REPORT

Remediation Plan

Mount Polley Mine Perimeter Embankment Breach

Submitted to:

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Executive Summary

This executive summary provides a high-level overview of the Remediation Plan (RP); however, because it is a brief summary, it should not be read in isolation of the full report.

Overview

The Mount Polley Mine, located in south-central British Columbia, 56 km northeast of Williams Lake near Likely, BC is an open-pit and underground copper and gold mine. On 4 August 2014, the failure of a glacial lacustrine layer beneath the Perimeter Embankment of the Tailings Storage Facility (TSF; "the breach") resulted in the release of a slurry of water, tailings, and dam construction material. The material released from the breach and the resulting debris flow resulted in physical impact to Hazeltine and Edney Creeks, Polley Lake, and Quesnel Lake. Approximately 1.36 km^2 of the breach area was scoured of forest and topsoil (floodplain zone). Tailings were also deposited on top of relatively undisturbed forest floor across an additional 100 hectares (ha; equivalent to 1.0 km^2) at the breach area. It is estimated that approximately 12.8 million m^3 (M m^3) of tailings was discharged to Quesnel Lake (plus an additional 5.8 M m^3 of native soil and TSF water) where some of that material settled in the West Basin over an area of approximately 1.81 km^2; and that an additional 1.6 M m^3 of tailings were deposited in the Polley Flats area and the Hazeltine Creek corridor.

Following the TSF breach an adaptive remediation framework was developed to guide and communicate the process of investigation, pollution abatement measures and remediation of areas affected by the breach. The strategy used a phased approach, focusing first on the immediate needs of establishing safe work conditions and controlling the further release of the tailings. To control turbidity, considerable erosion control work was carried out involving construction of a new foundational channel in Hazeltine Creek, designed with the foresight of re-establishing the creek as an aquatic and riparian habitat and planting adjacent soils. Habitat features have been installed on top of that foundational channel and though not yet complete, many of these habitat construction works have been advanced considerably and planning for them has been carried out through direct collaboration with environmental agencies and First Nations as well as their respective technical advisors for example, through the Habitat Remediation Working Group (HRWG).

The RP identifies the proposed remedial options and it outlines the rationale to select the preferred options where those have not already been selected during previous or ongoing work (e.g., by the HRWG). The RP is a requirement of the Ministry of Environment & Climate Change Strategy (ENV) Pollution Abatement Order (107461) which requires a RP that:

- Summarizes the remedial planning basis.
- Summarizes remedial actions that have already been carried out, including a description of the process and criteria that were used to evaluate options for remedial work that has been undertaken.
- Identifies the proposed remedial actions based on the results, conclusions and recommendations from the detailed site investigation, the human health risk assessment, and ecological risk assessment as delineated by area as defined in the Update Report: Post-Event Environmental Impact Assessment Report.

- Summarizes consultation on the remedial objectives and how the feedback received from that consultation has been accommodated within the remedial planning basis.
- Provides an implementation schedule.
- Provides a monitoring and reporting framework that will be integrated into the Comprehensive Environmental Monitoring Plan (CEMP) that is required in accordance with Permit 11678.

The remedial plan brings together agency requirements and commitments made by the Mount Polley Mining Corporation (MPMC), studies carried out to identify remedial needs and a roadmap towards compliance with the *Fisheries Act*, the *Environmental Management Act* and the *Water Sustainability Act*.

Remedial Planning Basis

The remedial planning basis provides a summary of the findings of previous studies that informed the evaluation of human and ecological risks, which in turn form the basis of the remediation that is needed to manage defined risks.

All scientific studies have uncertainties that are part of any scientific measurement. While uncertainty is not a basis for active remediation, such uncertainties do inform the need for monitoring and, if the monitoring results indicate that the objectives are not being met then they are used to identify further remedial actions as appropriate.

The remedial planning basis comes primarily from the human health and ecological risk assessments. The remedial planning basis is detailed by remediation area in the report; however, the impacts that require remediation are physical ones associated with scour and deposition of the breach-impacted water bodies and riparian areas. These physical impacts resulted in ecological effects in the form of fragmentation of water corridors in Edney and Hazeltine Creeks, loss of riparian vegetation, and the effects of those losses on aquatic organisms and riparian wildlife. Transient effects on water quality, mostly due to or associated with turbidity also occurred but these effects have subsided in most water bodies except for occasional increases in Hazeltine Creek, thought to be associated with remedial construction works. Changes to soil in the impacted area (such as a loss of organic carbon, soil nutrients and soil fauna), and changes to sediment (primarily low organic carbon content) particularly in the 1.81 km^2 of deposited outwash materials in Quesnel Lake, are also associated with risks for which remediation (or offsets) needs to be considered.

The remedial design basis comes from five outcomes that have connection to remediation. These are:

- Human health risks are acceptable and remediation for that purpose is not required.
- Some ecological risks are acceptable and remediation for that purpose is not required.
- Some ecological risks are acceptable but there is scientific uncertainty in that determination. Remediation is not identified for such risks, but monitoring is a requirement to address that uncertainty. Verification and, if data show it is necessary, then remedial work plans to address those risks would be developed.

- Some ecological risks are uncertain – neither an absence nor clear conclusion regarding risk can be made with current data. In such cases, a specific focused study/monitoring program is carried out as an addendum to the CEMP process. The results of that study will either identify the need for more detailed assessment, identify that risks are absent (compliance) or identify that remediation is required. For the latter finding, a remedial work plan would be developed.
- Remediation is clearly required (e.g., where an environmental effect has been identified without need for clarifying study). Remediation approaches are recommended in later sections of this plan. Because the remediation work is focused on habitat remediation, this includes identifiable physical work that has been completed, in progress, or to be carried out on site and habitat offsets to address impacts and productivity losses (including losses due to the passage of time) resulting from the breach.

Remediation Plan

Remediation Plan Components and Linkages

The remediation plan has been developed as information has been obtained from the numerous studies that have been carried out. The plan has connections to those studies, regulatory requirements, outcomes, and specific actions to be taken (e.g., habitat remediation and habitat offsets, monitoring). Figure ES-1 is a process diagram that outlines how risks and residual effects are managed: It outlines:

- The RP components that are identified for specific remedial actions.
- How remedial work is monitored and adjusted (either through repairs or adjustments to offset amounts) based on verification monitoring.
- How risks from tailings constituents in the environment are managed within the context of the various components of the remediation plan and how uncertainty, whether normal scientific uncertainty or uncertainty in whether a risk exists are addressed through the CEMP.
- How the RP is linked to compliance. In addition to standing regulatory requirements under both federal and provincial law, formal and specific regulatory requirements were invoked by ENV through the PAO and the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR) through an Engineer's Order issued pursuant to the *Water Sustainability Act*. Fisheries and Oceans Canada (DFO) has referred to the general provisions contained in the *Fisheries Act*.

Figure ES-1 is an overview-level diagram and the plan, its components, and specific approaches are detailed in the report itself.

Because the tailings constituent risks are currently being addressed through the CEMP, most of the remediation plan addresses remediation primarily for physical impacts. Additional remedial work plans to address tailings constituent risks may be necessary should monitoring demonstrate such need.

Creek Habitats

The overall remedial objective for impacted stream habitats is to restore the life history functions of fish, in particular salmonids, by constructing an engineered stream base in the otherwise erodible glacial lacustrine native soils below Hazeltine Creek, with habitat features to support an aquatic ecosystem. Design features will also restore life history functions for wildlife associated with small streams and their riparian environments. Based on the remedial planning basis for the creek habitat, remedial needs for creek habitat are associated with the physical impacts of the breach event.

Creek remediation has been ongoing since it was safe to access the area downstream of the TSF. The process of creek remediation is:

- Habitat objectives for each reach of stream habitat were determined by the HRWG.
- Based on these objectives, channel morphology and habitat characteristics are designed and reviewed with the HRWG before being constructed.
- Following the construction of habitat based on reach-specific objectives, the habitat is evaluated based on pre-determined criteria and residual effects of the TSF breach on fish habitat. The functionality and value of that habitat is evaluated to determine whether habitat offsetting measures to address residual effects is warranted. DFO policy is followed to evaluate, rank and select appropriate offsetting measures.
- All construction and repair is documented and record drawings are produced. Post-construction evaluation may result in adjustments or repair to installed habitat features resulting in another round of implementation and evaluation.

Lake Habitats

The residual effects in Quesnel and Polley Lakes arise from the physical impacts of the breach outflow and associated materials as well as the low organic carbon content of the tailings and scoured glacial soils underlying the Hazeltine Creek alignment. The ecological risk assessment indicated that altered water quality is no longer an operable pathway of effect and thus the focus of the identification of potential lake remediation needs was on physical effects.

Physical habitat remediation (e.g., of the shoreline) and offsets will be addressed by the HRWG whereas options for remediation of the bed of Quesnel Lake were evaluated in this report. The options considered were dredging, amendment with organic carbon (because addition of organic carbon improved test performance in sediment tests) and monitored natural recovery (MNR). Quesnel Lake benthic organisms are showing signs of recovery but do not yet have similar organism abundance or diversity as the reference location. An evaluation of the net environmental benefits of each of these three options identified MNR as the clearly preferred option because it retains the recovery that has already occurred to date and does not result in new disruption of the lake bed or various other effects from the disturbance associated with the other options. Productivity losses are addressed through offsets.

For Polley Lake sediments, the options evaluation was based on similar considerations although the circumstances of Polley Lake are different in terms of its stage of benthic community recovery (it is already similar in diversity and abundance to the reference lake) making MNR a clearly preferred option for similar reasons. An additional issue, unique to Polley Lake is the age class structure of Rainbow Trout which shows a decreased abundance of juvenile trout, inferred to be the result of the post-breach separation of Polley Lake from the outlet stream (Hazeltine Creek), the location of much of the spawning habitat that supported trout recruitment pre-breach. To help address the reduction in available spawning habitat a trout hatchery was developed. The construction of in-stream spawning habitat in upper Hazeltine Creek occurred in 2017 and Polley Lake trout were re-introduced to the upper reaches of Hazeltine Creek in 2018. The hatchery and re-introduction were both successful with an estimated 4,890 adults spawning in the constructed habitat and producing and estimated 40,000 juvenile trout while the hatchery produced an estimated 18,084 juvenile trout that were also released into Polley Lake.

Terrestrial Habitats

Terrestrial ecosystems include riparian areas, floodplains and upland areas that are at a higher elevation than even the highest water levels. The residual risks to terrestrial habitats are from the physical impacts of the breach outflow and because the tailings lack the heterogeneity and nutrient processing that is part of a healthy soil or sediment ecosystem. The physical impacts (e.g., undercutting of banks, scour) have in part been addressed through the re-contouring of the slopes along Hazeltine Creek; however, the loss of forest soils is part of the needed remediation.

The terrestrial remediation strategy takes a managed successional trajectory approach to remediation, based on the principles of ecological succession. Site preparation methods can be used to A) mix forest floor, mineral soils and any residual tailings to increase soil porosity, B) create raised microsites that have aerated root zones, and C) create plantable microsites. These approaches have been applied in the breach-impacted terrestrial areas. If monitoring indicates it to be necessary, soil fertility can be further improved in areas with nutrient deficiencies by applying soil amendments such as imported soils, microbial inoculum and fertilizer in planting zones or in each planting hole. In the areas where site preparation has yet to be applied, it is important to preserve the organic matter in situ as much as possible and avoid soil compaction during site work. Effort was made to retain existing forest soil to provide organic carbon and nutrients and, in particular, to provide a source of inoculum for beneficial soil microbes.

Once soil conditions are amenable to seed germination and growth, early successional species will establish, and late successional species will slowly colonize through dispersal from nearby seed sources. To assist this process, extensive planting efforts have been undertaken to establish early-mid successional native species in the TSF breach area.

Residual Effects and Offsetting

It is expected that additional habitat will need to be provided to offset for the loss of habitat use following the breach and before habitat remediation has been undertaken. The HRWG will have the role of evaluating and prioritizing offsetting options to be constructed. To assist the HRWG in prioritizing offsetting options, residual effects and preliminary offsetting estimates were prepared, and potential offsetting opportunities were identified.

Where possible the residual effects of the breach were estimated for aquatic habitats by first comparing the before and after condition of the Ecological Units (EU) defined by the HRWG to quantify spatial and temporal losses of productive use of the habitat. Habitat Equivalency Analysis (HEA) was then used to calculate the area of habitat that would be required to offset the lost productivity of a given ecological unit from the time it was damaged to the time it was reconstructed. This allows for an accounting of productivity lost over the time since the breach and allows a mechanism to make adjustments based on habitat verification monitoring of remedial or offset habitat construction. A similar approach was also followed for upland terrestrial habitat.

This evaluation resulted in one of the following determinations for each EU:

- No offsetting required: this category was applied to ecological units that were: 1) not physically affected by the breach; 2) access to the habitat was restored before it affected a given ecological function (e.g., spawning, rearing); or 3) the quantum reconstructed habitat was greater than the damaged habitat and lost productivity.
- Offsetting required: this category was applied to EUs for which a spatial or temporal deficit in productivity was quantified. For some EUs this is considered a preliminary determination because further reconstruction activities are either being planned or are underway. The HEA will need to be re-run when the remediation activities are completed to finalize the offsetting requirement.
- To be determined: this category was applied to EUs for which the losses in productivity cannot yet be quantified or where traditional offsetting approaches may not be suitable.

Monitoring

Monitoring at Mount Polley is carried out under the CEMP which has been approved with conditions and must be updated every three years. The CEMP, which is a required part of MPMC’s permits provides an adaptive framework and process for identifying monitoring needs and results across the whole of the mine. The main goal of RP monitoring is to support the successful implementation of the remediation plan and to verify that the remedial objectives have been met. In the event that the objectives have not been met, specific workplans focused on those areas will be developed with the benefit of the data obtained from the monitoring program. Because the technical backgrounds of specialists in monitoring programs that target chemical constituents and those that are focused on habitat construction success are different, the RP proposes that habitat success monitoring and adjustments be carried out through the HRWG. However, a single monitoring program could also work, provided that the necessary components were captured.

