	-	-	-	3.28	-	-	3,432	671	13.9	2.9	247	1,199	311	9.55	0.95	126
	Strontium	mg/kg	10.8	3.73	0.135	0.053	80	22.5	9.87	0.23	0.17	100	20.7	8.83	0.136	-	152	60.4	7.16	0.485	0.102	125	28.4	6.85	0.350	0.033	81
	Tin	mg/kg	0.148	0.080	<0.0001	0	1,479	<0.20	0	<0.0001	0	2,000	0.24	0.10	<0.0001	-	2,420	0.031	0.015	0.00013	0.00007	235	0.026	0.019	0.00013	0.00002	208
	Titanium	mg/kg	3.90	1.78	<0.01	0	390	-	-	<0.01	0	-	-	-	<0.01	-	-	51.3	27.3	0.0102	0.0003	5,056	48.2	26.0	0.018	0.013	2,624
	Vanadium	mg/kg	0.85	1.20	0.00086	0.00010	992	6.60	2.87	<0.001	0	6,602	11.0	6.16	<0.001	-	11,024	28.9	9.39	0.0013	0.0007	21,405	44.2	18.4	0.0017	0.0005	25,464

Notes:

1. Summary statistics were calculated using maximum method detection limit (MDL) values if data were below the MDL. Means are shown as < the maximum reported MDL if all data used in their calculation were < MDL. If MDLs were variable, means were reported as < the maximum MDL.

2. BCF = Bioconcentration Factor; [Mean concentration of analyte in benthic tissue (mg/kg dw)] / [Mean dissolved concentration of analyte in water (mg/L)]. Mean water concentrations calculated using all available data.

3. Results are based on a single sampling event, therefore data from this single sample are displayed.

Mean analyte concentration in benthic invertebrates was significantly higher than in the associated reference area (EDC, 2015), $p < 0.05$ (using a non-parametric Mann-Whitney U test).

Mean analyte concentration in benthic invertebrates was significantly lower than in the associated reference area (EDC, 2015) and pre-event data (2010, if available), $p < 0.05$ (using a non-parametric Mann-Whitney U test).

Mean analyte concentration in benthic invertebrates was significantly higher than in the associated reference area (EDC, 2015) and pre-event data (2010, if available), $p < 0.05$ (using a non-parametric Mann-Whitney U test).

Mean benthic invertebrate metal concentrations in Edney Creek show low concentrations, including concentrations of selenium below the dietary guideline of 4 ug/g for environmental protection. Prior to the tailings spill, mean concentrations of several metals, including selenium, were higher in upper and lower areas of Hazeltine Creek compared to samples taken in 2015. Concentrations of selenium in invertebrates collected in 2010 in upper and lower Hazeltine Creek were 10.9 ug/g dw and 3.5 ug/g dw, respectively, compared to 4.9 ug/g dw and 2.7 ug/g dw, respectively, in 2015. These data may indicate high natural variability for selenium in this area. Analyses of 10 samples of glacial sands, silts and varved clays (glaciolacustrine-glaciofluvial sediments) from along Hazeltine Creek yielded selenium values ranging from 0.3 to 4.8 ppm, while tailings (2013) averaged 1.14 ppm selenium. The 10 Hazeltine Creek glacial sediment samples had higher average cadmium and antimony than the average values in the 2013 tailings for these elements. (C.D.Anglin, pers comm, 2016) Post-event benthic invertebrate concentrations of copper and vanadium in the upper and lower Hazeltine Creek were higher than pre-event conditions. It is unknown at this time if the observed increase in concentrations of metals in benthic invertebrates is related to sediment particulates in the gut content of the benthic invertebrates or if these concentrations have been absorbed into tissues. Evaluation of fish tissue concentrations may help in this matter, as sediment bound metals would be more efficiently excreted. Further assessment of the metal concentrations in benthic invertebrates and the significance to predator species is underway.

3.2.3.6 Benthic Invertebrate Community

No benthic invertebrate community sampling was conducted in Hazeltine Creek in 2014 due to the absence of appropriate erosional habitat following the tailings spill (i.e., substrates were entirely fine materials derived from the tailings and scoured creek bed). Benthic invertebrate sampling was undertaken in 2015 following reconstruction of the creek channel to track recovery. The data were not available at the time of writing this report. These data will be included in the Risk Assessment report due later this year (2016).

3.3 Quesnel Lake

3.3.1 Physical

Quesnel Lake is a large, deep fjord lake reaching from the Cariboo Mountains into the Interior Plateau of BC. The lake has a surface area of 266 km^2 and is comprised of West, East, and North Arms. The average and maximum depths of the lake are 157 and 511 m, making Quesnel Lake one of the deepest fjord-type lakes in the world (Laval et al. 2008). The West Basin is a relatively shallow (113 m maximum depth) portion of the West Arm that is separated from the rest of the lake by a shallow sill approximately 35 m deep, near Cariboo Island, and is considered the area between Cariboo Island and the Quesnel River (Laval et al. 2008). The West Basin has vertical mixing that is typical of temperate lakes, with thermal stratification for most of the year interrupted by brief turnover periods in the spring and the fall when vertical density gradients are lowest. A thermocline typically forms at a mean depth of 12.4 m (Nidle et al. 1994). In the deeper portions of the lake, seasonal turnover events only occur in the upper 100 to 200 m of the water column due to changes in temperature-density relationships with increased pressure at greater depths. Nutrient data collected since the mid-1990 indicate that the trophic status of the lake is oligotrophic (Nidle et al. 1994).

Hazeltine Creek enters the West Basin of Quesnel Lake. It is estimated the tailings spill resulted in the discharge of about 18.6 million m^3 of mixed tailings, soil and water into Quesnel Lake (MPMC 2015 Appendix B). The majority of the discharged material settled in the West Basin at depths >100 m below surface (MPMC 2015 Appendix B). The area of this major deposit was estimated to be approximately 1.81 km^2 with thickness of the deposit ranging up to about 10 m. On the underwater lake side-slope from the mouth of Hazeltine Creek, native material was eroded by underwater debris flow; deposition of tailings material on the side-slope was considered negligible. Along the side-slope from the mouth of Hazeltine Creek and in the deep portion of the West Basin, the immediate physical impact to the lake bottom included the loss of habitat and displacement of the benthic community. No significant deposition of material was measure in the main body of the lake (MPMC 2015 Appendix B), but up to 40% of material that remained in suspension was predicted to disperse into the main body of the lake at low concentration.

Turbidity monitoring in Quesnel Lake following the tailings spill revealed within the West Basin a turbidity plume in the water column at depths >20 m below surface and below the thermocline. The turbidity plume persisted until late November 2014 when lake turnover occurred and the water column mixed. By January 2015, the turbidity in Quesnel Lake had decreased to below that prescribed by the BC WQGs (MPMC 2015 Appendix F). Throughout 2015, levels of turbidity and total suspended solids were low in the far-field areas of Quesnel Lake as well as in the West Basin, and generally remained below guidelines (Appendix D). Exceptions to this were instances between March and May 2015, where higher levels of turbidity were recorded in the near-field area at the mouth of Hazeltine Creek during turbid flow periods in Hazeltine Creek.

3.3.2 Chemical

3.3.2.1 Surface Water Quality Update

Water quality data collected from Quesnel Lake by MPMC has been evaluated to assess temporal trends of POIs since the tailings spill through December 2015 (Appendix D). The water quality assessment was based on comparison of water chemistry to BC WQGs and reference data. During the period immediately following the tailings spill, copper was identified as the primary POI within the West Basin of Quesnel Lake. Total copper was below applicable BC WQGs in the near-field, mid-field and far-field stations in Quesnel Lake throughout most of 2015. Exceptions to this were instances where total concentrations were above the BC WQG between March and May in the near-field area close to the mouth of Hazeltine Creek and to a lesser extent at the western mid-field station further away from the mouth. These higher total concentrations coincided with turbid flow periods in Hazeltine Creek and dissolved concentrations did not exceed BC WQGs. Other metals monitored at the Quesnel Lake stations in 2015 were below applicable BC WQGs. With respect to nutrients, phosphorus data collected throughout 2015 suggested that event-related changes with respect to the potential for a change in lake trophic status were not evident in Quesnel Lake. Based on the evaluation of 2015 water quality data, no POIs in surface water remain above WQGs in Quesnel Lake.

Metals concentrations in Quesnel Lake surface water will continue to be monitored as part of MPMC's routine monitoring program.

3.3.2.2 Free Metals in Surface Water

Between August and October 2015, Minnow deployed diffusive gradients in thin films (DGT) passive sampling devices in a profundal area of Quesnel Lake near the mouth of Hazeltine Creek to measure labile (free and weakly complexed) metals from water near the sediment-water interface (Appendix D). Calculated concentrations of free metals in water (based on accumulation by the DGT device) were compared to concentrations of total and dissolved metals (determined by filtering through a 0.45 um filter) in concurrent water samples, reference concentrations from a reference profundal area of Quesnel Lake, and BC WQGs. We note that WQG were not derived using DGT data, so the comparison is for information purposes only.

In Quesnel Lake, DGT-detectable parameters were measured by the DGT devices at concentrations similar to reference concentrations and lower than the applicable BC WQGs (Figure 3 above). In comparison to total and filtered concentrations, the DGT-labile concentrations in water near the bottom of Quesnel Lake were lower. These data show that the proportion of free and weakly complexed metals is low.

3.3.2.3 Sediment Quality Update

Sediment quality data collected from Quesnel Lake by Minnow has been evaluated to assess changes in sediment chemistry since the tailings spill occurred. Unlike water quality, concentrations of metals in the tailings-influenced sediment are not expected to have changed substantially between sampling events in 2014 and 2015. The sediment quality assessment was based on comparison of sediment chemistry to BC SQGs and reference data. Reference sediment data from areas of Quesnel Lake unlikely to be impacted by the tailings spill indicated that concentrations of metals were naturally elevated in the lake prior to the tailings spill (MPMC 2015 Appendix E).

Sediment has been collected from littoral and profundal areas in the lake, and at various distances from the mouth of Hazeltine Creek. The 2014 chemistry data indicated that several metals including arsenic and copper were elevated in comparison to guidelines and reference concentrations. Concentrations of metals were observed to decrease with distance from the mouth of Hazeltine Creek, while total organic carbon (TOC) was observed to increase. Sediment chemistry in 2015 was similar to 2014 and exhibited the same spatial pattern of decreasing copper concentrations and increasing TOC with distance from Hazeltine Creek mouth.

3.3.2.3.1 Evaluation of Mercury Biomagnification Potential

Golder reviewed the conditions that favour the methylation of mercury to assess whether these conditions occur in Quesnel Lake and reviewed the existing monitoring data to examine the evidence (if any) of increased mercury concentrations as a result of the tailings spill.

Factors Influencing Methylation of Mercury

Azimuth (2010, 2012, 2015) summarized environmental factors that influence mercury methylation. As outlined in Sections 4.3 to 4.5 of Azimuth (2012), key parameters that influence methylation potential are residence time, trophic status, temperature, DO, pH, dissolved organic carbon, total suspended solids, sulphate, sediment grain size, and total organic carbon in sediment. The correlation of these parameters with mercury methylation (i.e., positive or negative) is summarized in Table 3-8 below.

As summarized in Table 3-8 below, conditions in Quesnel Lake generally do not favour mercury methylation. Quesnel Lake is oligotrophic, cold, well oxygenated, slightly basic, and relatively low in concentrations of dissolved organic carbon, total suspended solids, and sulphate. Sediment grain size and TOC are also not favourable for mercury methylation.