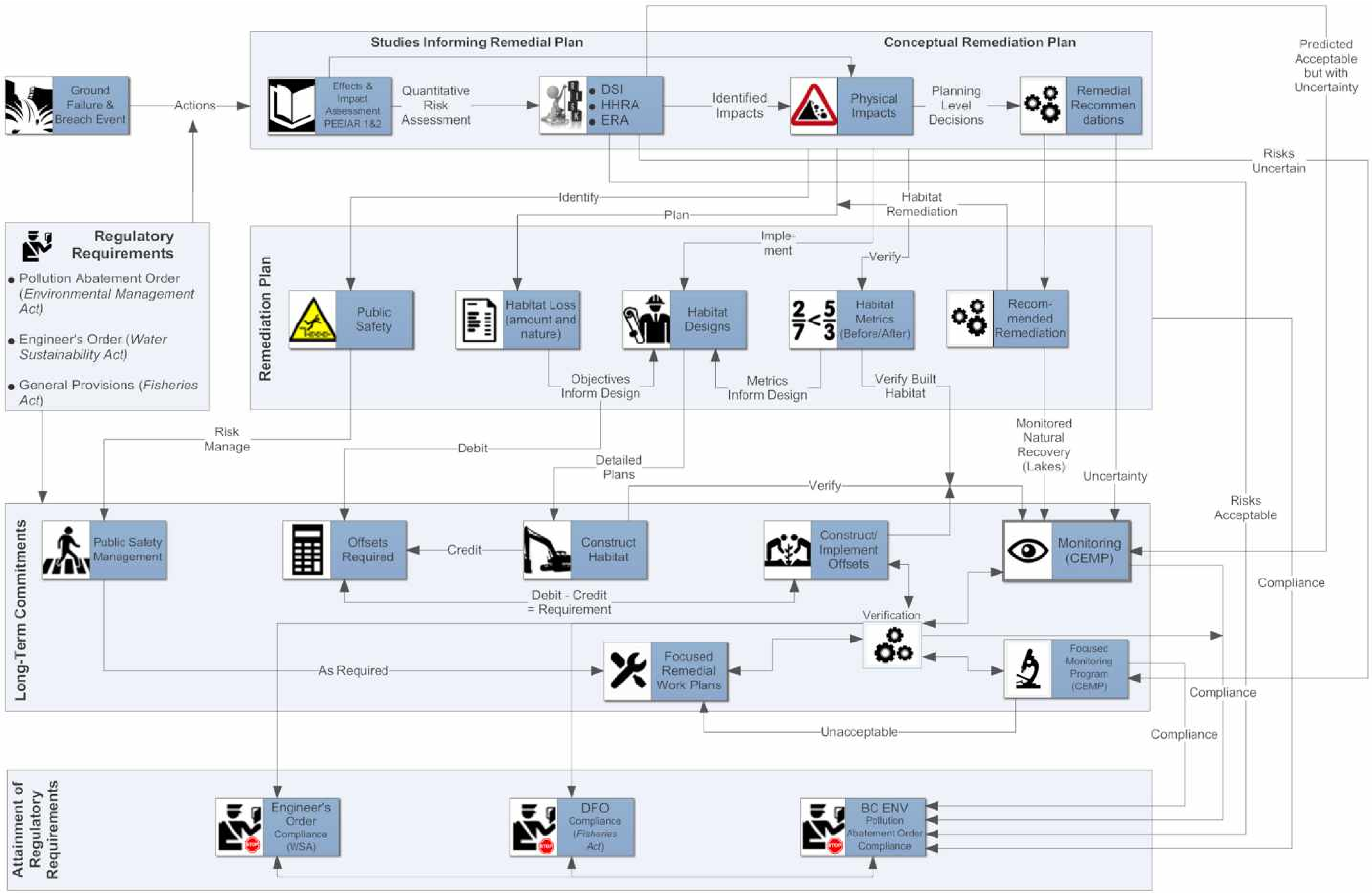

Figure ES-1: Diagrammatic Representation of Remediation Plan Component Linkages

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List of Abbreviations and Acronyms

% .... percent
ATV .... all-terrain vehicle
BC .... British Columbia
BEC .... Biogeoclimatic Ecosystem Classification
BLM .... biotic ligand model
CCHMC ....
CEMP .... Comprehensive Environmental Monitoring Plan
COPC .... contaminant of primary concern
CPUA .... catch per unit area
CPUE .... catch per unit effort
CRA .... commercial, recreational, and Aboriginal fishery
CSD .... cutter suction dredge
CSR .... Contaminated Sites Regulation
CWD .... coarse woody debris
DBH .... diameter at breast height
DCP .... Dynamic Cone Penetrometer
DFO .... Fisheries and Oceans Canada
DO .... dissolved oxygen
DSI .... detailed site investigation
EC1 .... Upper Edney Creek
EC2 .... Middle Edney Creek
EC3 .... Lower Edney Creek
EMA .... *Environmental Management Act*
EMPR .... Ministry of Energy, Mines and Petroleum Resources
ENV .... Ministry of Environment and Climate Change Strategy (formerly Ministry of Environment)
EO ....
EPT .... Ephemeroptera, Plecoptera, Trichoptera taxa
ERA .... Ecological Risk Assessment
EU .... ecological unit
FLNR .... Ministry of Forests, Lands, Natural Resource Operations and Rural Development
FPP .... Fisheries Protection Plan
Golder .... Golder Associates Ltd.
H1 .... Upper Hazeltine Creek
H2 .... Lower Hazeltine Creek
ha .... hectare
HEA .... Habitat Equivalency Analysis
HHRA .... human health risk assessment
HRWG .... Habitat Remediation Working Group
IC .... Implementation Committees
ICH .... Interior Cedar Hemlock
ICHmk3 .... Interior Cedar Hemlock Horsefly Moist Cool subzone variant

ICHwk2 .... Interior Cedar Hemlock Quesnel Wet Cool subzone variant
IERP.... Independent Expert Review Panel
km .... kilometer
LWD .... large woody debris
mg .... milligrams
m .... meter
MAF .... mean annual flood
mm .... millimeter
MDMER .... Metal and Diamond Mining Effluent Regulations
MOE.... Ministry of Environment (now Ministry of Environment and Climate Change Strategy)
MMER .... Metal Mining Effluent Regulations
MNA .... Monitored Natural Attenuation
MNR .... monitored natural recovery
MPMC .... Mount Polley Mining Corporation
NAG .... non-potentially acid generating
NEBA .... net environmental benefit analysis
NTU.... nephelometric turbidity unit
PAO .... Pollution Abatement Order
PBET.... physiologically based extraction test
PEEIAR.... Post-event Environmental Impact Assessment Report
PLC .... Public Liaison Committee
QL .... Quesnel Lake
QP.... Qualified Professional
ROV .... remote operated vehicle
RP.... Remediation Plan
SBEB .... science-based environmental benchmark
SCIB....
SOD .... small organic debris
TBD.... to be determined
TOC .... total organic carbon
TRV.... toxicity reference value
TSF .... Tailings Storage Facility
UBC .... University of British Columbia
Wbf.... bankfull width
WLIB ....
WQG.... water quality guidelines
WSA.... *Water Sustainability Act*
YOY .... Young of Year

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1.0 INTRODUCTION

1.1 Background

The Mount Polley Mine, located in south-central British Columbia, 56 km northeast of Williams Lake near Likely, British Columbia (BC) is an open-pit and underground copper and gold mine operating at a deposit formed approximately 200 million years ago and classified as an alkalic copper-gold porphyry. Primary ore minerals are chalcopyrite and bornite (copper sulfide minerals). Mining commenced in 1997, and produces approximately 22,000 tonne per day and employs approximately 350 persons when fully operational.

On 4 August 2014, the failure of a glacial lacustrine layer beneath the Perimeter Embankment of the Tailings Storage Facility (TSF; "the breach"), that was not appropriately characterized in initial geotechnical site investigations, resulted in the release of a slurry of water, tailings, and dam construction material. The TSF for the Mount Polley Mine is located on the east side of the mine site (Figure 1).

The material released from the breach and the resulting debris flow resulted in physical impact to Hazeltine and Edney Creeks, Polley Lake and Quesnel Lake. Approximately 1.36 km^2 of the breach-impacted area was scoured of forest and topsoil (floodplain zone). Tailings were also deposited on top of relatively undisturbed forest floor across an additional 100 hectares (ha; equivalent to 1.0 km^2) of the breach area. It is estimated that approximately 12.8 million m^3 (M m^3) of tailings was discharged to Quesnel Lake (plus an additional 5.8 M m^3 of native soil and TSF water), and that 1.6 M m^3 of tailings were deposited in the Polley Flats area and the Hazeltine Creek corridor. In areas where the tailings covered the forest floor, air exchange for plant roots and the soil microbial community was impeded causing a hypoxic or anaerobic environment for the plant roots, resulting in tree mortality.

The deposited breach materials exceeded some regulatory standards for soils and sediments (Golder 2016a), though it is noted that some of these standards were also exceeded in non-impacted soils and sediments. In the early post-breach stages, ambient water quality guidelines (WQG) in affected waters were also exceeded. Water quality has since returned to meeting WQG in most water, although exceedances of those guidelines still occur in parts of Hazeltine Creek. The WQG exceedances in Hazeltine Creek may be due to ongoing remediation-related construction activity and are being monitored to confirm expectations from geochemical studies (Kennedy et al. 2016).

Extensive environmental impact studies (MPMC 2015a; Golder 2016a; Nikl et al. 2016; Kennedy et al. 2016; Golder 2017a, b, c) and environmental remediation works (Bronsro et al. 2016; Ogilvie et al. 2018) have been undertaken since the breach. Immediately after the breach, Mount Polley Mining Corporation (MPMC) implemented a remediation strategy (Figure 1, described further below). That strategy included stabilization and containment of the breach and the tailings remaining in the TSF (estimated to be on the order of 75 to 80%), removal of the bulk of the spilled tailings, construction of sediment control ponds, construction of a new creek channel and other erosion control measures as well as ecological remediation (which included applying soil improvement and revegetation techniques to improve functional environmental values in the impacted areas). This work is ongoing and continues to improve the site conditions.

MPMC also developed a strategy following the breach to assist in the process of investigation and remediation of areas affected by the breach. The strategy followed a phased approach, focusing first on the immediate needs of establishing safe work conditions and controlling the release of the tailings. Many of these works have been advanced considerably and planning for them has been carried out through direct collaboration with government agencies and First Nations as well as their respective technical advisors; for example, through the Habitat Remediation Working Group (HRWG).

The original framework for the TSF breach response framework consists of four main phases (Figure 2) and nine identified remediation areas (Figure 1) that break up the breach-impacted areas into smaller management units. Ideally, the remediation framework phases are presented sequentially with the information generated or decisions made in one phase feeding into the planning, actions or definition of information needs for a subsequent phase. However, given the dynamic nature of the response and the environmental and regulatory conditions under which it was implemented, some of the actions required adaptive sequencing, but are nevertheless consistent with the intent of the framework (see for example Nikl et al. 2016). Some changes to the framework have occurred during implementation; for instance, the performance verification plan was replaced by the Comprehensive Environmental Monitoring Plan (CEMP).

Government and MPMC recognized that an adaptive response was required for an incident of this nature. The regulatory instruments (e.g., Pollution Abatement Order [PAO] 107461 [the Order], and the instructions issued pursuant to the Order) were themselves adaptive. Amended orders were issued by government during the response as physical works progressed, more data became available and government identified the need to adjust/update the contents of the order. The Remediation Plan (RP) lays out the basis for remediation such that the breach area is on a trajectory of self-sustaining ecological processes that result in productive and connected habitats for aquatic and terrestrial species.

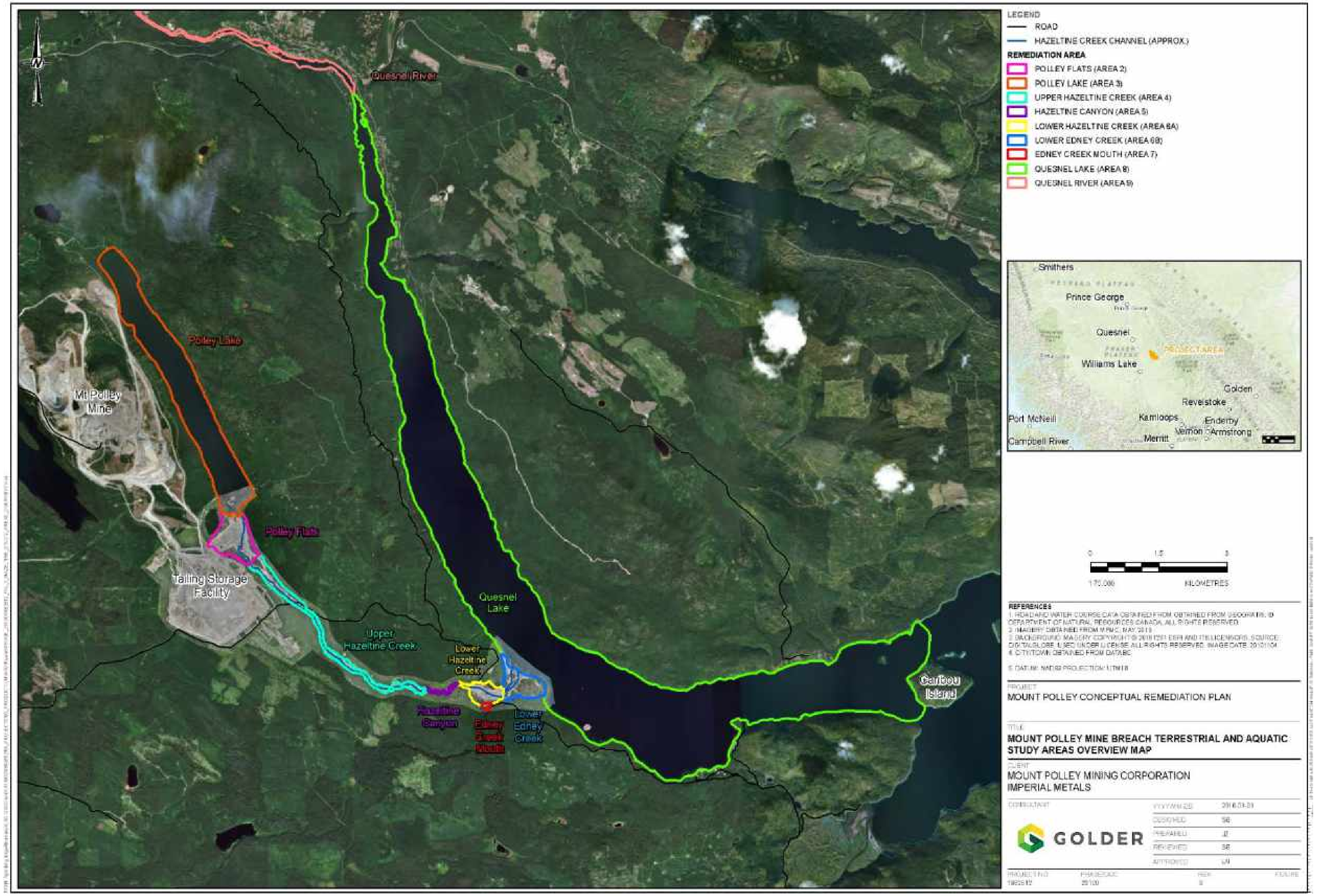

Figure 1: Mount Polley Mine Breach Terrestrial and Aquatic Remediation Areas Overview Map

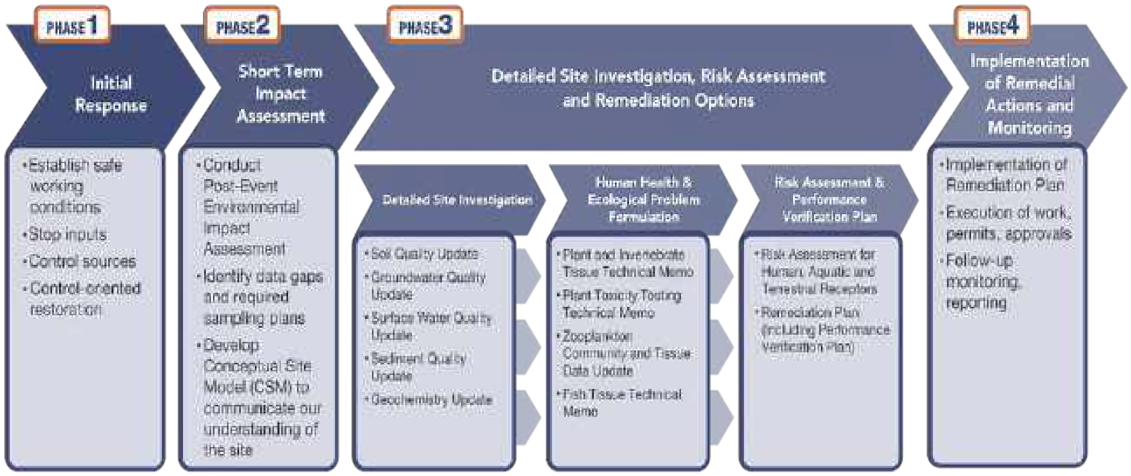

Figure 2: Mount Polley Tailings Storage Facility Breach Response Remediation Framework (this report represents the last element in Phase 3)

This RP was prepared for application to the area impacted by the 2014 TSF breach. Currently, remedial actions related to the breach are in the implementation or planning stages, depending on the specific area. This document describes the RP for the TSF breach-impacted area and identifies important issues that need to be considered so that further remediation can be undertaken in an efficient and compatible manner to maximize improvement of local ecosystems and fish habitat. Monitoring is an important part of the RP to assess the success of remediation and minimize risks and uncertainty. The verification monitoring program identified in this RP will become part of the CEMP. which includes breach-related monitoring carried forward to address uncertainties identified in the Ecological Risk Assessment (ERA) (Golder 2017c) and monitoring relating to permit conditions and other mine activities.

The RP follows common remediation practice as adapted for the specific circumstances of this site, though certain steps have necessarily been asynchronous, due to the adaptive response required (see above). Therefore, there are some differences in the report structure for each of the remediation areas because for some areas, remedial decisions were developed and implemented early in the breach response program (e.g., Upper Hazeltine Channel reconstruction), with options evaluations having taken place through the HRWG during the design-build process. In other areas, such as the profundal zone of Quesnel Lake where tailings material was deposited, an evaluation of remediation options is provided in this document.

1.2 Goals and Objectives

The scope of the RP considers the following requirements as contained in Section 3.0 of PAO 107461 (dated 9 June 2017):

i) A summary of the remedial planning basis (Section 3.0).

ii) A summary of remedial actions that have already been carried out, including a description of the process and criteria that were used to evaluate options for remedial work that has been undertaken (Section 4.0).

iii) The proposed remedial actions based on the results, conclusions and recommendations from the detailed site investigation (DSI), the human health risk assessment (HHRA), ERA, delineated by area as illustrated in Figure 1.

iv) A description of consultation completed with local First Nations and with stakeholders on the remedial objectives and how remedial objectives have been refined considering the outcome of such consultation (Section 3.4).

v) An implementation schedule (Section 6.0).

vi) Monitoring and reporting are a common expectation of a remediation plan; however, a monitoring and reporting framework will be integrated into the comprehensive environmental monitoring plan (CEMP) required in Permit 11678 and is therefore not included in this plan. A discussion on the implementation of monitoring for habitat remediation is provided in Section 6.0.

The definition of remedial actions as used here is adopted from the common definition provided by MOE (2015) and which means "…action to eliminate, limit, correct, counteract, mitigate or remove any contaminant or the adverse effects on the environment or human health of any contaminant". In this report, we have adopted remediation to also mean rehabilitation which has been used in the breach response program to refer primarily to the rehabilitation of ecological function due to physical impacts from the breach event. These definitions are sufficiently similar to expectations of Fisheries and Oceans Canada (DFO) and Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNR) such that this remedial plan is intended to provide a plan suitable for all environmental agencies. The regulatory and policy framework is further described in Section 2.0.

The remedial planning basis, which draws on the DSI, the HHRA and the ERA and outlines linkages between chemical and physical stressors, how these are being remediated and linkages to regulatory compliance requirements is provided in Section 4.0. Section 5.0 sets out specific remedial objectives and actions for each remediation area and identifies the impacts in need of remediation and offsetting amounts, based on available information at time of writing. Environmental remediation actions described in the RP integrate a range of technical disciplines including geotechnical and river engineering, geochemistry, aquatic and terrestrial ecology and ecological and human health risk assessment. The remediation actions described here incorporate input from the HRWG which includes representatives of MPMC and its consulting team, government and the local First Nations. The HRWG were also involved in the development of the reports that form the remedial planning basis.

This RP seeks to:

- Outline the remediation activities that MPMC have conducted and outline how those remedial decisions were made.
- Outline the basis (rationale) for remedial planning and decisions.
- Outline the components of the remedial plan and their linkages between physical remedial works such as for damaged habitats and how metal contaminants are addressed through risk management, additional study where risks are uncertain or monitoring where there is uncertainty and, where monitoring studies show that risk management is insufficient, the development of focused remedial work plans to address those.
- Identify areas and amounts where further remediation is needed.

- Identify options for remediation where applicable.
- Discuss advantages/limitations of remediation options.
- Make recommendations for remediation where needed.
- Develop a plan and schedule for remediation of additional areas where needed.
- Identify monitoring components that are applicable to the RP such that there is a logical linkage between the RP and the CEMP (also as noted above to address uncertainties in risk assessments).

Detailed workplans and designs are not typically provided within a RP. The detailed workplans will be developed within the context of the RP but external to the RP, for instance as guided by the outputs of the HRWG (see Section 3.3).

1.3 Remediation Areas

Remediation areas were defined early in the breach response. The areas were numbered approximately in the order of the event propagation and were defined based on distinct physical and biotic differences in the downstream area when compared to the upstream area. These remediation areas start at the TSF (Area 1), and continue on to Polley Flats (Area 2, which includes the previously named "Polley Plug" area), Polley Lake (Area 3), Upper Hazeltine Creek (Area 4), Hazeltine Canyon (Area 5), Lower Hazeltine Creek (Area 6 – which includes Lower Edney Creek), Edney Creek Mouth (Area 7), Quesnel Lake (Area 8) and Quesnel River (Area 9) (Figure 1). The areas were defined to better manage interim assessment and remediation efforts, and to define knowledge gaps to be addressed by subsequent studies. The remediation areas and interim remediation plan, originally produced as a table, were also developed to enable communication of the work and direction of future work to agencies, the local community and First Nations. Detailed descriptions of these areas are provided in Section 4.0.

For planning and execution of the habitat remediation work, Hazeltine Creek is further described by six stream reaches based on several attributes including dominant valley and stream types, stream order and tributary confluences, major infrastructure, and vegetation characteristics. Stream reaches are delineated in Figure 3 and described in the Section 4.0.

Aquatic habitat has also been divided into aquatic ecological units (EUs), based on fish community and the nature of disturbance, as part of the outputs of the HRWG (Figure 4). Edney Creek was split into three ecological units (E1 to E3), Hazeltine Creek was split into two EUs (H1 and H2), Quesnel Lake was split into three EUs (Limnetic, Littoral, and Benthic[1] zones), and Polley Lake and Quesnel River are each their own ecological unit (similar to the remediation area definitions). Additional information on these ecological units and how they are used is provided in Section 4.0. The ecological units approximately correspond to the remedial areas. The assessment and delineation of tailings and tailings constituent contamination has been delineated using the remedial areas (Figure 1 and Figure 3) whereas the EU delineations are more directly applicable to the remediation of aquatic habitats (Figure 4). In the text descriptions, we have attempted to cross reference each of these approaches to remedial areas.

[1] Also known as the "profundal" zone

LEGEND
- REACH
- ROAD
- WATERCOURSE
- HAZELTINE CREEK CHANNEL (APPROX.)

REMEDIATION AREA
- POLLEY FLATS (AREA 2)
- POLLEY LAKE (AREA 3)
- UPPER HAZELTINE CREEK (AREA 4)
- HAZELTINE CANYON (AREA 5)
- LOWER HAZELTINE CREEK (AREA 6A)
- LOWER EDNEY CREEK (AREA 6B)
- EDNEY CREEK MOUTH (AREA 7)
- QUESNEL LAKE (AREA 8)
- QUESNEL RIVER (AREA 9)

AREA NUMBER	AREA NAME	AREA (HECTARES)
2	Polley Flats	70.27
3	Polley Lake	385.21
4	Upper Hazeltine Creek	67.43
5	Hazeltine Canyon	4.28
6A	Lower Hazeltine Creek	29.15
6B	Lower Edney Creek	46.72
7	Edney Creek Mouth	2.05
8	Quesnel Lake	13126.07
9	Quesnel River	69.89

0 0.5 1
1:24,000 KILOMETRES

REFERENCES
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4. DATUM: NAD83 PROJECTION: UTM10

CLIENT
MOUNT POLLEY MINING CORPORATION
IMPERIAL METALS

PROJECT
MOUNT POLLEY CONCEPTUAL REMEDIATION PLAN

CONSULTANT
GOLDER

YYYY-MM-DD	2019-03-21
DESIGNED	EB
PREPARED	JZ
REVIEWED	EB
APPROVED	LH

TITLE
MOUNT POLLEY MINE BREACH TERRESTRIAL AND AQUATIC STUDY AREAS

PROJECT NO.	PHASE/DOC	REV.	FIGURE
1894924	23100	0	

Figure 3: Overview of Stream Reach Designations

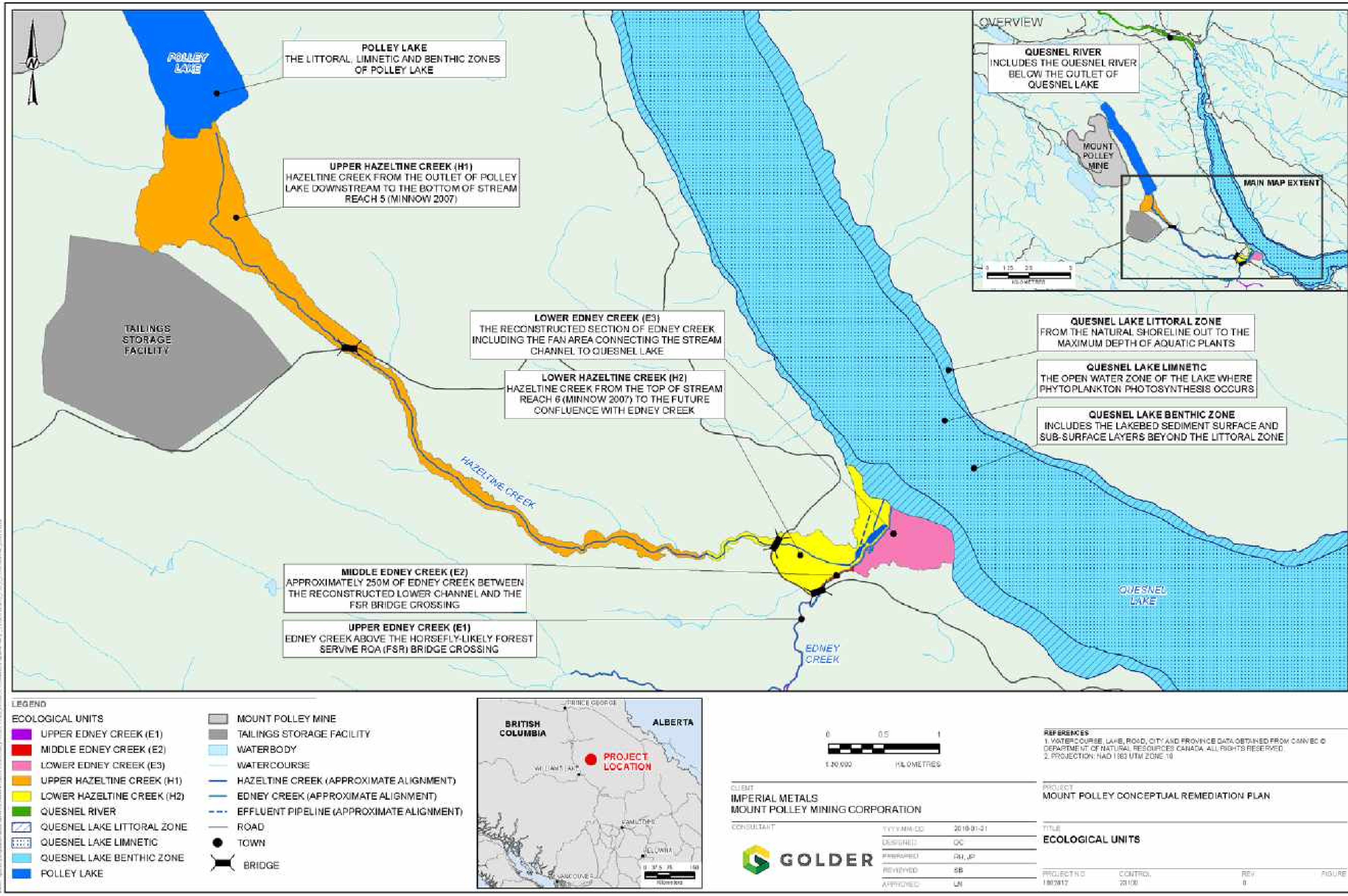


Figure 4: Map Showing the Ecological Units as Used by the Habitat Remediation Working Group

2.0 REGULATORY AND POLICY FRAMEWORK

This section articulates the regulatory requirements that form the basis of this RP. MPMC has obligations under PAO 107461 issued on 9 June 2017 (amending and consolidating previous Orders) pursuant to Section 83 (1c) of the *Environmental Management Act* (EMA). This overview is limited to remediation of the breach response event which is the subject of this RP; however, it is noted that the Mount Polley Mine is subject to other regulatory and policy drivers such as various operational permits, and the federal Metal and Diamond Mining Effluent Regulation (MDMER)[2].

While the repairs to the damaged portion of the perimeter embankment was part of breach response, those repairs, while ultimately environmental in outcomes, are of an engineering nature and have been regulated externally to PAO 107461 by BC Ministry of Energy, Mines and Petroleum Resources (EMPR). The breach repair and additional subsurface investigations and structural upgrade work has been completed and has been reviewed and inspected by government and by an Independent Expert Review Panel (IERP). It is not the subject of the RP which primarily deals with environmental matters.

2.1 Federal

Federal legislation and policy that applies to the breach response and remediation comes from the general provisions of the *Fisheries Act* regarding "Fisheries Protection and Pollution Prevention" (Sections 35 through 38). Early in the response, it was determined by DFO that an Authorization under the *Fisheries Act* was not required to remediate Hazeltine Creek (DFO 2014); however, that determination came with recommendations by DFO and reciprocal desire by MPMC to develop a framework for establishing habitat remediation objectives for each of the impacted areas and a recommendation that provincial agencies and First Nations be included in the development of such objectives. The resulting process was the establishment of what is presently called the HRWG that provides a collaborative process including federal and provincial agencies and First Nations that collectively contribute to the establishment of remedial objectives, an evaluation of the habitat design options to deliver those objectives and monitoring to verify objectives attainment. This collaborative process also provides a means by which agency mandates are met (e.g., *Fisheries Act* – S.38, BC *Water Sustainability Act* – Engineer's Order (EO), see below).

It is noted that while the Mount Polley Mine is subject to the MDMER because it is an operating metal mine, the remedial plan addresses the breach response and not mine operations which are addressed separately by MPMC.

The Fisheries Protection Program (FPP) of DFO administers the fisheries protection provisions of the *Fisheries Act*. The FPP manage impacts to commercial, recreational, and Aboriginal (CRA) fish and fish habitat through a set of policies that include the general guidance provided by the Fisheries Protection Policy Statement and the guiding principles related to the creation or enhancement of fish habitat provided by the Fisheries Productivity Investment Policy. DFO is a member of the HRWG and this is currently the main vehicle through which fish habitat remediation is provided direction and has linkages to the provincial requirements as described in the following section.

[2] The MDMER replaced the Metal Mining Effluent Regulations (MMER) in 2018.

2.2 Provincial

The main provincial regulatory mechanism applicable to the breach response has been PAO 107461. This PAO and its supporting legislation provides the BC Ministry of Environment and Climate Change Strategy (ENV) with broad powers to compel, among other actions, studies that quantify the impacts of the breach, measures to stop further discharges, identify and implement remediation works and to provide reports related to those measures. The documents that form the remedial planning basis (e.g., Post-event environmental impact assessment reports [PEEIAR], DSI, HHRA, and ERA) were requirements of the PAO and this RP also became a requirement of that PAO. A PAO is issued when ENV believe that “pollution” (as defined in EMA) has occurred, or is occurring, and that measures are needed to abate (decrease) pollution. An example of pollution abatement measures carried out by MPMC included stopping the discharge of turbid flows into Quesnel Lake along Hazeltine Creek. By agreement with the local First Nations, the provincial government exercises its authorities with the participation of the First Nations through a government-to-government (G2G) relationship and full information sharing has been a part of that agreement.

A provincial permit for the discharge of treated water (Permit 11678) primarily deals with matters of mine operation and not breach response; however, a condition of that permit is for an updated CEMP. The CEMP includes not only monitoring related to the permit but also includes monitoring related to the breach. Its inclusion as a permit condition provides ENV with an enduring means to compel breach-related monitoring. The CEMP is a key component of the RP as it is the main vehicle to address scientific uncertainty and situations where risks are uncertain. The CEMP also provides a suitable mechanism to adjust (adapt) the monitoring program to data that are collected in the future.

The *Water Sustainability Act* (WSA), which replaced the recently repealed *Water Act*, governs several activities related to habitat remediation, most directly so with regards to the remediation of Hazeltine Creek where there are works in and about a stream. The FLNR are responsible for the WSA and have issued an Engineer’s Order under that Act, dated 31 October 2014, amended 10 August 2015 and varied by way of letter. The underlying premise behind the Engineer’s Order arises from Section 46 of the WSA which prohibits the introduction of foreign material into a stream in such quantities that cause adverse impacts to the stream, existing water users, property owners aquifers or the aquatic ecosystem and Section 47 of that Act which sets out the authorities of the Engineer to order works in respect of Section 46.