Table 3-8: Summary of Parameters and their Correlation with Mercury Methylation (Azimuth 2012) and Current (Post-event) Conditions of these Parameters in Quesnel Lake

Parameter	Correlation	Conditions that Favour Methylation	Quesnel Lake	Source for Quesnel Lake data
Residence time	Positive	Longer residence time	10 years (entire lake); 3 months (West Basin); less likely	1,6
Trophic status	Positive	Highly productive systems	Low productivity; classified as oligotrophic; less likely	1
Water - Temperature	Positive	Warmer temperatures (weakly related)	Temperature < 10℃ at depths greater than 40 m; less likely	2
Water - Dissolved Oxygen	Negative	Low oxygen conditions	Concentrations > 5 mg/L at all depths; less likely	2
Water - pH	Negative	Slightly acidic waters (pH <6.5)	Median pH = 7.95; less likely	3
Water - dissolved organic carbon	Positive	Concentrations > 5 mg/L	Mean concentration = 2.2 mg/L; less likely	3
Water - total suspended solids	Positive	Higher concentrations (as transport media for mercury)	Below detection limit of 3 mg/L in most samples (n= 198); 13 samples had detected concentrations that ranged from 3 to 54.1 mg/L.; less likely	3
Water - sulphate	Positive	Higher concentrations over environmentally relevant range (5-30 mg/L)	Mean concentration = 6.6 mg/L; less likely	3
Sediment - grain size	Negative	Fine grain sediment[5]	In the <63 µm fraction, predominantly silt in profundal samples and predominantly sand in littoral samples.; less likely in littoral, more likely in profundal	4
Sediment - total organic carbon	Positive	Higher	Mean total organic carbon ≤ 2.3% in the <63 µm fraction; less likely	4

***Abbreviations**: < = less than; ≤ = less than or equal to; > = greater than; ~ = approximately; ℃ = degrees Celsius; m = metres; mg/L = milligrams per litre; µm = micrometres; % = percent.*

***Sources**:*

[1] MPMC (2015 Appendix F).

[2] Depth profiles presented in MPMC (2015 Appendix H).

[3] Appendix D. Values calculated using all Quesnel Lake samples or all Polley Lake samples collected in 2015.

[4] Appendix E. Based on mean particle size or mean total organic carbon at exposed locations sampled in 2014 and 2015.

[5] Condition that favours mercury methylation is described in Azimuth (2012).

[6] MPMC (2015 Appendix B).

Review of Existing Monitoring Data for Mercury

Water Chemistry

Water chemistry data collected between August 2014 and July 2015 are reported in Appendix D. Between August 2014 and July 2015, with the exception of one water sample, total aqueous mercury concentrations in Quesnel Lake samples have been below the reported detection limits of 50 ng/L (August 2014 samples), 10 ng/L (late August and September 2014 samples), or 5 ng/L (2015 samples). The single sample with a detected concentration (11 ng/L) was collected from station QUL-96 in September 2014. Water samples collected on the same day from nearby station QUL-2 were below the detection limit of 10 ng/L. Because mercury data are sparse and total aqueous mercury concentrations were below the reported detection limit in all but one sample, interpretation of aqueous mercury trends is limited.

The single measured aqueous mercury concentration and the detection limits for samples with no detected mercury were compared to the BC Water Quality Guideline (BC MoE 2001) of 10 ng/L, based on the assumption that the percent methylmercury in Quesnel Lake is 1%. Because the percent methylmercury in Quesnel Lake has not been measured the aqueous mercury data cannot be directly compared to the BC water quality guideline. However, comparison to the CCME (2003) water quality guidelines for inorganic mercury suggest that the potential for mercury effects is low. In water samples collected from late August 2014 (i.e., detection limit of 10 ng/L) to July 2015 (i.e., detection limit of 5 ng/L), aqueous mercury concentrations were lower than the CCME (2003) water quality guideline for inorganic mercury (26 ng/L).

Although the above comparison to the CCME (2003) water quality guideline suggests that the potential for mercury effects is low, CCME (2003) states that the water quality guideline may not fully protect higher trophic levels. Therefore, sediment, zooplankton tissue chemistry, and fish tissue chemistry data collected from Quesnel Lake were also reviewed to assess spatial and temporal trends in mercury concentrations.

Sediment Mercury

Sediment chemistry data are reported in MPMC (2015 Appendix E) and Appendix E. Sampling in Quesnel Lake was conducted in 2014 and 2015 at two depths: littoral (1 to 2 metres deep) and profundal (approximately 80 to 100 metres deep). In 2014, both the littoral and profundal sampling in Quesnel Lake included two reference areas and four exposed areas. For each sampling location, concentrations were measured in the <2 mm fraction and the <63 µm fraction. In 2015, both the littoral and profundal sampling included one reference area and one exposed area. Concentrations were measured in the <63 µm fraction only. Baseline sediment chemistry data were not available for Quesnel Lake (MPMC 2015 Appendix E).

In littoral and profundal sediment samples collected in 2014 and 2015, concentrations of mercury in exposed areas were generally higher than concentrations in reference areas. However, mercury concentrations in exposed areas were lower than the BC working sediment quality guideline. In 2014 and 2015, mean sediment mercury concentrations in exposed areas were either lower than or similar to the mean baseline concentration in Hazeltine Creek.

With respect to temporal comparisons, sediment mercury concentrations in 2015 were generally higher than concentrations measured in 2014 post-event. Mean sediment mercury concentrations appeared to be higher in 2015 relative to 2014 both in exposed areas (31 to 42%) and reference areas (16 to 19%).

Zooplankton Tissue Mercury

Zooplankton tissue chemistry collected in 2014 and 2015 from Quesnel Lake is reported in Appendix G. Tissue samples were collected from three stations in Quesnel Lake: one exposed station called Hazeltine (in the West Arm west of Cariboo Island) and two reference stations, Horsefly (near the Horsefly River) and Junction (in the Main Basin where the east and north arms meet).

Zooplankton tissue metals concentrations were variable at all three stations, with no consistent spatial or temporal trends.

Fish Tissue Mercury

Fish tissue chemistry collected in 2014 and 2015 from Quesnel Lake is reported in Appendix H. Tissue chemistry comparisons were conducted spatially (i.e., exposure versus reference areas) and temporally (i.e., 2014 versus 2015 data) for site, species, and tissue type, where data were available.

The following observations were made with respect to spatial comparisons in Quesnel Lake:

- For five of the sampled fish species with sufficient tissue mercury data to compare between exposed and reference areas (i.e., Lake Trout, Largescale Sucker, Northern Pikeminnow, Redside Shiner, and juvenile Sockeye Salmon), mercury concentrations in fish collected from exposed locations appeared to be similar to concentrations in fish collected from reference locations.
- Two species exhibited potential differences between exposed and reference areas:
  - Kokanee collected in 2014 from Quesnel Lake near Quesnel River (exposure) had higher mercury concentrations in ovary relative to Kokanee collected from Quesnel Lake North Arm (reference), although concentrations in liver and muscle samples were similar.
  - Peamouth Chub collected in 2015 from Quesnel Lake Hazeltine Creek Confluence (exposure) had higher mercury concentrations in whole body relative to fish collected from Quesnel Lake North Arm (reference). There is uncertainty in this comparison because it was not possible to confirm that similar length distributions were sampled in the two waterbodies due to a lack of fish length data.

With respect to temporal comparisons in Quesnel Lake, mercury concentrations in tissue appeared to be similar.

Overall, the spatial and temporal comparisons indicate that fish tissue mercury concentrations in Quesnel Lake are comparable to concentrations measured in reference locations and that concentrations have not increased since the tailings spill. These results are consistent with the lack of spatial and temporal trends observed in water chemistry, sediment chemistry, and zooplankton tissue chemistry. These data are considered to be preliminary at this time. Further monitoring of fish tissues will be conducted as part of the CEMP.

3.3.3 Biological

3.3.3.1 Sediment Toxicity Testing

MPMC conducted a post-event toxicity testing program between August and October 2014 (MPMC 2015 Appendix E), in which surface sediment samples collected from Quesnel Lake were tested using a series of standard laboratory tests using sensitive invertebrate test species. The program provided an important evaluation of the bioavailability and toxicity of POIs as they are observed in site-specific samples, as well as changes to physical conditions of the sediment that may affect the capacity of sediment to support sediment dwelling organisms. The laboratory testing provided a direct measure of biological effect to individual organisms under site-relevant conditions.

The results of post-event toxicity testing conducted in 2014 indicated effects to the survival and growth of test organisms in tailings-affected sediments collected in Quesnel Lake. Sediments collected from Quesnel Lake exhibited physical differences from sediments generally present in aquatic environments, and from sediment collected from reference areas and from the same locations pre-event. Physical differences included uniform particle size, relatively high density, and relatively low TOC content. Chemical differences included elevated metal concentrations. Effects were not clearly correlated with either physical or chemical characteristics of sediment following the series of tests conducted in 2014.

Additional testing was conducted in 2015 to elucidate the respective roles of the physical and chemical factors, as well as to confirm the general patterns of toxicity observed in Quesnel Lake sediments in the 2014 testing program. This additional investigation of toxicity of Quesnel Lake impacted sediments indicated no effect to the survival of either invertebrate test organism, which differed from 2014. In contrast, effects on growth of both invertebrate test organisms (*C. tentans* and *H. azteca*) were confirmed in 2015, with growth apparently being the more sensitive test endpoint in the impacted sediment tested. Effects on growth were not seen with the addition of TOC to concentrations similar to reference conditions, and comparisons of exposed sediments to a clay control indicated either no difference from the clay control (*C. dilutus*) or slightly greater growth than the clay control (*H. azteca*). This is consistent with previous findings that *C. ditutus* is intolerant of sediment with TOC lower than approximately 1% despite feeding of the test organisms (Suedel and Rodgers 1994). The consistent positive response to TOC amendment in both exposed sediment and reference clay (uncontaminated but with high fines content) suggests that the response to TOC was through provision of food resources rather than through additional metal binding capacity. Strong positive relationships were observed between growth of both organisms and TOC whereas there were no strong relationships with copper. These observations are consistent with geochemical investigations, which indicated that leaching of tailings-associated metals is low (Appendix A, MPMC 2015 Appendix C) and physical characteristics of the sediment may lead to slower rates of sediment recolonization in the profundal zone.

3.3.3.2 Benthic Invertebrate Biomass and Tissue Metal Analysis

3.3.3.2.1 Quesnel Lake Littoral

Benthic invertebrate biomass and tissue metal analysis is provided in Appendix G. The approximate biomass of benthic invertebrate subsamples retrieved from exposed and reference littoral areas of Quesnel Lake were similar (Table 3-9). Quesnel Lake littoral benthic invertebrate samples were composed mainly of chironomids, mayflies, leeches, amphipods, and pea clams.