The authorities available under this order also include consideration of impacts to physical and chemical conditions in the aquatic habitat in the streams, rivers and lakes. That order enabled and required several remedial actions such as Quesnel and Polley Lake debris removal from the lake surface and shorelines, management of Polley Lake water levels for safety purposes (when there was concern about the “Polley Plug”), bridge replacement work (Gavin Lake Road Bridge and Ditch Road Bridge), and habitat remediation work. Additionally, the Order is an enabling document in that the necessary “works in and about a stream”, particularly the habitat remediation work can lawfully proceed in accordance with the WSA.

The Engineer’s Order contains 3 requirements, which, as noted in the cover letter, are to have works carried out consistent with instructions from other provincial ministries and federal agencies. The 3 requirements are:

- Collect and remove such debris from Hazeltine Creek, Quesnel Lake, and Polley Lake that threaten public safety, road infrastructure and stream channel stability.
- Maintain the lake level of Polley Lake in a manner that prevents further mass movement of material from Polley Lake and Hazeltine Creek.

- In accordance with direction of the Provincial and Federal government officials: undertake habitat remediation work on Edney Creek, Hazeltine Creek, Quesnel Lake, and Polley Lake.

There is an expectation under the WSA that the natural functioning state of the impacted environment be returned (Section 47 (1) (c)). In situations where that is not feasible, or the functioning condition of the environment has been impaired, additional compensatory measures (offsetting) may be ordered by the Engineer as per section 47(2) of the WSA. A temporary water license (5002-458) was also issued by FLNR and this license enables habitat remediation work to be carried out outside of the mine area.

While there are differences between the various federal and provincial environmental requirements and agency specialization, in all cases a return to productive function of the impacted environment, and offsets for the residual effects are shared commonalities. While there may be some minor policy differences in how these requirements could be operationalized, these operational differences can be resolved through dialogue with MPMC and the three main agencies involved (ENV, FLNR, and DFO). At present, the forum for such discussions is the HRWG and the PAO. Although the HRWG primarily has a technical function, its membership includes those with agency authorities. This group will help to determine the point at which the impacts from the breach have been sufficiently remediated and/or offset and the Engineer may choose to accept their advice as a basis for compliance with the Engineer's Order.

3.0 REMEDIAL PLANNING BASIS

The remedial planning basis provides a brief review of the various studies (and compilations of studies) that identified the impacts of the TSF breach event and that evaluated the chemical and physical risks to human and ecological receptors, including physical risks affecting aquatic and terrestrial habitats and public safety. For detailed information on those study findings, the reader is referred to those studies directly. Human and ecological risk assessment quantifies whether changed conditions are (or are not) safe for people, plants, and animals. If they are clearly unsafe, those residual effects must be remediated, or the risks must be managed so that following such management, they are no longer a risk.

In addition to identified risks, there are uncertainties associated with all risk assessments. An uncertainty is not a risk that requires remediation, but the delineation of those uncertainties identifies issues that should form part of a monitoring program to verify risk where conclusions may lack adequate certainty. Such components of a monitoring program do not directly trigger a need for physical remediation work but do form part of verification monitoring, in this case carried out through the CEMP, and are part of risk management for those areas where the main concerns are tailings-related contaminants (e.g., copper exceeding soil standards). There may also be circumstances where risks are uncertain and where further study is necessary to resolve a possible risk. The remediation plan (Section 4.0) addresses both types of uncertainty and includes a feedback step for the development of focused remedial work plans should monitoring indicate that action is necessary (Figure 8).

3.1 Overview

A detailed description of the physical, chemical, and biological alterations observed following the TSF breach was provided in the 2015 PEEIAR and the 2016 update (MPMC 2015a; Golder 2016a), and in various other publications (Nikl et al. 2016, Bronsro et al. 2016, Kennedy et al. 2016). These information sources provide a quantification of the physical, chemical and biological impacts resulting from the breach. The significance of those impacts, in the specific context of the health of people and ecological impacts, were evaluated in the HHRA (Golder 2017b) and the ERA (Golder 2017c). The assessment of risks identifies the significance of impacts in the form of residual risks that may require remediation. Such residual effects form the basis of the resulting RP.

In summary, the TSF breach resulted in water, tailings and perimeter embankment construction materials (collectively referred to as outwash materials) to be released to Polley Lake, Hazeltine Creek, and Quesnel Lake. This release also eroded the slopes adjacent to Hazeltine Creek, removing the forest vegetation and native soil over an area of approximately 1.36 km^2, and depositing outwash material above relatively undisturbed forest floor across an additional approximately 1 km^2. Several hundred meters of lower Edney Creek was eroded which led to the lower portion of that creek being incised with a step of a few meters drop, preventing migration of fish from Quesnel Lake to Edney Creek. However, the middle and upper reaches of Edney Creek were unaffected by the breach, and the reconnection of middle and upper Edney Creek with Quesnel Lake was made a priority (Bronsro et al., 2016). A mixture of tailings and scoured native material was transported to Polley and Quesnel Lakes. Approximately 12.8 M m^3 of tailings (plus an additional 5.8 M m^3 of native soil and TSF water) was deposited to Quesnel Lake (MPMC 2015a). The chemical composition of sediments at the bottom of Quesnel and Polley Lakes and along the Hazeltine Creek corridor, reflect the composition of those tailings and other outwash materials. In particular, copper, was elevated above numeric sediment quality guidelines.

A high-level remediation framework was developed early in the breach response program (Figure 2) and that framework continues to be followed. Although that framework implies sequential steps, some of the impacts described above required early actions (e.g., the mouth of Edney Creek as noted above) and options were considered and evaluated with the input of government, First Nations and stakeholders. As of the time of writing, the status of the remediation framework is as follows:

- Phase I (Initial Response) involved the initial Hazeltine channel reconstruction and armouring to stabilize the channel (Bronsro et al. 2016), and the repair and upgrading of the TSF embankment.
- Phase II (Short-Term Impact Assessment) outputs were included in the PEEIAR (MPMC 2015a) and an update to that report based on subsequently collected data (Golder 2016a).
- Phase III of the remediation strategy, which is an active stage, included the preparation of a DSI, an HHRA and an ERA. This phase of the remediation framework focuses on the long-term conditions that remain following the initial impact and implementation of short-term remedial measures (e.g., channel for Hazeltine Channel/Edney Creek re-constructed and conveying water from the Mine Site to Quesnel Lake). This phase identified that unacceptable risks to human health were not present. The ERA identified either that risks were acceptable, acceptable with uncertainty or, in a few instances, risks were uncertain. Uncertainty is addressed through monitoring activities outlined in the CEMP and uncertain risks are addressed through separate, specific studies designed to answer those questions (as illustrated in Figure 8, Section 4.1). Known risks that require remediation (residual effects) are identified (Section 5.0) and these included physical impacts. The RP provides a quantification of the impacts that require remediation and/or may require offsets, a means to risk manage areas contaminated by tailings, a means to address uncertainty, and a process to verify the adequacy of remediation as it progresses.
- Phase IV of the remediation framework is the implementation of the RP. This will remain an active phase as part of MPMC's Long Term Commitments (Figure 8, Section 4.1) and is expected to draw on the input of the HRWG to address DFO and FLNR requirements and on the CEMP process to address risk management and uncertainty. Linkages contained within the remediation plan are further detailed in Section 4.1.

3.2 Previous Reports: Summary of Findings

Numerous reports and studies have been prepared following the TSF breach that discuss the current conditions and proposed remedial actions. A few of these recent reports, which are key background reports to the Remediation Plan are listed below:

- Post Event Environmental Impact Assessment Report (MPMC 2015a).
- Post Event Environmental Impact Assessment Report: Update Report (Golder 2016a).
- Detailed Site Investigation and DSI Addendum (Golder 2017a).
- Human Health Risk Assessment (Golder 2017b).
- Ecological Risk Assessment (Golder 2017c).
- Book of Appendices (used for both the HHRA and the ERA) (Golder 2017b, c).

High level summaries of these reports are provided below, with focus on aspects related to remedial planning. However, the reader should refer to those reports for specific details and data. In some cases, additional work has been conducted and monitoring data have been collected since these reports were submitted to government. It is not the intention of this section to update the reports and studies summarized in this section with newer data. Where relevant to remediation planning, newer data are provided in Section 4.0. The most current data are available in the annual data reports prepared by MPMC.

3.2.1 Post Event Environmental Impact Assessment Reports

The objective of the PEEIAR was to provide an assessment of the physical, chemical, and biological impacts of the tailings spill on terrestrial and aquatic environments. Because of the effects of season and studies that were in progress at the time of writing of the PEEIAR in 2015, an update document was produced with additional data collected subsequent to the 2015 PEEIAR. The update document was also intended to address comments from reviewers of the first PEEIAR. These documents also provided data that were used in the subsequent DSI, HHRA and ERA reports and, consistent with the adaptive nature of the breach response, the information developed in the two PEEIAR reports were also used to structure subsequent data collection and the study design of those subsequent reports.

The PEEIAR and its update concluded that the tailings spill resulted in physical impacts to Polley Lake, Hazeltine Creek, the mouth of Edney Creek, and the benthic environment in the West Basin of Quesnel Lake and the communities in those environments (MPMC 2015a, 2016). It also provided an initial delineation of tailings constituent (e.g., copper) concentrations, their distribution in the impacted areas and provided and estimate of the volume of material spilled and toxicity and other testing results. The data contained within the PEEIAR and its update formed part of the dataset used to guide subsequent studies and evaluate human and ecological risks, the results of which form the basis of remedial planning.

3.2.2 Summary of Detailed Site Investigation (DSI) and DSI Update

Golder (2016a) carried out a DSI and DSI update to characterize and delineate contamination associated with the TSF breach. A DSI is commonly used to define areas of contaminant concentration and, where concentrations exceed standards, the data are used to support the assessment of those risks in the form of an HHRA or ERA.

The impacted physical environment around Polley Lake, Edney Creek and Hazeltine Creek included approximately 136 ha (1.36 m^2) where topsoil was removed and an additional area of approximately 100 ha (1 km^2) where tailings were deposited overlying intact topsoil.

In some areas, the tailings settled out in two distinct layers: a grey fine silt and a black-orange sand. The two layers settled out according to particle size and density, generally with the finer material overlying the coarser sand. As the debris flow moved down the Hazeltine Creek alignment, it picked up and mixed with native till and other glacial sediments (fluvial and lacustrine) as well as native organic soils. Approximately 20 M m^3 of tailings, native soil, water and debris were deposited into Quesnel Lake where a very fine-grained turbidity plume formed and persisted below the thermocline at approximately 20 to 30 m below surface. The plume is interpreted to have included a significant amount of fine-grained natural lake sediment that became suspended by the debris flow from Hazeltine Creek. Turbidity in Quesnel Lake persisted into December 2014 but decreased over the winter.

Together, the soil, sediment, groundwater and surface water results indicate that while tailings-related metals are present above Contaminated Sites Regulations (CSR) standards in these media, research on impacted site materials has indicated that the leachability and migration potential of metals in these materials is low and that there are secondary geochemical controls on the materials which together suggest the bioavailable phase to be low (Kennedy et al. 2016). However, sampling of seeps has indicated elevated copper and monitoring of the geochemical predictions remains an appropriate component of the CEMP.

Section 7.0 of the DSI Update provides the following information:

- identification of areas of potential environmental concern
- determination of the potential contaminants of concern based on the applicable CSR standards
- delineation of the horizontal and vertical extent of contamination
- confirmation that the contamination at the site is stable or decreasing in concentration and extent over time

Because the remediation of the TSF breach is determined based on risks, the DSI/DSI Update does not directly provide a remedial planning basis (particularly for habitat damage) but does provide some of the information to support the assessment of risks (i.e., HHRA and ERA) and the identification of residual effects which are the drivers for the remediation plan.

3.2.3 Summary of Human Health Risk Assessment Findings

The HHRA (Golder 2017b) was conducted based on provincial guidance on the conduct of human health risk assessments and was externally reviewed by consultants retained by government and by First Nations and who have specific experience in the conduct of HHRAs. In response to requests by reviewers, the selection of contaminants of primary concern (COPCs) for the risk assessment was expanded beyond the methods outlined in guidance in order to consider substances not typically regulated under the CSR (i.e., aluminum). No COPCs were identified in soil; however, aluminum, copper and vanadium were conservatively[3] retained for the assessment of the ingestion of berries, traditional plants, wild game fish tissue and cattle pathways as part of a multi-media evaluation.

Risks to the subsistence and traditional land user, hiker/camper, all-terrain vehicle (ATV)/snowmobile user, boater/kayaker, sport fisher, hunter/trapper, Quesnel Lake resident, logger and mine/remediation worker from exposure to aluminum, copper and vanadium were evaluated in the HHRA. Specifically, the following exposure pathways were evaluated:

- Subsistence and Traditional Land User: incidental sediment and soil ingestion, dermal contact with sediment, soil and surface water, inhalation of soil particulates, ingestion of surface water and ingestion of berries, traditional plants, deer meat, deer liver, moose meat, moose liver, fish and grouse.
- Hiker/Camper: incidental sediment and soil ingestion, dermal contact with sediment, soil and surface water, inhalation of soil particulates, ingestion of surface water and ingestion of berries.
- ATV User: incidental soil ingestion, dermal contact with soil, inhalation of soil particulates, ingestion of surface water and ingestion of berries.

[3] Reference to conservatism or conservative approach in this report mean that the approach taken was a cautionary one.

- Boater/Kayaker: incidental sediment ingestion, dermal contact with sediment, ingestion of surface water and ingestion of fish.
- Sport Fisher: ingestion of surface water and ingestion of fish.
- Hunter/Trapper: incidental soil ingestion, dermal contact with soil, inhalation of soil particulates, ingestion of surface water and ingestion of deer, moose, fish and grouse.
- Quesnel Lake Resident: incidental sediment ingestion, dermal contact with sediment and surface water, ingestion of surface water and ingestion of berries, deer, moose, fish, grouse and cattle.
- Logger: incidental soil ingestion, dermal contact with soil, inhalation of soil particulates, ingestion of surface water, and ingestion of fish.
- Mine/Remediation Worker: incidental soil ingestion, dermal contact with soil, inhalation of soil particulates, ingestion of surface water and ingestion of berries and fish.

The hazard indices for these receptors were below the threshold of 1.0. This means that the dose that receptors are exposed to is less than the toxicity reference value, indicating that the conditions are not a risk to human health.

3.2.4 Summary of Ecological Risk Assessment Findings

An Ecological Risk Assessment was conducted to evaluate the ecological significance of the altered environmental conditions (physical, chemical, biological) that are present in the study area because of the TSF breach (Golder 2017c). Risk management and remediation activities have been underway since the TSF breach occurred and the physical impacts associated with the initial release are being addressed through a broad and consultative habitat remediation program through the HRWG. The breach response has been an adaptive program in which data collection and evaluation have been conducted on an ongoing basis since the breach to address a wide variety of investigation needs, regulatory requirements and information requests from First Nations and the Public. The data collected have been used to inform the design of subsequent stages of study. The risk assessment evaluates the available data considering the long-term management goal of successfully reintroducing a biologically diverse, functional, self-sustaining, and inter-dependent ecosystem.

The risk assessment was intentionally conservative in its approaches, assumptions, and decision criteria, consistent with relevant guidance and common practice in BC. A problem formulation identified the extent of the study, established the objectives of the risk assessment and formed the basis of the conceptual site model. The conceptual site model articulates the risk assessors understanding of the system under study including the ecological stressors and their sources, receptors of interest, and potentially significant exposure pathways. The conceptual site model considers the site investigation data and the understanding of the physicochemical properties and fate of the COPCs. The ERA drew extensively on not only the DSI and DSI Update but also the PEEIAR and its update and various studies carried out as part of the breach response program. An exposure and effects assessment was conducted using a weight of evidence approach that evaluated different types of data such as chemical measurements, toxicity testing and community structure data as would be present in an integrated assessment. The weight of evidence assessment enabled the articulation of the magnitude of risks for each of the major ecosystem components. The conclusions for individual ecosystem components are provided in Sections 3.5 and 4.9 of the ERA (Golder 2017c) for the terrestrial and aquatic risk assessments, respectively. The following are the main findings of the ERA:

- Copper is the primary contaminant of primary concern (COPC) associated with tailings, irrespective of whether tailings were deposited to land or water. There were no other chemical constituents that were found to be a significant ecological risk that was attributable to the TSF breach. The tailings also have deficiencies in terms of soil structure or nutrient/organic carbon that are important non-contaminant stressors.
- Numerous lines of evidence showed that the copper associated with tailings has low bioavailability. This finding was consistent in sediment, water, and soil. However, some copper uptake was noted in sample results (discussed in more detail in Section 4.7.3 of the ERA) though toxicity testing did not indicate that the degree of bioavailability/exposure was harmful. The relative influence of copper versus physical factors will need to be confirmed through monitoring.
- Assessment of several ecosystem components was made with the benefit of laboratory-based toxicity testing or other tools that allowed for experimental verification that the structural and nutrient deficiencies in the tailings are a cause of reduced performance. The specific attributes contributing to the deficiency varied somewhat by media (e.g., total organic carbon in sediment; plant available nutrients and bulk density in soil) but were broadly related to the fact that the tailings lack the heterogeneity and nutrient processing that is part of a healthy soil or sediment ecosystem. This deficiency is expected to decrease over time as organic carbon and biological function returns to the system (Frouz et al. 2008).
- The balance of evidence from the laboratory studies and experimentation, field observations, and inferences based on case studies or relevant literature is that the adverse effects associated with the structural and nutrient deficiencies in tailings, whether as sediment or as soil will have a larger influence on the speed of recovery/recolonization than the influence of copper. The risks associated with copper are low; where ecological risk levels were considered moderate, these were primarily associated with disruption to the physical substrate. For some components of the risk assessment, the findings were uncertain (e.g., risks to amphibians) and these have been carried forward to specific studies designed to address the uncertainties (see for example Figure 8).

The risk assessment findings by area are further summarized in the following sections and key uncertainties or areas of uncertain risk, as well as monitoring considerations for the CEMP, are summarized in Table 1. The RP is structured around known risks. However, the plan also includes feedback mechanisms from the CEMP and related focused studies (to address uncertain risks). Should monitoring or the results of those studies identify that there is a risk that requires remediation, then specific work plans would be developed to address those risks.

Delineation of areas physically damaged from the TSF breach were provided at a high level in the PEEIAR reports; however, environmental damages specific to the Ecological Units as applicable to quantification of habitat losses and potential offset requirements (of particular relevance to DFO and FLNR requirements) are detailed in Section 5.0.

Table 1: Key Uncertainties in the Ecological Risk Assessment and Monitoring Considerations (adapted from Golder 2017c)

Receiving Environment and Area	Receptor Group	Risk Conclusion	Key Uncertainty	Monitoring to Address Uncertainties (detailed in the CEMP)
Terrestrial – All areas	Plants	Low to moderate	Field observations of the plant community re-establishment is positive but in an early state of plant succession.	Field monitoring of plant performance will be incorporated as part of the remediation plan monitoring.
			Plant growth under-performed in soil tests, but the relative contribution of copper versus physical and structural limitations of the soil has not been confirmed.	Field monitoring of plant performance (see above). Focused investigations to determine relative contribution of copper versus physical limitations may be added, but only if needed based on findings from field monitoring.
	Soil invertebrates	Low to moderate	The early successional nature of soil conditions means limited soil invertebrates were available for sampling.	Field monitoring of soil invertebrate community will be incorporated as part of the remediation plan monitoring; Focused investigations to determine relative contribution of copper versus physical limitations may be added, but only if needed based on findings from field monitoring.
	Wildlife	Low	Existing mathematical relationships between soil and tissue concentrations are based on currently available data. This results in uncertainty in how risk estimates are being applied to smaller areas.	Field monitoring of plants and soil invertebrate (see above) will include sampling for tissue chemistry to supplement the currently available data.
			Understanding of copper bioavailability was informed by available PBET data and literature values, resulting in uncertainty in the HQ.	Field monitoring (see above) will include collection of soil samples for PBET analysis to increase spatial coverage and diversity of soil types covered by PBET. Targeted study to expand PBET analysis to determine relative bioavailability (e.g., include additional types of items in the PBET analysis).
			Toxicity Reference Values (denominator in the HQ calculation) were based on screening level benchmarks.	No specific field activities. Desktop refinement to develop a site-specific toxicity reference value to replace the default TRVs.
Terrestrial – Riparian Habitats	Amphibians	Indeterminate	Amphibians have not been formally assessed beyond the qualitative observations described in the risk assessment.	Existing data (potentially with a targeted supplemental program) to be used to determine a screening-level estimate of hazards to amphibians exposed to soil, sediment and water.
Aquatic – Hazeltine Channel	Benthic invertebrates and fish	Indeterminate – effects-based lines of evidence were deferred while restoration was in progress	Concentrations of copper exceed water quality guidelines.	Monitoring (post-habitat rehabilitation) to evaluate benthic invertebrate re-colonization. Ongoing monitoring of Hazeltine Creek water chemistry to evaluate trends.
Aquatic – Quesnel Lake	Benthic invertebrates	Low to moderate	Toxicity test performance was reduced but relative contribution of copper versus physical and structural limitations of the sediment has not been confirmed. Diversity metrics show improvement, transplant studies show positive recolonization potential but abundance remains reduced.	Monitoring of benthic community recovery to confirm that recolonization is progressing and that copper concentrations are not a barrier.
Aquatic – Polley Lake	Fish	Low	Clarification of the cause of Trout age-class structure alteration in Polley Lake.	Evaluate age class frequency of fish species in Polley Lake. Monitor copper concentrations in water samples from Polley Lake.

PBET - physiologically based extraction test; TRV – toxicity reference value.

3.2.4.1 Risks to the Terrestrial Environment

Overall, while certain metal concentrations are elevated over background risks to the terrestrial environment from tailings constituents were moderate; however, considerable physical impacts occurred. The physical nature of the tailings is expected to be an issue because tailings lack the heterogeneity and nutrient processing that is fundamental to a healthy soil ecosystem. This deficiency would be expected to decrease over time (Frouz et al. 2008), as organic carbon and biological function returns to the system, but currently, the magnitude of the effect is such that a conclusion of moderate risk is considered an appropriate characterization. Active intervention to enhance the return of such soil function is part of the ongoing remediation activities and is an identified residual effect for management under the RP.

There was no evidence that copper would act as an additional stressor over and above the influence of the physical and nutrient deficiency. Accumulation of copper in the food chain is considered to be low risk, based on the findings of the food chain model. The food chain model considered a wide variety of wildlife receptors with varying feeding strategies and dietary items and the general conclusion regarding low risks associated with copper bioaccumulation is therefore considered to be applicable to all wildlife species occupying the study area. Further information is contained in the ERA (Golder, 2017c).

Areas of uncertainty identified in the ERA have been carried through to the CEMP and additional assessment is underway as follows:

- Diversity of soil ecosystem: Field-based monitoring of the diversity or abundance of plants, soil invertebrates or other parts of the soil ecosystem is valuable in an ERA but was not practical to address at the time the ERA was prepared due to the variability associated with natural successional changes. Through the CEMP, a tiered program has been planned to further evaluate the potential for effects on the soil ecosystem (Golder 2018a).
- Copper bioaccumulation in plants and soil invertebrates: The ability to quantify the relative influence of copper versus the physical limitations of the soil is important from a theoretical perspective. This would typically be evaluated using controlled experiments. However, further experiment-based studies are not warranted unless there is evidence (from field monitoring) that natural succession is not progressing. It is reasonable to continue refining the site-specific understanding of copper bioaccumulation in plants and soil invertebrates in lieu of further experimental studies while the long-term field monitoring is conducted. Through the CEMP, a tiered program has been planned to further evaluate the relative influence of copper on soil invertebrates and plants (Golder 2018a).
- Wildlife: Risks to wildlife were assessed with a single technique (a food chain model). Conservative assumptions were used in the model, resulting in hazard quotients of less than one for 11 of the 15 receptor species evaluated in the model. Further refinement of the food chain model is being conducted for the four receptor species that had an HQ > 1 (Golder 2018a).
- Amphibians: Only a limited amount of direct measurement of exposure or effects relevant to amphibians was available at the time the ERA was undertaken. From a practical perspective, rehabilitation of the riparian areas, and restoration of Hazeltine Creek was ongoing throughout the risk assessment process and therefore the habitat suitability for amphibians was considered low. Moreover, completion of the ERA for other major groups of receptors (e.g., mammals, plants) was needed to determine if further remediation activities, which would further disrupt habitat suitability, was needed to address the residual concentrations of copper in the deposited material. Through the CEMP, a tiered program has been planned to further evaluate the potential for effects of metals on amphibians (Golder 2018a).

3.2.4.2 Risks to Polley Lake

In Polley Lake, no parameters were identified as stressors or COPCs in surface water based on comparisons of chemistry data collected between March and August 2015 with BC WQG. In terms of effects-based measures, there are multiple indications of recovery:

- Plankton - no adverse effects were observed in toxicity tests (acute or chronic tests with cladocerans) conducted in representative water samples, and no apparent change in biomass relative to background areas. The median concentration of copper in zooplankton collected from Polley Lake is lower than the upper limit of the normal range of samples collected from reference areas.
- Benthic Invertebrates - Polley Lake locations, in both deep and mid-depth locations, exhibited signs of biological recovery following the first year of sampling. Copper concentrations in benthic invertebrate tissue samples from Polley Lake, were significantly elevated relative to reference, but had lower concentrations than profundal Quesnel Lake benthic invertebrate tissues. The benthic organism species richness and abundance was not significantly different from Bootjack Lake, which has been used by MPMC as the reference location in their monitoring work (CEMP). A more detailed discussion of benthic invertebrate tissues is provided in Section 4.9.4 of the ERA.
- Fish - Median concentrations of copper in benthic invertebrate tissue were less than the dietary threshold for adverse effects to fish and water quality now meets guidelines. The fish population structure indicates a reduction in recruitment for Rainbow Trout (*Oncorhynchus mykiss*) (Minnow 2017a) which was inferred to be the result of precluded spawning access to upper Hazeltine Creek while it was being reconstructed. In 2018, following an evaluation of the suitability of the reconstructed habitat (water quality and temperature) for juvenile Trout (Golder 2018b), it was decided by the HRWG that fish would be re-introduced to upper Hazeltine Creek (discussed further in Section 4.5.1) and this resulted in successful spawning and recruitment of juveniles to Polley Lake (Connors et al. 2018). Additionally, MPMC established a temporary hatchery to supplement the population structure in Polley Lake as a contingency to the production from Hazeltine Creek.
- Physical effects to Polley Lake included deposition of settled outwash materials in the nearest approximately one third to one half of Polley Lake. Unlike Quesnel Lake, sediments in Polley Lake were mixed with existing Polley Lake sediments and organic material in the outwash area of Polley Flats. Lakeshore vegetation adjacent to Polley Flats was also damaged by the breach event and several logs/trees were washed into Polley Lake. Following observations that these logs and trees were providing cover for fish and fish were utilizing that area, a decision was made by the HRWG to leave those logs and trees in Polley Lake.
- The available data does not show a detectable impact on fish productivity of Polley Lake. However, the fish population structure does show signs of change as a result of the loss of their main outlet spawning area (upper Hazeltine Creek). Steps were taken in 2018 by MPMC to mitigate the population structure effects; however, monitoring is necessary to identify whether there may be productivity impairment using the metrics developed by the HRWG. While the benthos appears to have recovered quickly in Polley Lake, some impacts would have inevitably occurred, even if they could not be reflected in the monitoring data.

3.2.4.3 Risks to Hazeltine Channel and Lower Edney Creek

The assessment of risks for Hazeltine Channel was impeded by the coincidence in timing of when data would need to be collected and the timing of active remediation works which are a source of physical disturbance that would affect the data obtained. Given that the extensive construction and remediation efforts (see for example Bronsro et al. 2016) have modified the site conditions, the ERA report identified the risks in Hazeltine Creek as “indeterminate” (i.e., risks uncertain). The RP focuses on the current, post-remediation (where remediation has occurred) conditions. The RP is predicated on the present understanding of those conditions but is subject to the implementation of an acceptable CEMP to quantitatively validate that understanding and expectations regarding risks in Hazeltine Creek. Some relevant qualitative observations provided within the above context are outlined below. It should be noted that Hazeltine and to a lesser extent Edney Creek have been subject to physical disturbances from ongoing habitat remedial works. Quantitative sampling using accepted methodologies are required to provide a reliable basis to form risk management conclusions as well as to verify the performance of constructed habitats; however, such methods do not apply well to systems under physical disturbance. Qualitative observations are provided for context and are intended to be indicative but not confirmatory.

- Algae – Periphyton can be seen growing on the substrate in Hazeltine and Edney Creek and quantitative assessments are expected to occur when creek remediation has concluded, as part of the CEMP. Periphyton sampling was carried out in Edney and Hazeltine Creeks in 2017 but the data were not available for inclusion in the ERA.

- Benthic Invertebrates - There were statistically significant reductions (greater than 20% reduction) in diversity at upstream and downstream locations relative to reference for samples collected with Surber sampler or a kicknet. Data were limited to 2015, and creek remediation was subsequently initiated. It is worth noting that Edney Creek already shows clear evidence of recolonization, and similar recovery for Hazeltine Channel is anticipated in response to the remediation based on proximity to upstream organisms that provide a continued source of colonization and based on visual examination of substrates for macroinvertebrates which have shown the presence of EPT taxa[4]. Additional sampling was conducted in 2017 but the data were not available for inclusion in the ERA. This is an area of uncertainty that can best be addressed following the conclusions of construction activities and the physical disturbance associated with those activities.

- Fish - Direct assessment of fish in Hazeltine Creek could not be undertaken as part of the ERA because fish had been excluded over the course of the creek remediation with a series of fish fences near the Polley Lake outlet and the Quesnel Lake inlet. A partial (upper Hazeltine Creek) re-introduction of fish took place during the 2018 spawning season and Rainbow Trout successfully spawning (4,890 adults) and producing juvenile trout (an estimated 18,084 juveniles) that have since moved into Polley Lake (Connors et al. 2018). Monitoring of that age class within Polley Lake is ongoing by MPMC. MPMC’s sampling (Minnow 2018a) has found that all of the species of fish previously making use of Edney Creek are again present in Edney Creek, including the reconstructed portion. In addition, Kokanee (*Oncorhynchus nerka* freshwater variant) spawners were observed in the reconstructed portion of the channel. Detailed assessments of productivity will be required as part of the long-term commitments of MPMC with regards to verification of monitoring of habitat.

[4] EPT taxa are those organisms that are members of the orders Ephemeroptera, Plecoptera and Trichoptera (mayflies, stoneflies and caddisflies). EPT taxa are considered to be sensitive to aquatic pollution making their presence a positive indication of good water quality.

- Water quality in Hazeltine Creek shows an improving trend for dissolved copper concentrations (Golder 2018b) which are below the 30-day average BC WQG[5] (at higher values of water hardness) and have been below the biotic ligand model (BLM) site specific target values developed as part of the setting of treatment targets (Golder 2016b). The BLM used does not represent an accepted science-based environmental benchmark (SBEB; MOE 2016) or policy-based screening benchmark. Rather, it was used to provide context to the water quality data and an indication that development of an SBEB, should it be required in the future, may be feasible. Some of the earlier data was collected prior to the removal of tailings in the Polley Flats area and further monitoring of Hazeltine Creek water quality as well as seeps in Polley Flats remains a part of the CEMP. Dissolved copper has been used for planning purposes rather than total copper (for which the water quality guidelines apply) because it is more closely related to effects and because total copper would be affected by construction activities. Updated water quality data, including a broader suite of parameters (aluminum, copper, selenium, temperature, and dissolved oxygen), were also compiled as part of planning for re-introduction of fish into the upper portion of Hazeltine Creek (Golder 2018b). Those data were used to support the decision to re-introduce the fish. Water quality conditions in upper Hazeltine Creek do show an influence from construction activities related to remedial work (Golder 2018b).