Table 3-9: Summary whole benthic invertebrate and sediment chemistry results from lake sampling areas in Quesnel Lake, 2015[1]

Parameter		Units	Quesnel Lake																			
			Littoral										Profundal									
			Reference					Exposed					Reference					Exposed				
			LREF1					Far-field (LFF)					PREF1					Near-field (PNF)				
			Benthic Invertebrate Tissue		Sediment		BSAF [2]	Benthic Invertebrate Tissue		Sediment		BSAF [2]	Benthic Invertebrate Tissue		Sediment		BSAF [2]	Benthic Invertebrate Tissue		Sediment		BSAF [2]
			Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE		Mean	t*SE	Mean	t*SE	
Parameters of Interest (POIs)	Arsenic	mg/kg	1.84	1.23	4.5	1.94	0.40	2.20	0.86	4.04	2.21	0.55	12.5	4.76	8.88	0.52	1.41	4.55	6.08	15.4	1.90	0.30
	Copper	mg/kg	13.6	6.6	32	8.0	0.43	26.8	11.6	65.7	51.7	0.41	54.9	17.7	55.1	11.8	1.00	**178**	118	859	378	0.21
	Iron	mg/kg	1,964	1,852	23,200	4,245	0.08	2,880	1,606	27,280	8,966	0.11	7,636	5,945	31,300	5,187	0.24	8,742	8,031	40,620	6,727	0.22
	Manganese	mg/kg	96.6	84.4	322	103	0.30	130	22.4	308	88.3	0.42	140	73.3	491	54.6	0.29	187	145	1,033	329	0.18
	Nickel	mg/kg	3.77	3.66	30.7	6.81	0.12	4.99	2.76	26.2	5.70	0.19	8.53	4.64	39.1	6.67	0.22	17.1	32.4	20.2	6.84	0.85
	Zinc	mg/kg	129	143	62.3	11.0	2.08	123	32.5	49.1	9.8	2.51	96.8	8.3	79.8	17.8	1.21	233	169	96.0	41.2	2.43
Indicator Parameters (IPs)	Barium	mg/kg	22.5	14.8	115	19.0	0.20	25.8	17.9	68.6	25.1	0.38	86.8	39.0	147	9.9	0.59	50.5	52.3	255	72.1	0.20
	Calcium	mg/kg	82,818	198,333	7,483	1,498	11.07	9,818	16,263	10,622	2,157	0.92	2,996	1,253	8,747	283	0.34	4,032	3,375	31,160	3,467	0.13
	Cobalt	mg/kg	2.03	1.96	10.8	2.30	0.19	2.89	0.20	10.9	3.43	0.27	3.57	1.80	14.5	2.45	0.25	4.81	5.68	25.5	10.6	0.19
	Molybdenum	mg/kg	0.38	0.27	0.83	0.37	0.46	0.46	0.47	0.67	0.35	0.69	0.83	0.25	1.08	0.27	0.77	1.31	0.97	4.05	0.89	0.32
	Phosphorus	mg/kg	6,031	5,387	1,143	103	5.27	5,504	1,848	971	343	5.67	7,388	1,238	1,180	65.7	6.26	11,274	5,234	1,352	297	8.34
	Selenium	mg/kg	3.24	2.75	0.64	0.23	5.09	3.46	0.43	0.52	0.37	6.65	8.12	1.10	0.97	0.29	8.37	**4.59**	3.16	1.23	0.46	3.74
	Silver	mg/kg	0.047	0.012	0.148	0.030	0.32	0.033	0.018	0.099	0.025	0.34	0.191	0.079	0.214	0.061	0.89	0.191	0.270	0.369	0.106	0.52
	Sodium	mg/kg	1,854	648	460	50	4.03	1,850	1,228	386	219	4.79	3,634	810	497	62.5	7.32	5,922	2,623	1,396	411	4.24
	Strontium	mg/kg	149	255	69	15.7	2.16	61.3	88.5	79.3	34.6	0.77	30.1	12.3	85.1	8.7	0.35	43.2	39.5	212	45.2	0.20
	Tin	mg/kg	0.016	0.011	0.38	0.025	0.04	0.022	0.017	0.440	0.178	0.05	0.056	0.051	0.453	0.100	0.12	0.225	0.344	1.99	0.528	0.11
	Titanium	mg/kg	28.2	24.8	936	86.8	0.03	53.3	68.0	1,085	387	0.05	143	178	1,130	197	0.13	218	230	1,996	509	0.11
	Vanadium	mg/kg	5.94	8.06	57	9.3	0.10	12.1	5.95	85.3	46.6	0.14	17.0	9.67	70.1	11.2	0.24	24.4	18.9	142	32.6	0.17

Notes:

1. Summary statistics were calculated using method detection limit (MDL) values if data were below the MDL. Means are shown with a < symbol if all data used in their calculation were < MDL. If MDLs were variable, means were reported as < the maximum MDL.

2. BSAF = Biota Sediment Accumulation Factor; [Mean concentration of analyte in benthic tissue (mg/kg dw)] / [Mean concentration of analyte in sediment (mg/kg dw)]

***Bold** font indicates mean analyte concentration in benthic invertebrates was significantly lower than in the associated reference area, $p < 0.05$ (using a non-parametric Mann-Whitney U test).*

Mean concentrations of metals in benthic invertebrates from the littoral far-field area of Quesnel Lake did not differ from the reference area (Table 3-9), including copper. PCA results supported this finding, with very little distinction between the exposed and reference area results.

Biota-to-sediment accumulation factors (BSAFs) for the Quesnel Lake littoral exposed area (Quesnel Lake LFF) were similar to those at the reference area. Copper concentrations in sediment were below the sensitive sediment standard in the littoral exposed area. Although the BSAF for selenium in invertebrates collected from the littoral zone was greater than 1.0, it was similar to reference and concentrations of selenium in invertebrates were less than the wildlife dietary guideline of 4 ug/g dw.

3.3.3.2.2 Quesnel Lake Profundal

The approximate biomass of benthic invertebrates retrieved from the profundal exposed area of Quesnel Lake was lower than the approximate biomass of benthic invertebrate subsamples retrieved from the corresponding profundal reference area (exposed mean <0.09 g/m^2 wet weight; reference mean >0.34 g/m^2 wet weight; Appendix G). Samples collected from both profundal areas of Quesnel Lake were composed mainly of chironomids.

Copper was the only metal with a mean benthic invertebrate concentration in the profundal near-field area of Quesnel Lake that was significantly greater than the reference area mean (Table 3-9 above). A higher concentration of copper in benthic invertebrates was expected, as the sediment concentrations were significantly higher in copper in near field profundal compared to reference. However, the biota-to-sediment accumulation (BSAF) for the relationship of copper in invertebrates to copper in sediment was less than 1.0 and had a negative slope (Appendix G, Figure 3). The concentration of copper in benthic invertebrates collected from the near-field exposed area appeared to be greater than reference by approximately three times compared to a 16x difference in sediment concentrations of copper. These data show that copper is not a biomagnifying metal.

For selenium, the mean benthic invertebrate concentrations for near field profundal was slightly greater than the dietary guideline (4.6 ug/g vs 4 ug/g), but significantly less than reference. The mean benthic invertebrate concentration of selenium was 8.1 ug/g in the reference samples. These preliminary data may indicate that Quesnel Lake selenium concentrations in invertebrates varies above and below the guideline naturally or from other sources. Further investigation into the concentrations of metals in benthic invertebrates in Quesnel Lake exposed and reference sites is planned as part of the CEMP.

3.3.3.3 Benthic Invertebrate Community

Analysis of the benthic invertebrate community in Quesnel Lake has been conducted by Minnow to assess the initial impacts of the tailings spill and track recovery (MPMC 2015 Appendix E). The benthic invertebrate community assessment was based on comparison of community metrics (e.g., diversity, richness, evenness) to reference areas in Quesnel Lake. Sampling in 2014 at littoral areas in Quesnel Lake, at various distances from the Hazeltine Creek mouth (near-field, far-field and far-far-field) indicated that richness and density were lower at near-field locations compared to reference. Metrics for far-field and far-far-field littoral locations indicated those communities were similar to reference. Samples from profundal areas exhibited greater difference from reference, with lower richness and density at both near and far field locations; several samples yielded no benthic invertebrates, indicating the benthic community was entirely covered and/or displaced by tailings. Additional samples of benthic community diversity and abundance were collected from Quesnel Lake in the fall of 2015. Although the data were not ready at the time of preparing this report, based on the biomass data provided above, there appear to no longer be a difference in biomass in the Quesnel Lake littoral zone. A difference in biomass continues to exist in the profundal zone. The data were not ready at the time of preparing this report. These data will be included in the Risk Assessment report that will be submitted later this year (2016).

3.3.3.4 Surface Water Toxicity Testing

MPMC has conducted a post-event toxicity testing program since the tailings spill occurred, in which surface water samples collected from Quesnel Lake were tested using a series of standard laboratory tests using sensitive plant, invertebrate, and fish test species. The program provides an important evaluation of the bioavailability and toxicity of POIs as they are observed in site-specific samples. The laboratory testing provides a direct measure of biological effect to individual organisms under site-relevant conditions, and includes sensitive test species representing primary producers, primary consumers, and secondary consumers.

The results of post-event toxicity testing conducted between August 2014 and February 2015 (MPMC 2015 Appendix F) indicated that receiving environment waters in Quesnel Lake were not acutely toxic (i.e., lethal) to sensitive plant, invertebrate, and fish species, nor chronically toxic (i.e., sub-lethal, longer term effects) to sensitive plant and fish species. Reproductive test responses in *Ceriodaphnia* were observed in three samples. The responses were inferred to be related to suspended matter in the samples, as filtered samples from the same locations did not elicit toxicity.

In subsequent sub-lethal toxicity tests with water samples collected from Quesnel Lake between March and December 2015, no impacts on survival and growth of fish were observed, and no impacts on survival of invertebrates were observed (Appendix F). The only observed effects were on reproduction of invertebrates in a subset of the unfiltered samples collected in Quesnel Lake close to the Hazeltine Creek mouth in January and March 2015. Again, no effects were reported in the corresponding filtered samples. Dissolved copper concentrations were not different between filtered and unfiltered samples. All measured parameters were below corresponding BC WQGs, supporting our interpretation that exposure to suspended particulate matter in the unfiltered samples may have resulted in the reproduction responses. The results of toxicity testing conducted between March and December 2015 are presented in Table 3-10.

Table 3-10: Summary of Surface Water Toxicity Testing in Quesnel Lake (March to December 2015)

Test	Sample ID	Date	T. Cu (mg/L)	D. Cu (mg/L)	LC50 (% v/v)	IC25 (% v/v)	IC50 (% v/v)
7-d fathead minnow survival and growth	QUL-66-0m	15 Jan 2015	0.0043	0.0019	>100	83.2 (46.7-100)	>100
	QUL-66-85m		0.0049	0.002	>100	95.6 (25.4-100)	>100
	QUL-66-0M	02 Mar 2015	-	-	>100	>100	>100
7-d Rainbow Trout swim-up survival and growth	QUL-66-0m	15 Jan 2015	0.0043	0.0019	>100	>100	>100
	QUL-66-85m		0.0049	0.002	>100	>100	>100
	QUL-55-0M	16 Jun 2015	0.0014	0.0011	>100	>100	>100
	QUL-55a-0M	25 Aug 2015	0.00095	0.00055	>100	>100	>100
7- to 8-d *C. dubia* survival and reproduction	QUL-66-0m	15 Jan 2015	0.0043	0.0019	>100	11.1 (7.2-29.1)	>100
	QUL-66-0m (Filtered)		-	0.0019	>100	>100	>100
	QUL-66-85m		0.0049	0.002	>100	8.3 (2.3-23.0)	>100
	QUL-66-85m (Filtered)		-	0.002	>100	>100	>100
	QUL-66-0M	02 Mar 2015	-	-	>100	74.2 (5.7-NC)	>100
	QUL-66-0M (Filtered)		-	-	>100	>100	>100
	QUL-55a-0M	25 Aug 2015	0.00095	0.00055	>100	>100	>100

Notes: Samples were not filtered, unless indicated otherwise. Effect concentration expressed on a volume/volume basis; in instances where an effect was observed, 95% confidence limits were not always calculable (NC). LC50 = Lethal concentration causing 50% mortality. IC25/IC50 = Non-lethal concentration causing 25% or 50% reduction in growth or reproduction. Total and dissolved copper (T. Cu and D. Cu) concentrations for January to August samples are provided in Appendix B.

3.3.3.5 Plankton Community and Tissue Metal Analysis

Sampling of plankton was conducted weekly in 2014 in the months immediately following the tailings spill (September to November; MPMC 2015 Appendix H) and then monthly between May and September 2015 (Appendix G). Plankton communities exhibit inherent variability related to temperature, daylight, depth sampled etc. Because the same months were not sampled in both 2014 and 2015 the data between years are not directly comparable. Due to differences in resolution of taxonomic identification as well as units, the zooplankton abundance and biomass data were not compared to pre-event data presented in Hume et al. (2005) and MacLellan et al. (1993). Thus, the update report focuses on characterizing the plankton community observed between May and September 2015.

In 2015, plankton communities were sampled at three stations in Quesnel Lake (one near field exposure station and two far field reference stations) during the open water period from May to September. Spatial and temporal trends in phytoplankton biomass (as chlorophyll a), and zooplankton abundance and biomass were qualitatively examined by plotting the data. Trophic status of Quesnel Lake was determined through comparison of chlorophyll *a,* nutrient concentrations, and water transparency (Secchi depths). The evaluation of trophic status indicated that Quesnel Lake is oligotrophic (nutrient-poor, unproductive system). Chlorophyll *a* in Quesnel Lake was low and seasonally variable, and chlorophyll *a* concentrations generally increased through the open water period from May to September.