The RP for Hazeltine Creek is focused on habitat reconstruction, subject to monitoring data confirming that copper and other parameters either meet the BC WQG or, alternatively, an SBEB derived following ENV policy (MOE 2016). An SBEB has not been developed for Hazeltine Creek at this time. If risks associated with changing water quality are identified through ongoing monitoring, additional remediation may be planned (vis-à-vis Section 4.1 and Figure 8).

3.2.4.4 Risks to Quesnel Lake

Risks are low for organisms associated with the water column (plankton, pelagic fish). Water chemistry shows that copper and turbidity are unlikely to present hazards to aquatic life especially after turbidity decreased over the first several months following the TSF breach (MPMC 2015b; Nikl et al. 2016). However, impairment to the benthic community remains in the profundal (deep lake bottom) environment where tailings deposited, and also in shallow portions of the lake close to Hazeltine Channel. These signs of impairment are associated with the physical burial of benthic communities and associated changes to substrates, in particular a low organic carbon content which is characteristic of the tailings material. The profundal areas are recovering, but the rate of recovery appears to be slower than in Polley Lake.

- Plankton - There were no significant reductions in chronic water algal growth tests or vascular plant growth toxicity tests on field collected water samples, or apparent change in primary productivity. There was no chronic toxicity to cladocerans in representative non-turbid waters, and no discernable difference in copper concentrations of zooplankton tissue samples between the exposed area and the reference areas of Quesnel Lake. There was also no discernable response in total zooplankton biomass or abundance, or in the relative biomass or abundance of dominant taxa, relative to reference.

[5] The 30-day average WQG is intended to be used in conjunction with the average of five samples collected weekly. In some cases, the monitoring data were not collected on this frequency; however, the values are conservative and where individual receiving environment concentrations are lower than the 30-day average guidelines, effects would not be expected.

- Benthic Invertebrates - The results of toxicity tests with two species indicate potential risk, based on the observation of greater than 20% responses in several samples; however, results were likely influenced by physical factors, particularly organic carbon. The responses were higher in sediments characteristic of tailings (elevated copper and low organic carbon). The addition of organic carbon or mixing samples (1:1 ratio) with reference sediment that contained higher organic carbon eliminated those observed growth effects in toxicity tests using the near field sediments. In terms of benthic community alterations, several Quesnel Lake assemblages remain impaired but data indicate that they are improving. Species richness in 2015 was not significantly different from reference areas but invertebrate abundance was lower in the impact area. A study in which breach-impacted sediments were transplanted to a reference area shows that recolonization of breach-impacted sediments is not impaired (these data are discussed further in Section 4.11.3). The main factors that are making recolonization slower is the need to accumulate organic carbon in the lake bed and the large (approximately 1.8 km^2) impact zone which makes in-migration of benthic invertebrates slower than when the transplanted sediments were surrounded by colonized sediments. Overall, recovery at these stations is slower than what has been observed in Polley Lake.
- Fish - No meaningful impairment from water quality was observed (i.e., performance is not inhibited by more than 25% relative to control samples) in fish toxicity tests that included the 7-d Rainbow Trout survival and growth test and the 7-d Fathead Minnow (*Pimephales promelas*) survival and growth toxicity tests in field collected water samples. The concentrations of copper in field-collected samples of representative fish diet (benthic invertebrates) are below the dietary threshold for adverse effects by consumption as derived in the ERA (Golder 2017c). Information available on the microscopic structure of fish tissues (histology) does not indicate ongoing water quality-induced stress associated with the presence of the tailings in the lake (unpublished DFO study). The condition factors of juvenile Sockeye Salmon (*Oncorhynchus nerka*) collected from different sampling zones in Quesnel Lake do not indicate a negative tailings influence – the fish were larger and more numerous in the West Basin of Quesnel Lake (DFO data, unpublished). Fish have also been observed using the profundal zone of the West Basin during an ROV inspection of the outfall (Figure 5); however, these are coincidental observations during an ROV survey of the outfall structure and not quantitative surveys.
- Physical effects to Quesnel Lake were summarized in the PEEIAR (MPMC 2015a). Material volumes estimated to have been transported to Quesnel Lake include 12.8 M m^3 of tailings and interstitial water, 1.2 M m^3 of native soils scoured along Hazeltine Creek and 4.6 M m^3 of overlying water in the TSF. The entry of this material resulted in water quality impacts, most notably/visibly on turbidity, particularly in the deeper parts of Quesnel Lake at first and throughout the water column following lake overturn in November 2014. The breach outwash materials settled onto the bottom of Quesnel Lake, covering an estimated 1.81 km^2 of lake bed. Although the depth of settling was variable, it was estimated to be up to 10 m deep in some locations (Figure 6). Physical changes to the lakeshore area, including scour and vegetation loss adjacent to Hazeltine and Edney Creeks also occurred.

Figure 5: Image extracted from an ROV video (coincident observations, not a quantitative fish survey) recorded during an outfall inspection, showing that the lakebed is being used by fish in Quesnel Lake, near the outlet of Hazeltine Creek (fish is in the upper right quadrant of the image, the rope was temporarily placed to set the course for the ROV).

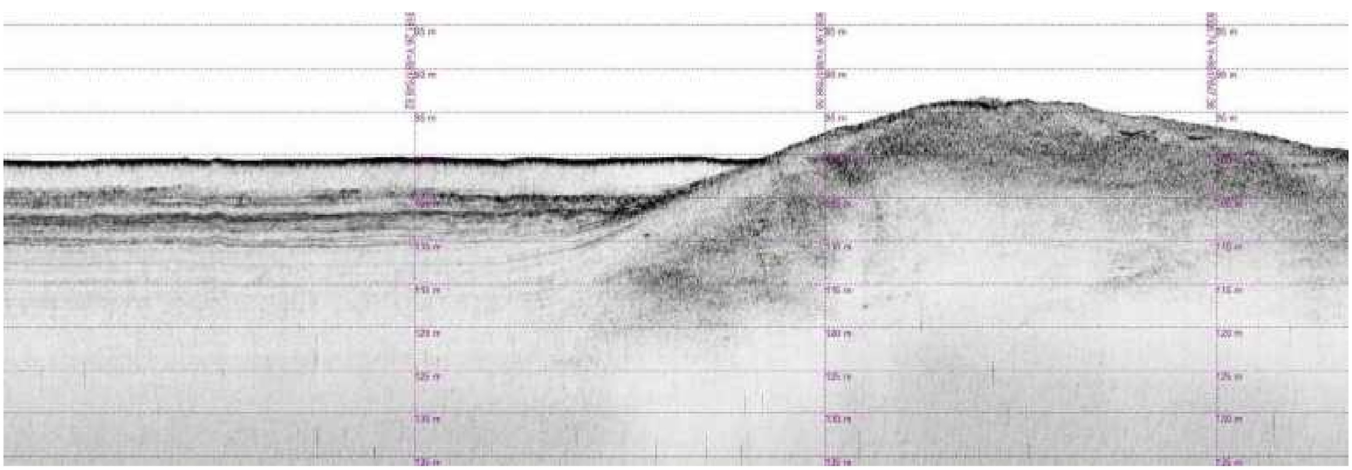


Figure 6: A sub-bottom profile image of a section of Quesnel Lake showing fine-grained sediments settled along a flat section (left of image) and an underwater lake side slope along the rise on the right half of the image.

3.2.4.5 Risks to Quesnel River

The available evidence indicates a low magnitude of risk comparable to reference conditions:

- Plankton - No significant reductions in chronic water algal growth tests or vascular plant growth toxicity tests on field-collected water samples. No chronic toxicity to cladocerans in representative non-turbid waters.
- Benthic Invertebrates - Benthic invertebrate samples collected from Quesnel River and the corresponding reference area in Cariboo River had concentrations of COPCs similar to reference conditions.
- Fish – Significant effects were not observed for fish toxicity tests including 7-d Rainbow Trout survival and growth, 30-d Rainbow Trout survival and development, and 7-d Fathead Minnow survival and growth toxicity tests on field collected water samples.

3.3 Habitat Remediation Working Group

The HRWG (previously called the Habitat Objectives Working Group) was formed to provide a forum that would enable collaborative input from agencies and First Nations on the remediation of fish habitat based on objectives developed for each area or ecological unit of fish habitat affected by the TSF breach. These objectives are based on physical conditions (e.g., gradient), constructability, life history requirements of the fish species and a broader ecosystem context (e.g., amount of spawning or rearing habitat available). DFO (2014) determined that a S. 35 Authorization under the *Fisheries Act* was not required to carry out the remediation work and that the field design and build approach was a prudent means of advancing such remediation. DFO further recommended the development of a framework to guide the designs where restoration objectives were set for each of the ecological units. The HRWG is composed of DFO, ENV, FLNR, Soda Creek and Williams Lake Indian Bands and their representatives, and MPMC and their representatives. The group has provided input and independent external review of designs to MPMC and its river engineering and habitat ecology Qualified Professionals (QPs).

The HRWG has been the forum in which remedial options for breach-impacted sections of Hazeltine and Edney Creeks are considered and evaluated and become the aquatic remedial plan for that area. The detailed implementation of the remediation plan then becomes the responsibility of MPMC who coordinate equipment and construction materials and the QPs who engineer river work, design habitat elements and oversee their construction. Members of the HRWG carry out site visits either in a regulatory or contributory capacity.

Areas of Hazeltine Creek, Edney Creek, Quesnel Lake and Polley Lake were categorized into EU by the HRWG based on the nature of disturbance and the fish species known to use that area (Figure 4). These EUs are somewhat different from the Remediation Areas or Reaches described in Section 1.3, but are devised to help guide the development of habitat objectives, evaluation of the effects and compare pre-breach and post-remediation conditions. The Working Group developed a habitat remediation framework (separate from the broader remediation framework and specific to habitat) that identified the fish community within each EU, the ecological function of the EU, the pathway, magnitude, and duration of the breach effects, the life history component affected by the breach, available baseline data for pre-breach conditions, and potential indicators that may be used to quantify effects and evaluate the success of remediation.

3.4 Input to the RP Through Consultation

The PAO requires:

> *A description of consultation completed with local First Nations and with stakeholders on the remedial objectives and how remedial objectives have been refined taking into account the outcome of such consultation.*

Public and First Nations consultation has occurred prior to the Remediation Plan. In 2011 and 2012, MPMC executed Participation Agreements with the Williams Lake Indian Band (WLIB) and the Soda Creek Indian Band (SCIB), respectively. In August 2016 and April 2017, MPMC and WLIB and SCIB (respectively) renewed these agreements. Through these respective Participation Agreements, Implementation Committees (IC) were formed to facilitate open dialogue between each of the First Nations and MPMC, providing a formalized, regular venue to discuss environmental, social and economic matters related to mine development, operation, reclamation, and closure (e.g., mine updates, permitting, environmental protection, reclamation, employment opportunities, and potential joint ventures). In addition, First Nations have been providing extensive technical input into habitat remediation work through the HRWG and as reviewers of the various documents that form part of the remedial planning basis and habitat remedial designs.

Numerous and varied public and First Nations comments have been received by MPMC before and particularly following the breach. The input subject matter has varied widely. With specific regard to this RP, the following public meetings took place:

- Mount Polley Public Liaison Committee (PLC) on 16 November 2017.
- Williams Lake Public Meeting on 16 November 2017.
- Town of Likely Community Meeting on 17 November 2017 on the Human Health and Ecological Risk Assessments that form part of the remedial planning basis.
- Public Webinar using GoToMeeting™ to project slides via the web and voice via web or telephone on 10 January 2017.
- Public Meetings During December 2018 at: Quesnel, Williams Lake, and Likely.
- A web-based meeting for the Public Liaison Committee on 25 February 2019.

At the above meetings, a number of questions were asked and answers were provided. With regards to questions or concerns raised that may relate specifically to the remedial planning basis, the following items were identified:

- Concerns were expressed by a local resident about potential resuspension of the breach outwash materials that have settled on the bottom of the lake, particularly during lake overturn.
- Concerns have been expressed by some residents who have occasionally observed a green-coloured tinge to the water (this has at times been connected to the preceding bullet), plugging of water intake filters with organic material and local observations that algae growth on rocks appears to be greater than it was before the breach.
- A question was posed by another local resident (and Professional Biologist) about the potential for predation on Trout by birds upon trout re-introduction to upper Hazeltine Creek in 2018.

Resuspension of Lake Bed Materials

This concern stems from the clear (low turbidity) water characteristics of Quesnel Lake, which local residents and vacationers value and the effect of lake overturn in November 2014 which resulted in the mixing of deeper, post-breach turbid waters with surface waters making the Quesnel Lake surface water cloudy in appearance (turbidity of ~ 15 NTU; MPMC 2014a) over a period of several months until turbidity measurements showed dissipation in the summer of 2015. These concerns have been previously raised as have those of an intermittent cloudiness and greenish hue to the lake. This occasional cloudiness has not been observed by all residents in the area.

The possibility of resuspension of breach outwash materials was identified as a strategic information need to inform remedial decisions and was part of early evaluations carried out as part of the Post-Event Environmental Impact Assessment (MPMC 2015a). Tetra Tech EBA (Tetra Tech 2015a) carried out a study of Quesnel Lake water column quality and evaluations based on a 3-dimensional hydrodynamic model that they constructed. The model predicted that mixing, flushing and settling of the fine-grained breach-related materials suspended in Quesnel Lake would occur but it predicted that resuspension would not occur once these materials had settled. In response to the public concerns noted above and as a cautionary step, MPMC retained Tetra Tech to carry out an updated evaluation using additional information not available in 2015 to re-examine whether re-suspension was likely. The new information available included water column profiling data, data on the rate of sediment deposition, contemporary grain size distribution data from the bed of Quesnel Lake and observations regarding the extent to which settled materials are consolidated, computational analysis of critical bed shear stress forces that would be needed to initiate erosion and the near bed hydraulic loading that could be expected, and remote operated vehicle (submersible) video analysis. Based on the abundant additional observational and computational lines of evidence, Tetra Tech concluded that the tailings would remain on the lake bed (Tetra Tech 2017).

The observations of some, though not all residents, of an occasional mildly cloudy-green hue to the lake that they feel was not there pre-breach cannot be reconciled against the extensive turbidity data set and the observational and computational analyses noted above. Public perception of water colour can, under circumstances be accurate but can also be prone to interference by a variety of factors (Smith et al. 1995). The remedial planning basis adopts the findings based on multiple lines of evidence regarding the physical stability (i.e., that they are not re-suspending) of the tailings (Tetra Tech 2017).

We are aware of subsequent work by university researchers that suggests some turbidity near the lake bed; however, this information is based on a hypothesis. Details of methods and findings have not been published or provided to Golder as of writing.

Lake Colour, Water Filters and Algal Growth on Rocks

The potential influence of resuspension has formed part of studies as noted above. Regarding the potential for increased organic production in the water column and increased algal growth on the rocks, data are not available to directly address these observations. However, chlorophyll *a* data are available for a period of time before mining at Mount Polley Mine (Nidle et al. 1994) as well as for the years following the breach (Figure 7). A comparison of whole lake averages over the period for which pre-impact data are available (1985 to 1990) with chlorophyll *a* concentrations in the years following the breach indicates that the algal biomass of Quesnel Lake may have been higher prior to mining at Mount Polley than has been the case following the breach. This suggests that the conditions favouring algal growth are not higher post-breach.

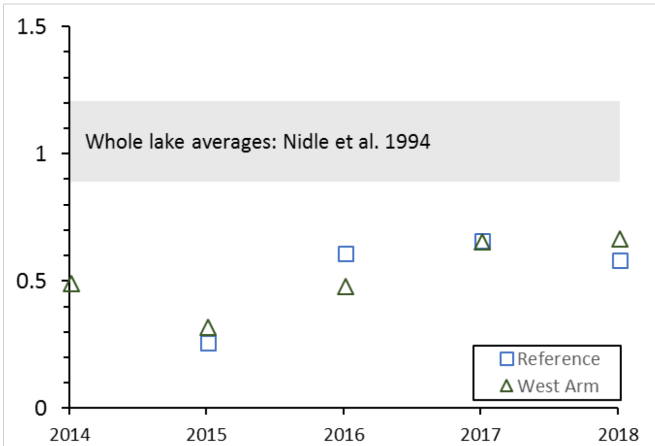


Figure 7: A comparison of pre-mining (1985-1990) chlorophyll *a* whole lake averages (grey band) concentrations and post-breach chlorophyll *a* concentrations in the West Arm and reference area.

Predation by Birds on Fish Re-Introduced to Hazeltine Creek

A question was asked whether consideration had been given to use of anti-avian predator netting upon the re-introduction of fish to Hazeltine Creek. The revegetation along Hazeltine Creek, following habitat build-out will take several years to provide over-story vegetative cover of Hazeltine Creek which, in a natural system provides some cover from predation of fish by birds – though not against all species of piscivorous birds or other piscivorous wildlife. The potential effect of predation on fish re-introduced into Hazeltine Creek was identified in a Golder memorandum (Golder 2017d). The re-introduction took place and while some small numbers of fish were taken by predators, as is natural, there were nevertheless an estimated 18,084 juvenile trout that returned to Polley Lake (Connors et al. 2018). Instream cover installed as part of the second phase of creek remediation provided sufficient protection from predators based on numbers of fish enumerated. MPMC are monitoring the population structure of Polley Lake fish to quantify the adequacy of these steps vis-à-vis fish productivity of Polley Lake Trout.

3.4.1 Remediation Plan Implementation – Future Consultation

Implementation of the remedial plan will require consultation with regulators, First Nations and the local community. The purpose of this consultation is to inform, listen to concerns and provide answers, identify whether revisions to the CEMP are needed, take input to enhance the outcomes of remedial work and to comply with statutory/permit requirements. Some of the bodies with whom beneficial consultation would occur are:

- BC ENV, FLNR, DFO – regulatory oversight, technical expertise from the respective agency).
- MPMC Public Liaison Committee – community representatives who are expected to bring community concerns to the table from the community and to facilitate the dissemination of information provided by MPMC and a forum to discuss concerns, concepts, ideas and community aspirations.
- HRWG – technical input from local knowledge of First Nations and their staff, technical input and oversight by agency specialists.
- First Nations Implementation Committee – a forum that includes environmental remediation topics but also includes broader First Nations/MPMC relations, opportunities and concerns.
- Public meetings/field tours – direct engagement of the broader community (i.e., beyond the public liaison committee) to provide information updates and opportunities to directly observe remedial works.

4.0 REMEDIATION PLAN

This RP identifies the proposed actions to remediate residual effects from the TSF breach identified by the preceding assessments (Golder 2016a, 2017b,c). This report provides a consideration of options for remediation of those risks and an evaluation and recommendation of the selected remedial option. Where remediation has already started or is substantially advanced in certain areas, the RP describes the process under which the remedial options were developed and selected. An example of the latter situation was the initiation of Hazeltine and Edney Creek remediation, on an expedited basis, to control erosion and turbid water discharge and, in the case of Edney Creek to reconnect unaffected habitat in the upstream portions of Edney Creek with Quesnel Lake to allow access to the watershed by fish returning to spawn. In this case, various remedial options were identified and considered as the work progressed, with oversight and input provided by the HRWG.

The RP is presented by area with a presentation of the generalized approach applicable to the main habitat types (creek, terrestrial and lake). Quantification of habitat losses and identification of potential remedial/offset requirements in each EU is provided in Section 5.0.

4.1 Remediation Plan Components and Linkages

The remediation plan has been developed as information has been obtained from the numerous studies that have been carried out. The plan has connections to those studies, regulatory requirements, outcomes, and specific actions to be taken (e.g., habitat remediation and habitat offsets, monitoring). Figure 8 shows various components of the remediation plan and how those components are linked to information obtained as part of preceding studies, actions that have been taken, still need to be taken and how those actions lead to compliance with regulatory requirements. It should be noted that compliance is expected to be part of an ongoing compliance program by MPMC and that there are several long-term commitments for MPMC. Figure 8 is a process diagram that represents how remediation plan components turn into specific work, how that work is monitored and adjusted based on verification monitoring as part of MPMC's long-term commitments and how the remediation plan is linked to compliance when concluded.

The RP linkages start with the breach event. In addition to standing regulatory requirements under both federal and provincial law, formal and specific regulatory requirements were invoked by ENV and FLNR the following day (PAO, EO). DFO relied on the general provisions contained in the *Fisheries Act*. The remedial design basis, summarized in Section 3.0, results in five outcomes that have connection to remediation. These are:

- Human health risks are acceptable and remediation for that purpose is not required.
- Some ecological risks are acceptable and remediation for that purpose is not required.
- Some ecological risks are acceptable but there is scientific uncertainty in that determination. Remediation is not identified for such risks, but monitoring is a requirement to address that uncertainty. Verification and, if data show it is necessary, then remedial work plans to address those risks would be developed.
- Some ecological risks are uncertain – neither an absence nor clear conclusion regarding risk can be made with current data. In such cases, a specific focused study/monitoring program is carried out as an addendum to the CEMP process. The results of that study will either identify the need for more detailed assessment, identify that risks are absent (compliance) or identify that remediation is required. For the latter finding, a remedial work plan would be developed.

- Remediation is clearly required (e.g., where an environmental effect has been identified without need for clarifying study). Remediation approaches are recommended in later sections of this plan. Because the remediation work is focused on habitat remediation, this includes identifiable physical work that has been completed, in progress, or to be carried out on site and habitat offsets to address impacts and productivity losses (including time) resulting from the breach.

The areas where physical remediation work was required are those involving physical damage to aquatic and terrestrial habitats and those involving public safety risks. The focus of the RP is therefore on planning out the amounts of habitat that are needed to offset the losses from the TSF breach event. Some of those offset “credits” have been and will be constructed at the location where the damage took place. However, additional offset habitat will be needed, and the amounts are set out in subsequent section of the RP. Figure 8 outlines a high-level process flow for evaluating habitat losses, identifying habitat designs, quantifying habitat “debits” and “credits” and quantifying offset requirements. That process has been set out in general by the HRWG, is described quantitatively in the RP and remains part of MPMC’s long-term commitments. These long-term commitments include monitoring of remediated habitats (including for contaminant endpoints), quantification of “credits” and “debits” and outstanding “balance” of offsets owing. The specific offsetting projects will be determined by the HRWG, as they have been since the early stages of breach response. Habitat verification will include maintaining a ledger of offsets completed, credits “made good” and habitat work still owed.

Habitat monitoring is a necessary component of the RP because uncertainty exists when habitat is constructed. When uncertainties are known and anticipated, they can form part of the design process and calculations, but verification monitoring of physical habitat stability and function remain necessary. Some of the common means of addressing uncertainty in habitat remediation is using arbitrary compensation ratios *a priori*. Such ratios are typically reduced or eliminated when habitat is constructed in advance of a loss because structure and function can be verified, thereby addressing the uncertainty of outcome. Given the scale of the TSF breach event, we have proposed the use of Habitat Equivalency Analysis (HEA; Section 4.2.4) and performance verification to address uncertainty. Offsets can therefore be scaled to provide a reasonable amount of offset habitat and can be scaled upwards should actual habitat function fall short of expectations. MPMC’s long-term commitments are underlain by attainment of regulatory requirements.

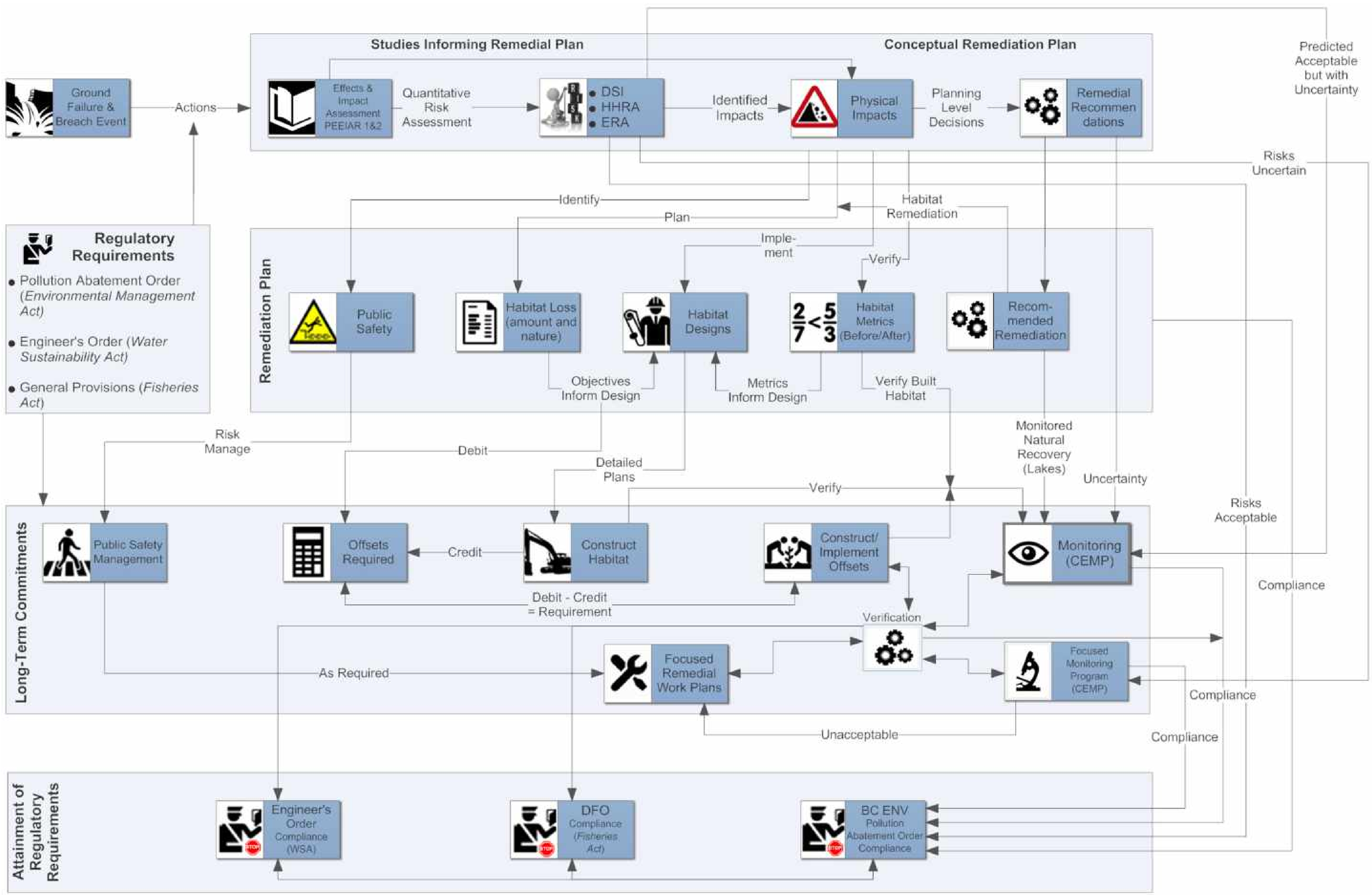


Figure 8: Diagrammatic Representation of Remediation Plan Component Linkages

4.2 Remediation and Offsetting Approach

4.2.1 Remediation of Creek Habitats

Based on the remedial planning basis for the creek habitat, remedial needs for creek habitat are associated with the physical impacts of the breach event. The overall remedial objective for impacted stream habitats is to restore the life history functions of fish, particularly salmonids, by constructing an engineered stream base in the otherwise erodible (fluvial and lacustrine) native sediments below Hazeltine Creek, with habitat features to support an aquatic ecosystem. Design features will also restore ecological functions for wildlife associated with small streams and their riparian environments. For the purposes of developing habitat objectives for creek remediation, the HRWG defined ecological units and potential pathways of effects in a manner guided by DFO (2012) (Table 2).

Table 2: Potential Pathways of Effect Associated with Creek Ecological Functions and Indicator Fish Species (DFO 2012)

Remediation Area / Ecological Unit	Ecological Function	Potential Pathway of Effect				Indicator Fish Species
		Deposition of Material	Alteration or Removal of Structure	Alteration of Riparian Habitat	Exclusion from Habitat by Temporary Fences or Blockages	
Upper Hazeltine (H1)	Spawning	●	●		●	Rainbow Trout
	Rearing	●	●	●		
	Overwintering	●	●			
	Migration	●			●	
Lower Hazeltine Creek (H2)	Spawning	●	●			Rainbow Trout Coho, Chinook and Sockeye Salmon Kokanee Mountain Whitefish Burbot
	Rearing	●	●	●		
	Overwintering	●	●			
	Migration	●				
Upper Edney Creek (E1)	Spawning				●	Rainbow Trout
	Migration				●	
Lower Edney Creek (E2 and E3)	Spawning	●	●			Rainbow Trout Coho, Chinook and Sockeye Salmon Kokanee Mountain Whitefish Burbot
	Rearing	●	●	●		
	Overwintering	●	●			
	Migration	●				

● - pathway of effect potentially operable.

Pre-disturbance morphology of Hazeltine Creek is relatively well known due to previous stream assessment work done in the area (Bruce and Slaney 1991, MPMC 2009). An important aspect of the remedial design of fish habitat is the integration of three specific channel meander patterns. Each pattern is associated with features of the overall channel of Hazeltine Creek, specifically the lower floodplain, the mean annual flood (MAF) channel, and the low flow channel. The primary meander pattern is exhibited by the lower floodplain; this part of the overall floodplain will be engaged by flows associated with freshet. The second meander pattern is displayed by the MAF channel. This channel can convey the average peak discharge of Hazeltine Creek throughout the year; flows overtop the channel during freshet and enter the lower floodplain. The MAF channel meanders off the centre line of the lower floodplain. The tertiary meander pattern is associated with the low flow channel. This channel meanders off the centre line of the MAF channel. It will concentrate low flows during late summer, fall and winter.

The process of creek habitat remediation that has been carried out is as follows:

- Habitat objectives for each reach of stream habitat were determined by the HRWG and in some cases (detailed in the sections below) habitat that fits those objectives has been constructed.
- Based on these objectives, channel morphology and habitat characteristics are designed and reviewed with the HRWG before being constructed.
- Following the construction of the habitat based on reach-specific objectives, the habitat is evaluated based on pre-determined criteria (set by HRWG; Table 3) and residual effects of the TSF breach on fish habitat and the functionality and value of the habitat is evaluated to determine whether habitat offsetting measures to address residual effects are warranted. In addition, the HRWG will follow DFO policy (DFO 2013) to developed criteria for evaluating, ranking and selecting appropriate offsetting measures.
- All construction and repair is documented, and record drawings are produced. Once the initial habitat meets the design specifications, monitoring based on the evaluation criteria (Table 3) continues annually until the habitat has reached project objectives. Post-construction evaluation may result in adjustments or repair to installed habitat features resulting in another round of implementation and evaluation.

A list of design and record drawings issued for Hazeltine Creek remediation is provided in Appendix A.

Creek habitat remediation by remediation area / reach is described in further detail in the following sections for each of the areas.