The zooplankton tissue results are presented in Figures 9a to 9d, below. A brief summary of the findings for Quesnel Lake sampling is as follows:

- Phytoplankton biomass (as chlorophyll *a*) in Quesnel Lake was below 1.0 µg/L in all sampling events, but varied seasonally. Chlorophyll *a* concentrations generally increased through the open water period from May to September. Overall, Quesnel Lake is classified as oligotrophic based on several classification systems, which use nutrients (total phosphorus and total nitrogen), Secchi depths, and chlorophyll *a* concentrations to evaluate trophic status.

- Total zooplankton biomass and abundance in Quesnel Lake during the open water period of 2015 was generally higher than values observed during post-event sampling in fall of 2014. Seasonal variability was observed through the open water period of 2015 with a generally increasing trend in biomass and a generally decreasing trend in abundance observed from May to September 2015.

- Zooplankton biomass and abundance in Quesnel Lake were generally dominated by either cyclopoid copepods or cladocerans. Seasonal differences were observed throughout the open water period of 2015 with cyclopoid copepods generally dominant in spring and early-summer and cladocerans dominant in late-summer and fall. Limited spatial variability was observed among stations with similar trends observed at the Hazeltine, Horsefly, and Junction stations through the open water period in 2015.

- Zooplankton tissue concentrations of copper, selenium, mercury, and arsenic were plotted by sampling period for each station in Quesnel Lake to qualitative evaluate trends in these parameters in comparison to aqueous concentrations of these parameters at comparable water quality sampling locations.

  - An increasing trend in arsenic concentrations was observed in zooplankton tissue from all three stations; however, this trend was not observed in aqueous arsenic concentrations at comparable water sampling stations. In 2015, aqueous arsenic concentrations were generally similar at all three stations and all concentrations were below the BC WQG. The trends in tissue concentrations do not reflect what is observed in arsenic concentrations in surface water collected from nearby locations.

  - No consistent trends were observed in zooplankton copper concentrations measured in sampling events from 2014 and 2015. Tissue concentrations of copper were generally higher at Hazeltine compared to the other two stations. In 2014, tissue concentrations of copper appeared to increase from October to November; however, this same increasing trend was not observed to continue in 2015. One elevated copper concentration was observed at Hazeltine in May 2015. Given that copper does not biomagnify in freshwater systems (Cardwell et al. 2013) and aqueous copper concentrations in May 2015 were similar to or lower than aqueous concentrations during other sampling events that did not result in comparable copper concentrations in tissue, this elevated value appears to be anomalous.

  - Zooplankton tissue mercury concentrations were variable at all three stations, with no consistent spatial or temporal trends. In 2015, tissue concentrations of mercury at Hazeltine and Junction increased between May and September to values within the range observed at Junction in September 2014. Aqueous mercury data are sparse and aqueous concentrations were below the reported detection limit in all samples and interpretation of aqueous mercury trends is therefore limited.

  - Zooplankton tissue selenium concentrations appeared to exhibit a generally increasing trend at all stations throughout the 2015 sampling period with the exception of the August 2015 sampling event when lower concentrations were observed. Over the open-water period of 2015, aqueous selenium concentrations exhibited a slight decreasing trend.

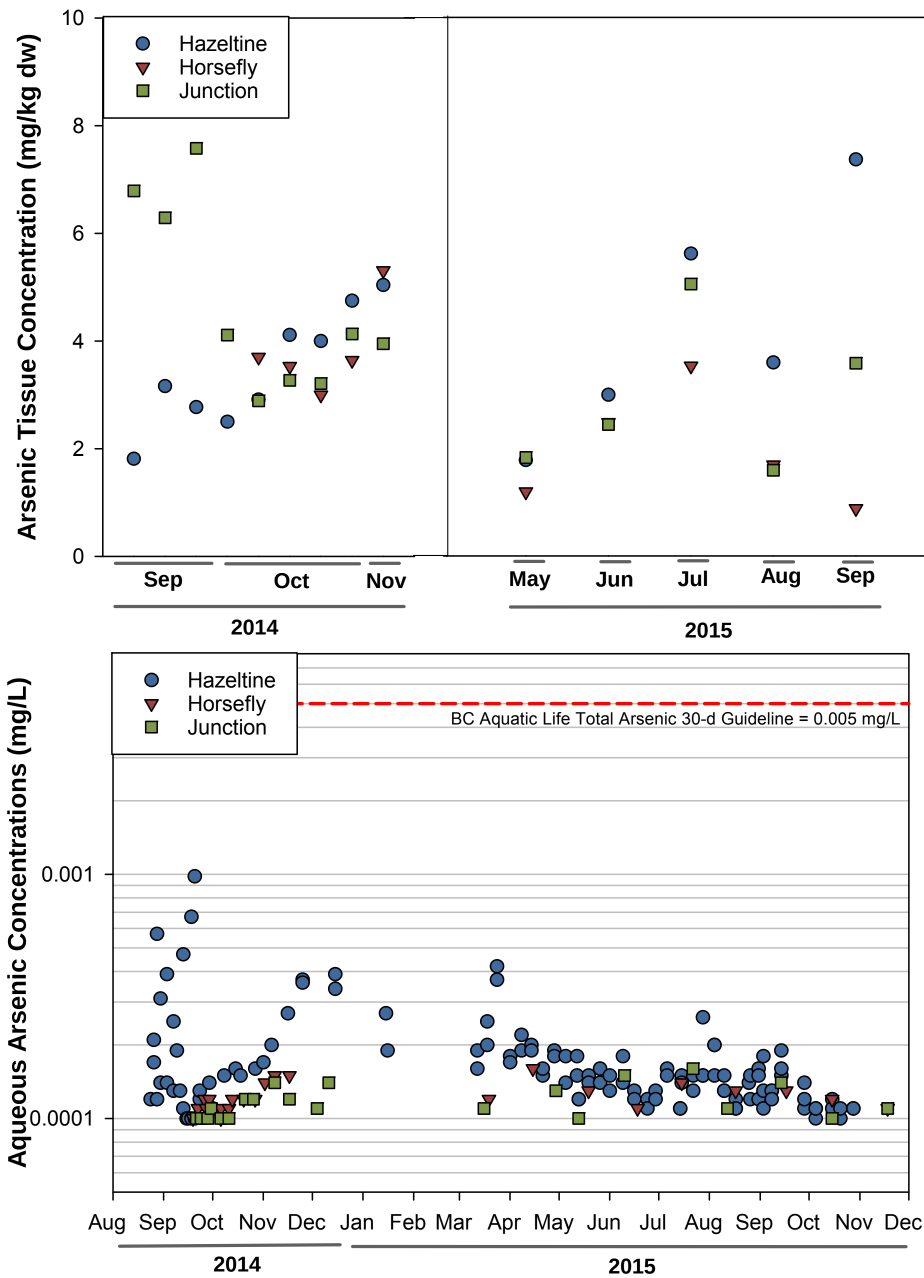
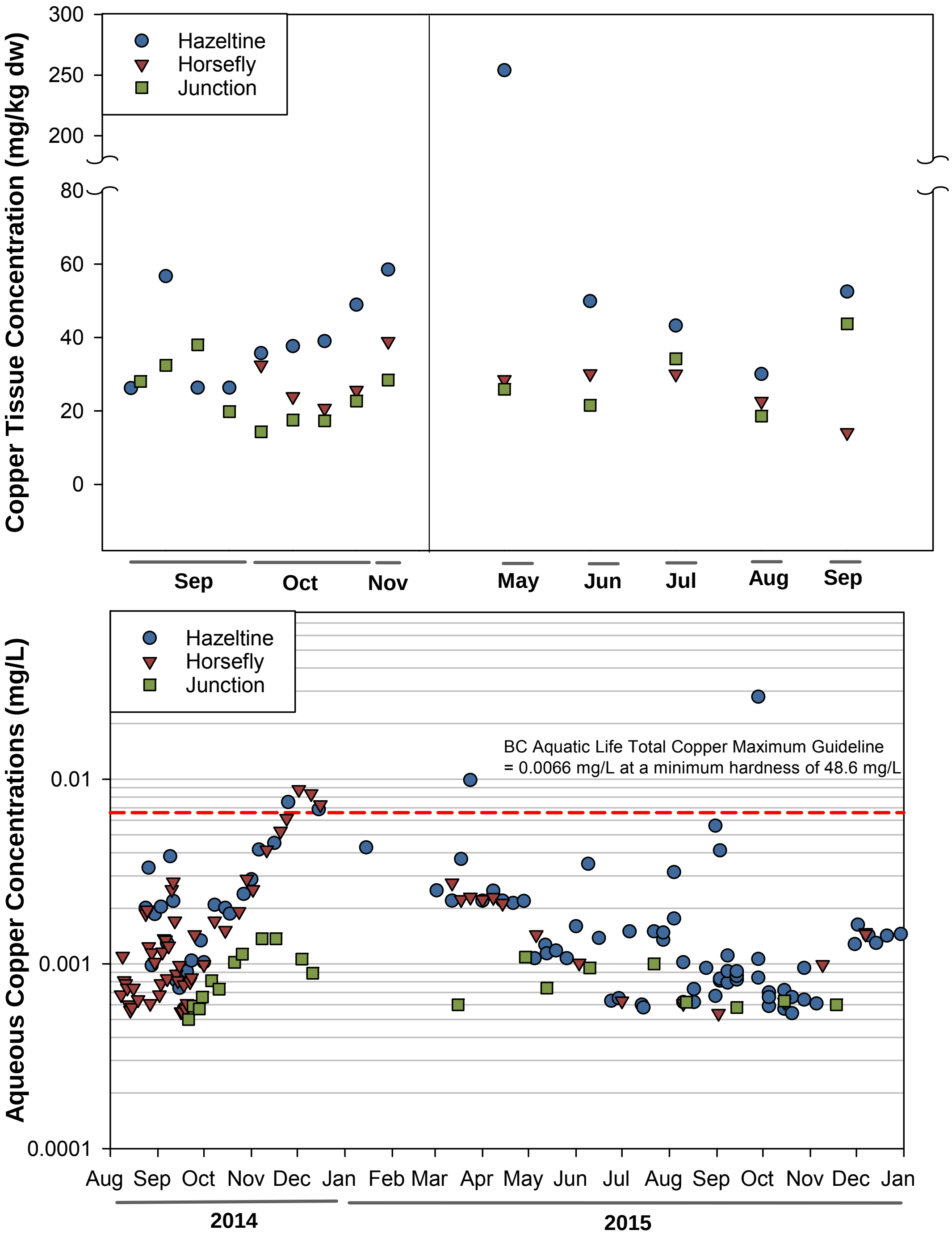
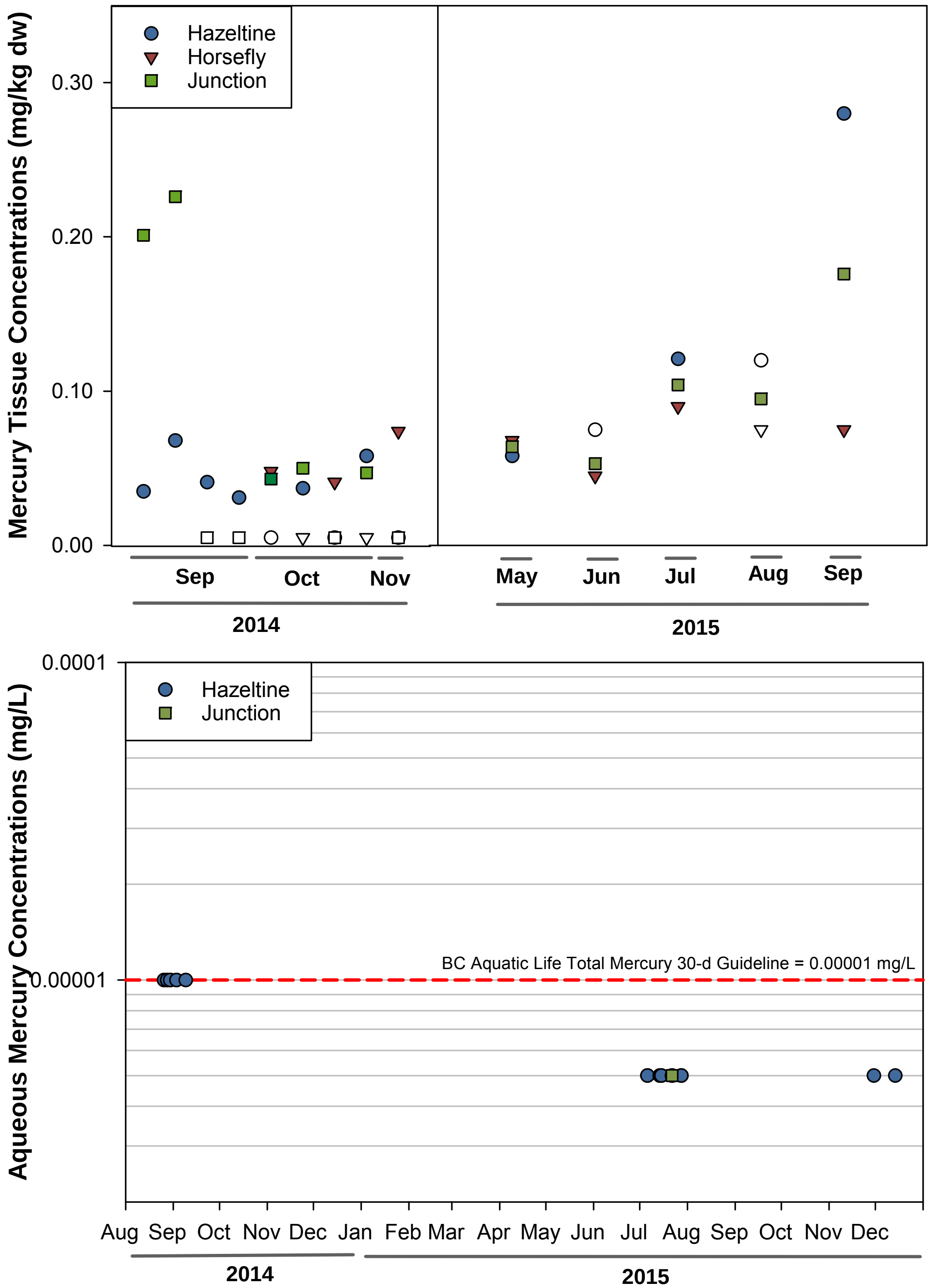


Figure 9a: Concentrations of Arsenic in Zooplankton Tissue and Surface Water Collected from Quesnel Lake in Fall 2014 and 2015.



Note: Potentially anomalous value observed in Hazeltine in May 2015.

Figure 9b: Concentrations of Copper in Zooplankton Tissue and Surface Water Collected from Quesnel Lake in Fall 2014 and 2015.



Note: Open symbols represent non-detect values.

Figure 9c: Concentrations of Mercury in Zooplankton Tissue and Surface Water Collected from Quesnel Lake in Fall 2014 and 2015.

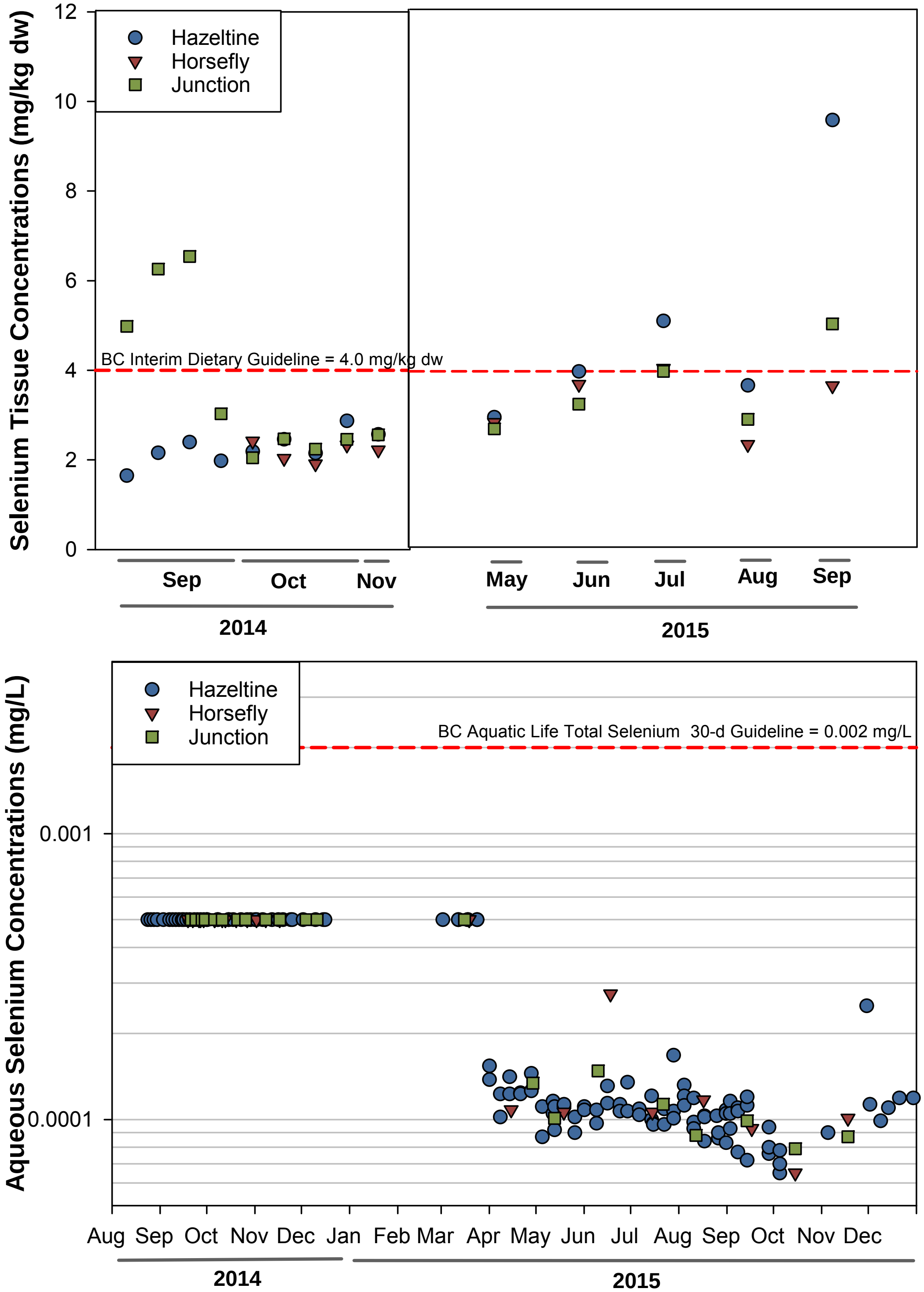


Figure 9d: Concentrations of Selenium in Zooplankton Tissue and Surface Water Collected from Quesnel Lake in Fall 2014 and 2015.

3.3.3.6 Fish Productivity

Post-event toxicity testing indicated that Quesnel Lake water did not affect survival or growth of fish, survival or growth of daphnid zooplankton, or growth of plant test species. The literature indicates that the direction of change in primary productivity as a result of introduction of suspended sediments to a lake depends on whether the phytoplankton are light limited or nutrient limited. The information available suggest that there was an influx of phosphorus into Quesnel Lake. Although changes in phytoplankton and zooplankton biomass were not observed, juvenile Sockeye Salmon collected west of Cariboo Island in 2014 were larger than those from the lake east of Cariboo Island. Juvenile Sockeye Salmon collected west of Cariboo Island in 2015 were similar in size to fish collected in other parts of the lake pre-event and in 2015. The absence of an observed increase in either phytoplankton or zooplankton abundance may reflect grazing/predation, which may in turn be reflected in the larger and possibly more numerous juvenile Sockeye observed in DFO's data compared to previous years.

3.3.3.7 Fish Tissue Metal Concentrations

Multiple stakeholders collected fish tissue samples following the release of tailings. Golder consolidated the data from these multiple sources into a single dataset to facilitate data review. The methods used to present the data are discussed in detail in Appendix H. The following section summarizes the observations made for Quesnel Lake.

3.3.3.7.1 Comparison to Tissue Guideline

- There were no arsenic guideline exceedances observed for Quesnel Lake fish.
- There were mercury guideline exceedances observed for Quesnel Lake fish, as outlined in Table 3-11, below:

Table 3-11: Summary of mercury guideline exceedances in fish sampled from Quesnel Lake (2014-2015)

Year	Species	Location	Number and Type
2014	Burbot	Quesnel Lake Horsefly River Confluence (exposure)	1 of 1 muscle
	Burbot	Quesnel Lake Hazeltine Creek Confluence (exposure)	4 of 12 muscle and 2 of 12 liver samples
	Lake Trout	Quesnel Lake Hazeltine Creek Confluence (exposure)	5 of 51 muscle, 15 of 51 liver, and 1 of 33 ovary sample
	Rainbow Trout	Quesnel Lake near Quesnel River (exposure)	1 of 2 muscle and 1 of 2 liver sample
2015	Burbot	Quesnel Lake East (reference)	1 of 7 muscle
	Lake Trout	Quesnel Lake Hazeltine Creek Confluence (exposure)	1 of 10 muscle, 1 of 10 liver, and 2 of 9 kidney
	Lake Trout	Quesnel Lake East (reference)	1 of 10 muscle, 2 of 10 liver, and 5 of 10 kidney

Selenium concentrations that exceed the BC MoE screening values for the protection of First Nation subsistence consumers and the general population are outlined in Table 3-12, below. The screening value for the protection of First Nation subsistence consumers of 7.3 ug/g dw was based on a fish ingestion rate of 220 g/day (Health Canada, 2004). The screening value for the protection of the general population of 17.5 ug/g dw was based on a fish ingestion rate of 111 g/day (Health Canada, 2004). Exceedances were noted for both exposed and reference sites. Selenium concentrations in Quesnel Lake fish that exceed the BC MoE guideline for Environmental Protection are outlined in Table 3-13, below.

Table 3-12: Exceedances of MoE selenium screening values in fish tissues collected from exposed and reference sites in Quesnel Lake

Guideline	Year	Species	Location	Number and Type
Low Fish Intake (75 mg/kg dw) Recreational Fishers	2014	Rainbow Trout	Quesnel Lake near Quesnel River (exposure)	1 of 2 liver
		Rainbow Trout	Quesnel River (exposure)	1 of 12 liver
	2015	Kokanee	Quesnel Lake near Quesnel River (exposure)	1 of 8 liver
Moderate Fish Intake (14.5 mg/kg dw) General Population	2014	Burbot	Quesnel Lake Hazeltine Creek (exposure)	2 of 12 liver
		Kokanee	Quesnel Lake near Quesnel River (exposure)	10 of 10 liver
		Kokanee	Quesnel Lake North Arm (reference)	10 of 10 liver
		Lake Trout	Quesnel Lake Hazeltine Creek (exposure)	1 of 51 liver
		Rainbow Trout	Quesnel Lake near Quesnel River (exposure)	2 of 2 liver
		Rainbow Trout	Quesnel River (exposure)	2 of 3 ovary, 8 of 12 liver, 1 of 12 muscle

Guideline	Year	Species	Location	Number and Type
	2015	Kokanee	Quesnel Lake near Quesnel River (exposure)	8 of 8 liver
		Rainbow Trout	Quesnel River (exposure)	6 of 8 liver
		Sockeye Salmon (juvenile)	Quesnel Lake East (reference)	1 of 3 liver
		Sockeye Salmon (juvenile)	Quesnel Lake North Arm (reference)	1 of 3 liver
		Sockeye Salmon (juvenile)	Quesnel Lake Middle (exposure)	1 of 4 liver
		Sockeye Salmon (juvenile)	Quesnel Lake West (exposure)	1 of 7 liver
High Fish Intake (7.3 mg/kg dw) First Nation Subsistence	2014	Burbot	Quesnel Lake Hazeltine Creek (exposure)	1 of 8 ovary, 2 of 12 liver
		Kokanee	Quesnel Lake Quesnel River (exposure)	10 of 10 liver
		Kokanee	Quesnel Lake North Arm (reference)	10 of 10 liver
		Lake Trout	Quesnel Lake Hazeltine Creek (exposure)	36 of 51 liver
		Mountain Whitefish	Quesnel Lake Hazeltine Creek (exposure)	3 of 3 ovary, 3 of 4 liver
		Rainbow Trout	Quesnel Lake near Quesnel River (exposure)	2 of 2 liver
		Rainbow Trout	Quesnel River (exposure)	3 of 3 ovary, 10 of 12 liver, and 1 of 12 muscle
		Sockeye Salmon (juvenile)	Quesnel Lake North Arm (reference)	3 of 3 liver
		Sockeye Salmon (juvenile)	Quesnel Lake Middle (exposure)	1 of 3 liver
		Sockeye Salmon (juvenile)	Quesnel Lake West (exposure)	6 of 6 liver

Guideline	Year	Species	Location	Number and Type
	2015	Burbot	Quesnel Lake Hazeltine Creek (exposure)	1 of 1 ovary
		Kokanee	Quesnel Lake Quesnel River (exposure)	8 of 8 liver
		Lake Trout	Quesnel Lake Hazeltine Creek (exposure)	2 of 9 kidney, 1 of 10 liver
		Lake Trout	Quesnel Lake East (reference)	3 of 10 kidney, 2 of 10 liver
		Rainbow Trout	Quesnel River (exposure)	1 of 1 ovary, 7 of 8 kidney, 8 of 8 liver
		Sockeye Salmon (juvenile)	Quesnel Lake North Arm (reference)	3 of 3 liver
		Sockeye Salmon (juvenile)	Quesnel Lake Middle (exposure)	4 of 4 liver
		Sockeye Salmon (juvenile)	Quesnel Lake West (exposure)	7 of 7 liver
		Sockeye Salmon (juvenile)	Quesnel Lake East (reference)	3 of 3 liver

Table 3-13: Summary of Selenium Tissue Exceedances for Environmental Protection

Year	Species	Location	Type and Number
2014	Rainbow Trout	Quesnel Lake near Quesnel River (exposure)	1 of 2 muscle
	Northern Pikeminnow	Quesnel Lake Hazeltine Creek Confluence (exposure)	2 of 36 whole-body
	Northern Pikeminnow	Quesnel Lake Horsefly River Confluence (exposure)	1 of 10 whole-body
	Northern Pikeminnow	Quesnel Lake North Arm (reference)	1 of 31 whole-body
2015	Largescale Sucker	Quesnel Lake Hazeltine Creek Confluence (exposure)	1 of 8 muscle
	Peamouth Chub	Quesnel Lake Hazeltine Creek Confluence (exposure)	1 of 8 whole-body

Notes: Quesnel Lake Horsefly River confluence was previously classified as “exposure” by DFO and this classification was retained.

3.3.3.7.2 Risk Assessment and Toxicological Context

For Quesnel Lake, Golder selected a subset of fish species for which there are adequate data (e.g., at least 8 samples in both exposure and reference sites; sampled in both years) and focused on species that represent small-bodied fish that are more likely to reflect local conditions and large bodied fish that likely reflect exposure in a larger area and are valued for human consumption. The following species were selected:

- Peamouth Chub and juvenile Sockeye Salmon were selected as a representative small-bodied fish that are expected to occupy a smaller home range (relative to large-bodied fish such as Lake Trout or Rainbow Trout) and would be consumed by piscivorous fish. Definitive data regarding Peamouth Chub home range size are not currently available, but literature supports this assumption (e.g., Environment Canada 1995). There is also an adequate number of Peamouth Chub samples from both exposed and reference sites in both years. Juvenile Sockeye Salmon were also considered to occupy a smaller home range, although they move from their spawning habitats out into the open lakes as they mature.
- Lake Trout and Rainbow Trout were selected as representative larger-bodied fish that are likely to be consumed by humans (and potentially, by large piscivorous wildlife). There are also adequate numbers of Lake Trout and Rainbow Trout samples from both exposed and reference sites in both years.
- Adult Sockeye Salmon were excluded because the duration and frequency of their time in impacted areas is limited to migration back to their natal streams. Feeding during this time is expected to be minimal. Juvenile Sockeye Salmon are included because they would be residents within the study area and are of concern to many stakeholders.

The primary focus of the comparison was between locations that shared a similar ecology. Fish samples from exposed sites in Quesnel Lake were compared to reference sites in Quesnel Lake.

Human Consumption of Fish

Figure 5 in the Polley Lake section above, provides a summary of the available box plots for specific metals in the muscle samples from large-bodied fish species. As described above, Lake Trout, Rainbow Trout and juvenile Sockeye Salmon were identified as a reasonable surrogate for the preliminary consideration of this pathway. Individual box plots with pair-wise comparisons for different sites, species and years are provided in Appendix H. The purpose of this figure is to highlight whether there are obvious changes in metal accumulation between reference and exposed sites, or between years that would indicate that there has been a change in metal concentrations in muscle tissue that is frequently consumed by people. In brief, results are summarized as follows:

- Arsenic concentrations in muscle samples were similar among reference and the exposed sites. The box plots for Rainbow Trout and Lake Trout caught in exposed sites in Quesnel Lake overlapped with the box plots for Lake Trout collected from the reference sites in Quesnel Lake, indicating that there was not a significant increase in fish tissue concentrations observed. All measured concentrations were less than the preliminary tissue guideline.
- Copper, selenium and zinc concentrations in muscle samples were similar among reference and exposed sites. There was one muscle sample from a Rainbow Trout collected at Quesnel River in 2014 that exceeded the BC screening value for selenium for the protection of subsistence fish consumers. Concentrations were below the screening value in 2015.

- Mercury concentrations in muscle samples appeared to be similarly variable between exposed sites and reference sites. About 10% Lake Trout muscle samples from both exposed and reference areas of Quesnel Lake had tissue concentrations that exceeded the muscle preliminary tissue guideline for the protection of human health in both years.

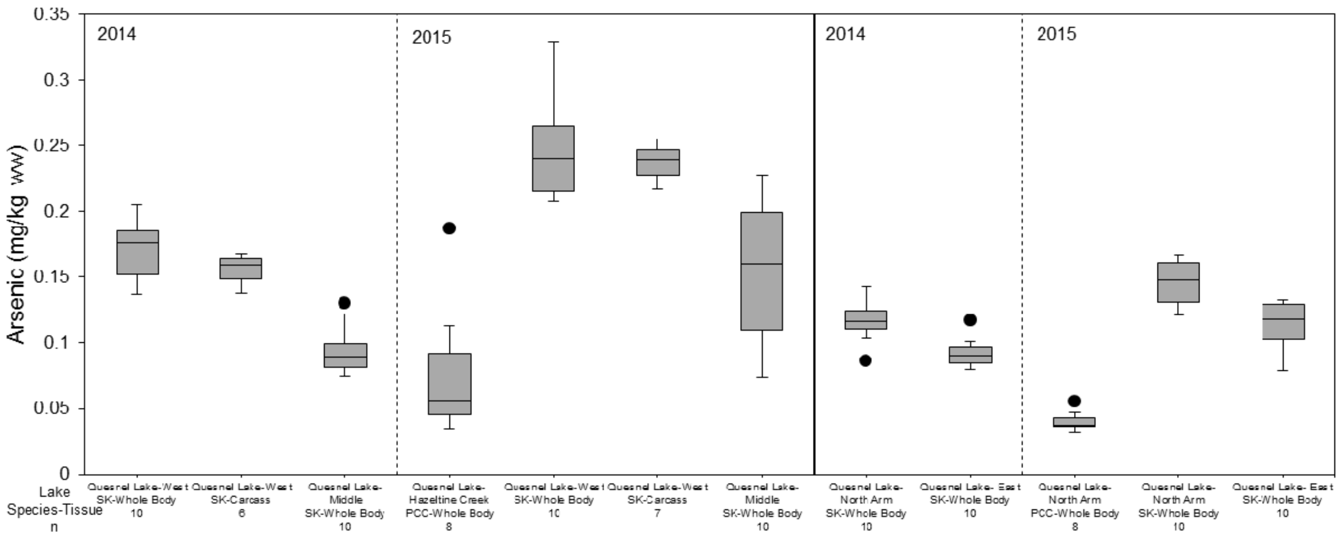
Bioaccumulation by Fish

Figures 6 and 7 (liver and ovary) in the Polley Lake section above, provide summaries of the available fish tissue chemistry data for organ-specific samples presented as censored box plots for the specific metals identified. Individual censored box plots showing comparisons of exposure and reference sites, species and years are provided in Appendix H, Attachment 2. The purpose of the summary figures presented herein is to highlight changes in metal concentrations between reference and exposed sites, or between years in tissues that have been associated with metal accumulation. In brief, results are summarized as follows:

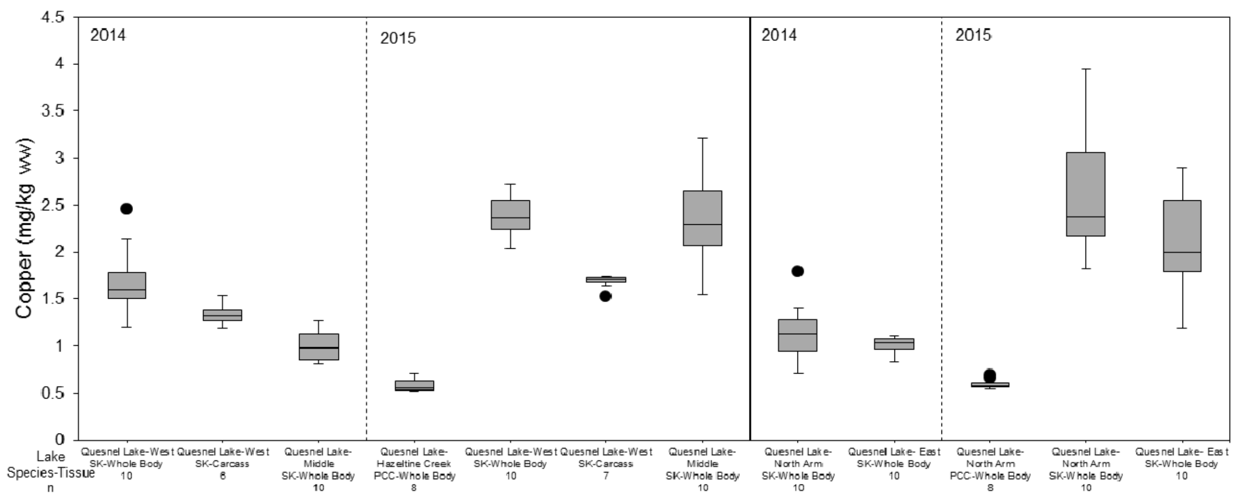
- For arsenic and copper, liver concentrations were generally consistent between the exposed and reference sites. One potential exception is juvenile Sockeye Salmon from Quesnel Lake (West) which tended to have higher liver arsenic and copper concentrations than those observed in other species. There are no juvenile Sockeye Salmon liver samples from reference sites, and therefore, it is not clear whether this is a species-specific difference (i.e., Sockeye accumulate more arsenic in their liver than Rainbow Trout) or a potential site-specific influence. For arsenic in kidney samples, there may be an increased concentration at the Quesnel River exposed site compared to Quesnel Lake – East. However the Lake Trout collected from Quesnel Lake at Hazeltine were similarly low compared to Quesnel Lake – East.
- Mercury concentrations in fish liver were variable for both the reference sites and exposed sites. Some of these concentrations exceeded the fish tissue guidelines as outlined above. Liver tissue is not commonly consumed, but Golder would welcome input on this from the Williams Lake Indian Band and Soda Creek First Nation.
- Selenium concentrations in liver were similar between exposed and reference samples in Quesnel Lake and concentrations exceeded the guideline for environmental protection in some samples.
- Vanadium concentrations were generally not detected in fish from either exposed or reference in Quesnel Lake.
- Zinc concentrations in Lake Trout liver and kidney were low in both reference and exposed areas of Quesnel Lake.

Consumption by Piscivores

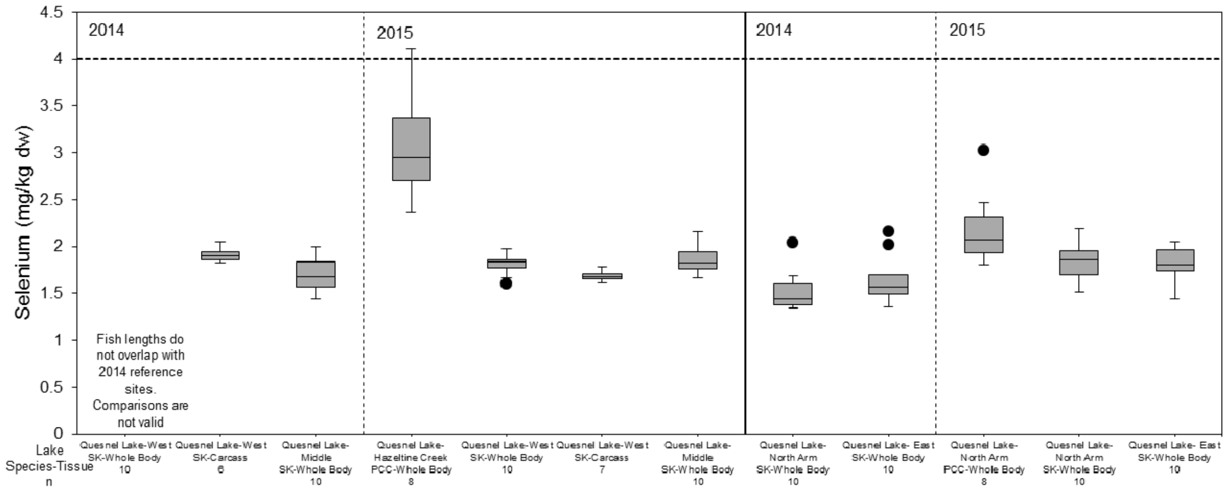
A summary of the box plots for specific metals in the available whole body Peamouth Chub and juvenile Sockeye Salmon samples is provided in Appendix H and Figure 10 below. Peamouth Chub and juvenile Sockeye Salmon were considered reasonable surrogates for the preliminary consideration of potential risks to piscivorous wildlife. The purpose of this summary figure is to highlight whether there are obvious changes in metal accumulation between reference and exposed sites, or between years that would indicate that this pathway is operable.

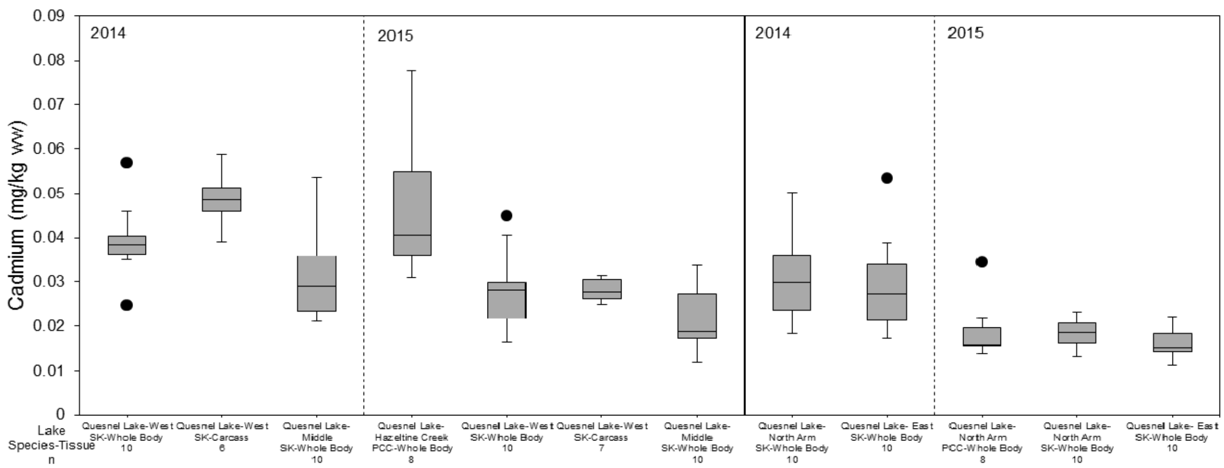


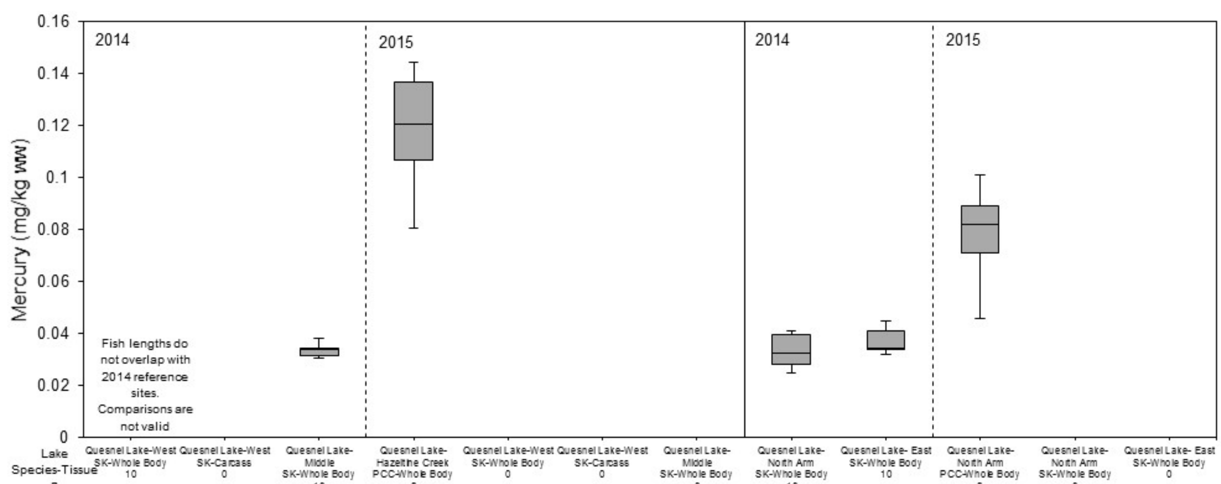
Arsenic (mg/kg ww)
2014
2015
2014
2015
Lake
Species-Tissue
n
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 6
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-Hazeltine Creek PCC-Whole Body 8
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 7
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10
Quesnel Lake-North Arm PCC-Whole Body 8
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10



Copper (mg/kg ww)
2014
2015
2014
2015
Lake
Species-Tissue
n
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 6
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-Hazeltine Creek PCC-Whole Body 8
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 7
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10
Quesnel Lake-North Arm PCC-Whole Body 8
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10


Selenium (mg/kg dw)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference sites. Comparisons are not valid
Lake
Species-Tissue
n
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 6
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-Hazeltine Creek PCC-Whole Body 8
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 7
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10
Quesnel Lake-North Arm PCC-Whole Body 8
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10


Cadmium (mg/kg ww)
2014
2015
2014
2015
Lake
Species-Tissue
n
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 6
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-Hazeltine Creek PCC-Whole Body 8
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 7
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10
Quesnel Lake-North Arm PCC-Whole Body 8
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10


Mercury (mg/kg ww)
2014
2015
2014
2015
Fish lengths do not overlap with 2014 reference sites. Comparisons are not valid
Lake
Species-Tissue
n
Quesnel Lake-West SK-Whole Body 10
Quesnel Lake-West SK-Carcass 0
Quesnel Lake-Middle SK-Whole Body 10
Quesnel Lake-Hazeltine Creek PCC-Whole Body 8
Quesnel Lake-West SK-Whole Body 0
Quesnel Lake-West SK-Carcass 0
Quesnel Lake-Middle SK-Whole Body 0
Quesnel Lake-North Arm SK-Whole Body 10
Quesnel Lake- East SK-Whole Body 10
Quesnel Lake-North Arm PCC-Whole Body 8
Quesnel Lake-North Arm SK-Whole Body 0
Quesnel Lake- East SK-Whole Body 0

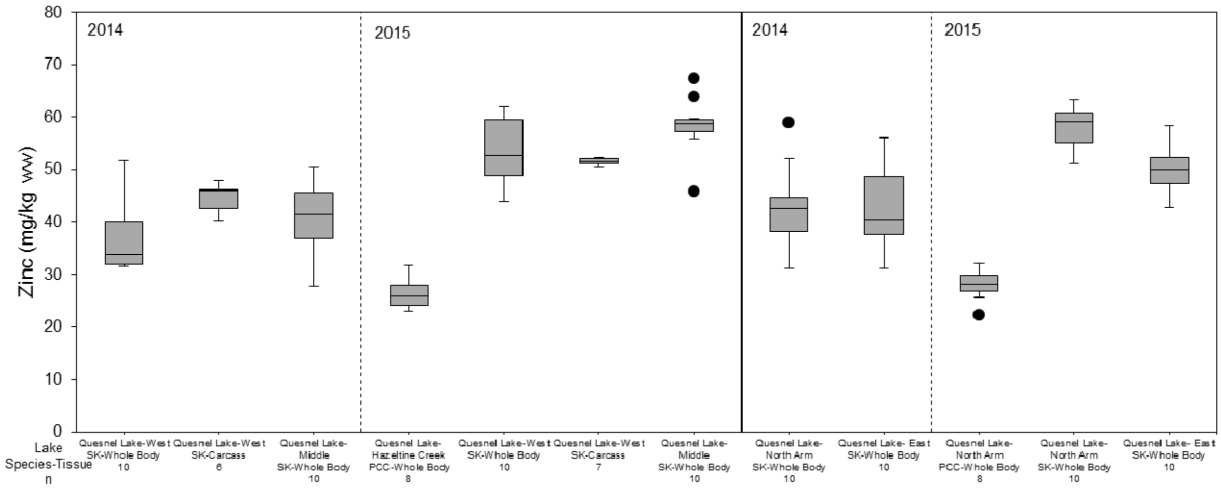


Figure 10: Summary of Available Whole Body and Carcass Chemistry Data for Sockeye Salmon and Peamouth Chub from Relevant Sampling Sites (2014, 2015).

Note: Boxplots are censored at the detection limit (DL = solid horizontal line). Concentrations below the DL are plotted as an open symbol at half the DL. Extreme values are plotted as individual values. mg/kg ww = milligrams per kilogram wet weight; mg/kg dw = milligrams per kilogram dry weight; n = sample size. Dashed vertical lines (- - -) indicate the separation of years. Solid vertical lines (−) indicate the separation of exposure and reference; dashed horizontal lines. (- - -) indicate guidelines from CFIA (mercury) or BC MoE (selenium).

Cadmium, mercury and selenium concentrations may be elevated in whole body Peamouth Chub samples collected from Quesnel Lake at Hazeltine Creek relative to Quesnel Lake in the North Arm, based on the lack of overlap in their box plots. Conversely, the box plots overlapped for zinc and copper, indicating that the concentrations were similar between exposed and reference fish. This comparison is limited to one exposed site (Quesnel Lake – Hazeltine Creek) compared to one reference site (Quesnel Lake – North Arm).

For juvenile Sockeye Salmon, arsenic concentrations may be higher in whole body samples from exposed compared to reference and also higher in 2015 compared to 2014. For mercury, a difference in fish length did not allow a comparison between exposed and reference fish. There were no apparent spatial or temporal trends in the whole body concentrations of copper, cadmium, selenium and zinc in juvenile Sockeye Salmon. MPMC will continue to monitor fish tissue metal concentrations under the CEMP.

3.4 Quesnel River

3.4.1 Physical

Quesnel River is the major drainage from Quesnel Lake and is located at the north end of the lake's West Basin. The river is located approximately 13 km north of where Hazeltine Creek discharges into Quesnel Lake. Modelling predicted that by summer 2015, between 15% and 20% of the original amount of suspended material in Quesnel Lake from the tailings spill would have been discharged into Quesnel River (MPMC 2015 Appendix B). That amount of material represents 12% or less of the river's annual sediment load.

Following the tailings spill, turbidity concentrations in Quesnel River were generally below the long-term BC WQG, with the exception of measurements from late November 2014 to late January 2015 following the fall turnover of Quesnel Lake and mixing of the deep turbid water. Daily average and in situ turbidity concentrations in Quesnel River have shown an overall progressive decrease over time throughout 2015.

3.4.2 Chemical

Surface Water Quality Update

Water quality data collected from Quesnel River by MPMC has been evaluated to assess temporal trends of POI since the tailings spill through December 2015 (Appendix D). The water quality assessment was based on comparison of water chemistry to BC WQGs. For a period of time following the fall turnover of Quesnel Lake, concentrations of total copper in Quesnel River exceeded the short-term BC WQG. However, water quality in Quesnel River since January 2015 has not exhibited any concentrations of metals greater than guidelines or standards. Based on the evaluation of 2015 water quality data, no POIs remain in Quesnel River.

Sediment Quality Update

The Quesnel River is erosional and no areas of sediment deposition were identified during sampling and therefore impact characterization did not include sediment.

3.4.3 Biological

3.4.3.1 Benthic Invertebrate Biomass and Tissue Metal Concentrations

Benthic invertebrate samples collected from the Quesnel River and the corresponding reference area (Cariboo River) were more diverse than those collected from Hazeltine Creek, and were composed mainly of stoneflies, mayflies, caddisflies, and snails.

Benthic invertebrates from the Quesnel River did not have significantly different mean concentrations of any of the contaminants relative to those from the reference river (upper Cariboo River; Appendix E). PCA results supported this finding, with very little to no distinction present between the exposed and reference.

3.4.3.2 Surface Water Toxicity Testing

MPMC has conducted a post-event toxicity testing program since the tailings spill occurred, in which surface water samples collected from Quesnel River were tested using a battery of standard laboratory tests using sensitive plant, invertebrate, and fish test species. The program provides an important evaluation of the bioavailability and toxicity of POIs as they are observed in site-specific samples. The laboratory testing provides a direct measure of biological effect to individual organisms under site-relevant conditions, and includes sensitive test species representing primary producers, primary consumers, and secondary consumers.

The results of post-event toxicity testing conducted between August 2014 and February 2015 (MPMC 2015 Appendix F) indicated that receiving environment waters in Quesnel River were not acutely toxic (i.e., lethal) to sensitive plant, invertebrate, and fish species, nor chronically toxic (i.e., sub-lethal, longer term effects) to sensitive plant and fish species.

In subsequent sub-lethal toxicity tests with water samples collected from Quesnel River between March and December 2015, no impacts on survival and growth of fish were observed, and no impacts on survival of invertebrates were observed (Appendix F). One unfiltered sample collected from Quesnel River in March 2015 showed a slight (IC25% = 95.9) reproductive test response. This response was not associated with elevated water chemistry (i.e., concentrations of all parameters in this sample were below applicable BC WQGs), nor did the response align with fish toxicity testing results reported for the same sample. The results of toxicity testing conducted between January and December 2015 are presented in Table 3-14 .

Table 3-14: Summary of Surface Water Toxicity Testing in Quesnel River (January to December 2015)

Test	Sample ID	Date	T. Cu (mg/L)	D. Cu (mg/L)	LC50 (% v/v)	IC25 (% v/v)	IC50 (% v/v)
7-d fathead minnow survival and growth	QUR-1	07 Jan 2015	0.004	0.0016	>100	>100	>100
	QUR-1	10 Feb 2015	0.0024	0.0013	>100	>100	>100
	QUR-1	03 Mar 2015	0.0021	0.0013	>100	>100	>100
7-d Rainbow Trout swim-up survival and growth	QUR-1	07 Jan 2015	0.004	0.0016	>100	>100	>100
	QUR-1	16 Jun 2015	0.0015	0.00085	>100	>100	>100
	QUR-1	24 Aug 2015	0.00067	<0.00050	>100	>100	>100
	QUR-1	12 Nov 2015	0.00082	<0.00050	>100	>100	>100
7- to 8-d *C. dubia* survival and reproduction	QUR-1	07 Jan 2015	0.004	0.0016	>100	>100	>100
	QUR-1 (Filtered)		-	0.0016	>100	>100	>100
	QUR-1	10 Feb 2015	0.0024	0.0013	>100	>100	>100
	QUR-1	03 Mar 2015	0.0021	0.0013	>100	95.9 (50-NC)	>100
	QUR-1	24 Aug 2015	0.00067	<0.00050	>100	>100	>100
	QUR-1	12 Nov 2015	0.00082	<0.00050	>100	>100	>100

Notes: Samples were not filtered, unless indicated otherwise. Effect concentration expressed on a volume/volume basis; in instances where an effect was observed, 95% confidence limits were not always calculable (NC). LC50 = Lethal concentration causing 50% mortality. IC25/IC50 = Non-lethal concentration causing 25% or 50% reduction in growth or reproduction. Total and dissolved copper (T. Cu and D. Cu) concentrations for January to August samples are provided in Appendix B; concentrations for September to November samples are MPMC unpublished data.

4.0 OVERALL SUMMARY OF IMPACTS FROM TAILINGS SPILL

To date, the post-event studies continue to indicate that the tailings spill has resulted in physical impact to Polley Lake, Hazeltine Creek and valley, the mouth of Edney Creek, the benthic environment in the West Basin of Quesnel Lake, and the communities in these environments. Observations of potential chemical and biological impacts have been made:

- Soil and sediment data show that there are some metals that exceed guidelines and/or standards.
- Geochemistry investigations continue to indicate that the tailings are not acid-generating and have low leaching potential. A preliminary groundwater investigation involving limited sampling of shallow groundwater from within the tailings deposited in Hazeltine Creek valley had concentrations of metals that were below groundwater standards. Further investigation is planned for the summer of 2016.
- Surface water data has shown a decreasing trend in the concentrations of total metals and turbidity that were associated with the tailings spill. Concentrations of all contaminants that were initially elevated are now below water quality guidelines, with the exception of copper in Hazeltine Creek.
- Surface water has been tested using a series of toxicity tests and found to be not toxic to various aquatic test species. Some turbid samples appeared to impact on performance of one of the aquatic insects. However, zooplankton samples have not shown a decreasing trend in biomass in Quesnel Lake.
- Sediment toxicity testing was conducted and found to be associated with low toxicity. The sediment substrate, low in TOC and particle size, was found to hinder performance of benthic invertebrates in standard tests. The changed environment may also slow the progress of natural re-colonization in the profundal zone.
- Benthic invertebrate biomass measurements indicate lower populations in Polley Lake and the deeper (profundal) areas of the West Arm of Quesnel Lake.
- Benthic invertebrate biomass was similar to reference in the littoral areas of Quesnel Lake, Quesnel River and Edney Creek.
- Benthic invertebrate tissue concentrations indicate higher concentrations of metals, including selenium in Polley Lake compared to Bootjack Lake. Copper concentrations were higher in the deeper (profundal) areas of the West Arm of Quesnel Lake compared to reference. Concentrations of copper and vanadium in benthic invertebrates were higher in Hazeltine Creek following the tailings spill, but the concentrations of selenium were higher prior to the breach than after, and higher than 2015 measurements for Polley Lake. Concentrations of metals in Edney Creek benthic invertebrates were not different from reference.
- Available data for evaluating fish productivity for Polley Lake indicates that it is currently similar to reference conditions. Further investigation into potential impacts of selenium tissue concentrations in Rainbow Trout to productivity are in-progress. Fish productivity in the West Arm of Quesnel Lake was found to be similar to reference conditions.
- Concentrations of metals in fish were generally found to be variable and, with a few exceptions, the concentrations observed at exposed sites were similar to reference sites. Selenium in Polley Lake Rainbow Trout ovary tissue in 2015 was one of the few metal/tissue combinations that suggest a significant increase in metal accumulation may be present; however, this data set is considered anomalous relative to the preponderance of available selenium tissue data and was not duplicated by data collected in the spring of 2016. Notwithstanding the potential for anomalous data in a subset of the available ovary data, Golder recommends further evaluation of long-term trends in selenium concentrations and their potential for adverse effects to aquatic populations in a site-specific risk assessment and monitoring of selenium concentrations in Polley Lake biota as part of the CEMP.

5.0 NEXT STEPS

The next steps in the Rehabilitation and Remediation Strategy is conducting the Human Health and Ecological Risk Assessment (HHERA) and this work is currently underway. Supplementary investigations conducted during the summer of 2016 will provide addition data for the risk assessment and reduce uncertainty regarding environmental conditions. MPMC is moving ahead with further remediation of the affected areas on the mine site and in Hazeltine Creek and have also developed their CEMP, required under Permit 11678. The CEMP contains a detailed plan to monitor potential impacts associated with on-going operations and to provide confirmation that conditions associated with the tailings spill measured during these earlier investigations are either representative of conditions in the future, or that conditions will continue to improve over time.

6.0 CLOSURE

We trust that this report meets your needs at this time. If you have any questions regarding this work, please do not hesitate to call Trish Miller.

GOLDER ASSOCIATES LTD.

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APPENDIX A

Geochemical Characterization

Mount Polley Mine Tailings Dam Failure: Update on Geochemical Characterization of Spilled Tailings

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APPENDIX B

Soil Quality

Factual Report for Soil Investigation, Hazeltine Creek Floodplain

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APPENDIX C

Groundwater Quality

Factual Data Report on Groundwater Quality, Hazeltine Creek Floodplain, August 2015

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APPENDIX D

Surface Water Quality

Mount Polley Surface Water Quality Impact Assessment Update, March to August 2015

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Addendum to Mount Polley Surface Water Quality Impact Assessment Update.

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Results of Diffusive Gradients in Thin Films Device Deployment – August to October 2015.

Prepared by: Pierre Stecko, M.Sc., EP, R.P.Bio.

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APPENDIX E

Sediment Quality

Sediment Quality Data Report – August 2015 Collections

Application of the SEM-AVS Method and Selective Extraction Analysis in Evaluating Sediments Collected in the Vicinity of Mount Polley Mine – August 2015.

Prepared by:

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APPENDIX F

Toxicology and Benthic Invertebrate Tissue Metal Analysis

Investigation of the Influence of Sediment Physical Characteristics on Sediment Toxicity Test Results

Summary and Interpretation of Water Toxicity Tests (August to September 2014)

Summary and Interpretation of Water Toxicity Tests (Nov 2014 to Apr 2015)

Prepared by:

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Update on Post-event Aquatic Toxicity Testing – March to November 2015.

Prepared by:

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APPENDIX G

Lake Productivity and Lower Trophic Tissue Metal Analysis

Chemical Analysis of Benthic Invertebrates Collected in the Vicinity of the Mount Polley Mine – August 2015.

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Quesnel and Polley Lakes 2015 Plankton Update Report

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Mount Polley Mine – Update of Quesnel and Polley Lakes Productivity Assessment.

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APPENDIX H

Fish Tissue Metal Analysis

Summary of Available Fish Tissue Chemistry Data (2014-2015) for Assessment of Potential Changes in Concentrations related to the Mount Polley Tailings Storage Facility Dam Failure.

Prepared by:

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Summary of Selenium in Tissue Data Verification for Mount Polley Mining Corporation Frypan Gonad Tissue Samples – ALS Work Order L1621080 – ALS Corrective Action Report (CAR) #143968.

Prepared by:

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APPENDIX I

Terrestrial Ecosystem Assessment

Terrestrial Ecosystem Assessment of Hazeltine Creek Halo

Prepared by:

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APPENDIX J

Terrestrial Plant and Invertebrate Tissue Metal Analysis

Terrestrial Vegetation Data Report

Terrestrial Invertebrate Tissue Data Report

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APPENDIX K

Evaluation of the Mercury Biomagnification Potential in Quesnel and Polley Lakes

Review of Mercury Data in Quesnel Lake and Polley Lake

Prepared by:

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