Table 3: Metric Criteria for Defining Poor, Fair, and Good Quality Stream Habitat and Channel Structure and Form

Habitat Parameter	Quality Rating		
	Poor	Fair	Good
Bankfull width-to-depth ratio	>25:1	16-25:1	≤15:1
Entrenchment ratio	<1.4	1.4 to 2.2	>2.2
Channel complexity	<2 mesohabitat units/10xWbf	2-3 mesohabitat units/10xWbf	3 mesohabitat units/10xWbf
Percent pool (by area)*	<15	15 to 40	40 to 60
Pool frequency (mean pool spacing)*	>10 channel widths/pool	>8-10 channel widths/pool	<8 channel widths/pool
Holding pools (adult migration)	<1 pool/km >1 m deep with good cover (30% of pool area)	1 to 2 pools/km >1 m deep with good cover (30% of pool area)	>2 pools/km >1 m deep with good cover (30% of pool area)
LWD pieces per channel length, measured as bankfull width*	<1	1 to 2	>2
Percent wood cover in pools* (i.e., wood cover as a percent of pool area)	pools in reach average 0 to 5% LWD cover	pools in reach average 6 to 20% LWD cover	pools in reach average >20% LWD cover
Spawning substrate size, quality and area	size mostly <6 or >60 mm; >25% fines (<2 mm); <10% spawning gravel area within wetted area of all habitats surveyed	size 6-60 mm; 15 to 25% fines (<2 mm); ≤25% spawning gravel area within wetted area of all habitats surveyed	size 6-60 mm; ≤15% fines (<2 mm); >25% spawning gravel area within wetted area of all habitats surveyed

Modified after Johnston and Slaney 1996, Slaney and Zaldokas 1997, Newbury and Gabourey 1993 and Hickman and Raleigh 1982.

Note: For riffle-pool streams with mean gradient <2%, bankfull widths <15 m, and for summer/winter rearing use.

LWD - Large woody debris; Wbf – bankfull width.

The quality ratings are specific to the habitat parameters identified by the HRWG and are not intended to imply quality of remediation.

4.2.2 Remediation of Lake Habitats

The residual effects that require remediation in Quesnel and Polley Lakes are risks that arise from the physical impacts of the breach outflow and associated materials and the low organic carbon content which is characteristic of the tailings material. The size and profile of a lake results in distinct ecological components that have implications for habitat types and fish usage, and ultimately the influence that the event had on Polley Lake and Quesnel Lake. These components are illustrated in Figure 9 and described below:

- Benthic – associated with the lake bottom.
- Emerging insects – insects that have a water-based larval stage and a flying adult stage.
- Epilimnion – the water column above the thermocline.

- Hypolimnion – the water column below the thermocline.
- Limnetic zone – the portion of the water column through which light penetrates.
- Littoral zone – the area of the lakeshore where aquatic plants grow. In Quesnel Lake, this area is variable but approximately 4 to 6 m deep.
- Phytoplankton – free-floating plants/algae and photosynthetic bacteria.
- Profundal zone – the portion of the water column that light does not reach and as a result does not support plant growth. Elsewhere in this report, this may also be referred to as the "benthic" zone.
- Thermocline – a sharp density gradient in the water column that limits mixing of the water column which is caused by differences in temperature between the upper and lower water column. In the summer, the surface of the water column is warmer and the water at depth is cooler.
- Zooplankton – free-floating invertebrates.

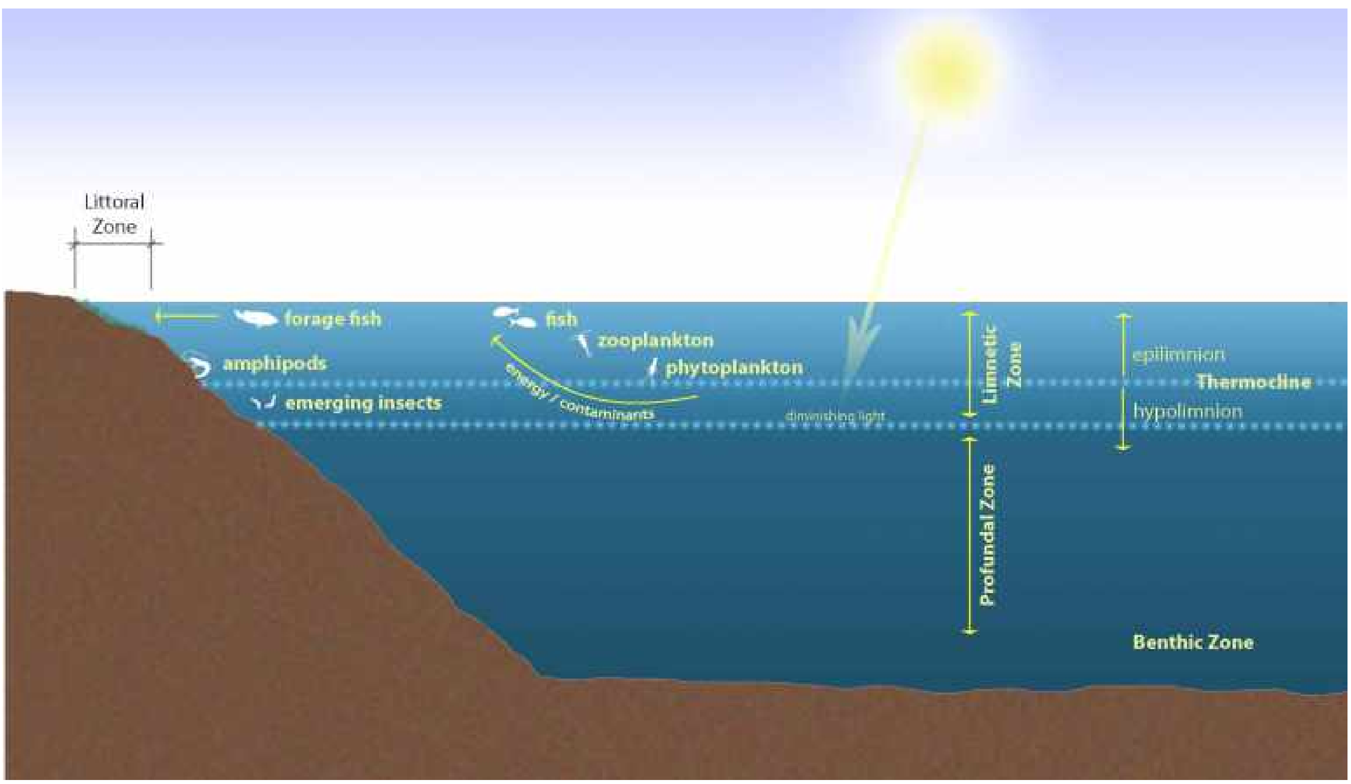


Figure 9: Generalized Conceptual Ecological Model for a Lake

Golder (2015c) reviewed life history and feeding requirements for the 20 fish species identified in Quesnel Lake and developed a conceptual ecological model for fish-habitat-food assemblages in Quesnel Lake, of which three general assemblages were identified:

- Littoral zone and benthic habitats – Fish associated with the littoral zone and benthic habitats are oriented to the near-shore environment and feed largely on benthic prey, periphyton, or in some cases crustacean zooplankton in the water column (McPhail 2007, Scott and Crossman 1973). Fish in this group include juvenile stages of salmon (*Oncorhynchus* spp.) and adult and juvenile Mountain Whitefish (*Prosopium williamsoni*) which eat plankton, Lake Whitefish (*Coregonus clupeaformis*) and Pygmy Whitefish (*Prosopium coulterii*), and juvenile Burbot (*Lota lota*), which are benthivores (i.e., their food comes from benthic substrates), and forage fish such as sucker, sculpin, chub, shiner and Northern Pikeminnow (*Ptychocheilus oregonensis*). The forage fish have a range of feeding habits and may consume primarily benthic invertebrates or periphyton, or in the case of Northern Pikeminnow, eat other fish (i.e., they are piscivorous). Other fish considered in this assemblage are adult Burbot, which are also piscivorous, and make vertical migrations in the summer to feed on Trout, minnow, sucker and sculpin.
- Open-water habitat and fish that feed on emerging insects – Fish that are associated with open-water habitat and feed on emerging insects include Mountain Whitefish, which typically inhabit the upper 20 m of the water column, and smaller Rainbow Trout, which undertake a diel (i.e., daily) vertical migration (McPhail 2007, Scott and Crossman 1973). Larger adult Rainbow Trout in Quesnel Lake may consume juvenile Sockeye Salmon and Kokanee (Parkinson et al. 1989).
- Open-water habitat and fish that feed on crustacean zooplankton - The assemblage of fish that is associated with open-water habitat and that feed on crustacean zooplankton consists of juvenile Sockeye Salmon which undertake a diel vertical migration, orienting to the lower boundary of the thermocline at night (Levy et al. 1991) and descending to 60 to 80 m depth at night (McPhail 2007; Morton and Williams 1990; Scott and Crossman 1973). Kokanee also undertake a vertical migration, generally feeding near surface at dawn and dusk, and staying below the thermocline during the day and at night. During the summer, this assemblage may also include Lake Trout (*Salvelinus namaycush*).

The conceptual ecological model for Polley Lake is a simplified version of that of Quesnel Lake. Rainbow Trout is the only CRA fish species present and other fish in the lake include Longnose Sucker and Redside Shiner. The conceptual model for open-water habitat and fish that feed on emerging insects is applicable to Rainbow Trout.

For the purposes of developing habitat objectives for lake remediation, the HRWG refined the conceptual ecological model for Quesnel Lake into three ecological units and selected ecological functions and indicator fish species for each unit (Table 4) in a manner guided by DFO (2012). Polley Lake is considered one ecological unit.

As described in previous sections, the breach event resulted in scouring and deposition of material in and along Polley Lake and Quesnel Lake and temporarily altered water quality. The ERA indicated that altered water quality is no longer an operable pathway of effect and thus the focus of the identification of potential lake remediation needs was on physical effects. Physical habitat remediation and offsets will be addressed by the HRWG. An analysis of the remedial options for Quesnel Lake is provided in Section 4.11. For Polley Lake, the options evaluation would be based on similar considerations although the circumstances of Polley Lake are different in terms of its stage of benthic community recovery and it has specific issues with regards to the age class structure of Rainbow Trout in Polley Lake.

Table 4: Potential Pathways of Effect Associated with Lake Ecological Functions and Indicator Fish Species (DFO 2012)

Ecological Unit	Ecological Function	Potential Pathway of Effect				Indicator Fish Species
		Deposition of material	Alteration or Removal of structure	Alteration of Riparian Habitat	Exclusion from Habitat by Temporary Fences	
Polley Lake	Spawning	●	●		●	Rainbow Trout
	Rearing	●	●	●		
	Overwintering	●	●			
	Migration	●			●	
Quesnel Lake Limnetic Zone	Rearing					Rainbow Trout, Coho Salmon, Chinook Salmon, Sockeye Salmon, Mountain Whitefish, Bull Trout, Kokanee, Lake Trout, Lake Whitefish, Pygmy Whitefish, Burbot
	Migration					
Quesnel Lake Littoral Zone	Spawning	●	●			Rainbow Trout, Coho Salmon, Chinook Salmon, Sockeye Salmon, Mountain Whitefish, Bull Trout, Kokanee, Lake Trout, Lake Whitefish, Pygmy Whitefish, Burbot
	Rearing	●	●	●		
	Migration					
Quesnel Lake Benthic Zone	Rearing	●	●			Rainbow Trout, Bull Trout, Lake Trout, Mountain Whitefish, Pygmy Whitefish, Lake Whitefish, Burbot

● - pathway of effect potentially operable.

4.2.3 Remediation of Terrestrial Habitats

Aquatic ecosystems are linked to adjacent terrestrial ecosystems by transitional riparian zones and wetland areas (Gregory et al. 1991). For the purposes of this report, terrestrial ecosystems include riparian areas, floodplains and upland areas that may escape even the highest water levels. The residual effects to terrestrial habitats that need to be remediated are from the physical impacts of the breach outflow and because the tailings lack the heterogeneity and nutrient processing that is part of a healthy soil or sediment ecosystem. The physical impacts (e.g., undercutting of banks, scour) have in part been addressed through the re-contouring of the slopes along Hazeltine Creek; however, the loss of forest soils is part of the needed remediation.

Terrestrial conditions after the TSF breach consisted of a general absence of original vegetation in the Hazeltine Creek corridor and floodplain. 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 variable thickness layer of mixed tailings, soil and debris. Where the tailings cover was thicker, it led to anoxic conditions in the location of the tree root causing root death and eventually the trees died (Golder 2015a). Further summary of the impacts to the forest community within the halo area is provided in Golder (2016a, 2017c).

The general forest successional process, as observed in natural disturbances, can be emulated, with enhancement, when re-establishing functional ecosystems on disturbed sites. Successful remediation will put reclaimed ecosystems onto a trajectory that will eventually lead to successional processes similar to natural systems. Deliberate actions such as mixing in natural soils which contain soil fauna and local seed banks, selecting and planting appropriate species that accelerate restored soil structure and making the soil more “rough and loose” to enable seed and oxygen penetration and root formation will accelerate the speed with which that trajectory can progress. The goal is to establish naturally diverse and functional communities on the ecosystem, landform, and landscape scales. These ecosystems will provide services similar to undisturbed ones. The establishment of this trajectory will develop conditions that allow a self-sustaining ecologically diverse community in the affected riparian and adjacent forest areas. Part of developing this trajectory is to establish key pioneering species which are typically tolerant of difficult growing conditions, contribute to the re-establishment of soil organic content and soil fauna, and establish suitable growing conditions for later-successional seedlings by creating shade and increasing relative humidity in the understory (Walker and del Moral 2003).

The terrestrial remediation strategy applied by MPMC takes a managed successional trajectory approach to remediation, based on the principles of ecological succession, and relies on the assisted auto-regeneration capacities of vegetation and natural processes of soil renewal. Site preparation methods can be used to A) mix forest floor, mineral soils and any residual tailings to increase soil porosity, B) create raised microsites that have aerated root zones, and C) create plantable microsites. These approaches have been applied in the breach-impacted terrestrial areas. If monitoring indicates it to be necessary, soil fertility can be further improved in areas with nutrient deficiencies by applying soil amendments such as imported soils, microbial inoculum and fertilizer in planting zones or in each planting hole. In the areas where site preparation has yet to be applied, it is important to preserve the organic matter in situ as much as possible and avoid soil compaction during site work.

Once soil conditions are amenable to seed germination and growth, early successional species will establish and late successional species will slowly colonize through dispersal from nearby seed sources. To assist this process, various planting efforts have been undertaken to establish early-mid successional native species in the TSF breach area.

The choice of the remediation target for terrestrial ecosystems is based on the types of habitats and ecological parameters of a given area, according to local ecosystem classification and end land use. The goal of remediation in this case is to assist the establishment of as many functional elements as possible relative to target ecosystems. MPMC is currently in the process of implementing terrestrial remediation and revegetation actions in the TSF breach area and these efforts are detailed for each Remedial Area in the report sections that follow.

Target ecosystems are based on the BC Biogeoclimatic Ecosystem Classification (BEC) system, which categorizes ecosystems using a hierarchical system. Landscapes are divided into zones, subzones, and variants based on climate (Pojar et al. 1987). BEC subzones are further divided into site series, which are ecosystems that are classified on the basis of site, soil, and vegetation characteristics, resulting in sites capable of producing the same basic mature or "near-climax" plant communities (Meidinger and Pojar 1991). The TSF breach area falls within the Interior Cedar Hemlock biogeoclimatic zone (ICH) and the Quesnel Wet Cool (ICHwk2) and Horsefly Moist Cool (ICHmk3) subzone variants.

Revegetation as part of the RP uses the BEC system to identify appropriate ecosystem targets (i.e., late succession ecosystems) by matching site conditions of areas to be rehabilitated to predicted site series in the ICH-wk2 and -mk3. Vegetation communities present in the TSF breach area were primarily riparian and wetland communities along Hazeltine Creek consisting of forested, shrub-dominated or meadow vegetation communities. The distribution of pre-breach mapped ecosystems is shown in the PEEIAR, (Appendix G: Terrestrial Wildlife and Vegetation; MPMC 2015a).

Considerable planting has occurred under the direction of MPMC, by experienced contractors, in the breach outwash area. Planting data provided by MPMC are broken down as follows:

- all of Hazeltine Creek
  - shrubs (355,112)
  - conifers (192,480)
  - wattles (10,498 meters)
  - ground cover by seeding (136 ha)
- lower floodplains and Quesnel Lake shoreline
  - willow and cottonwood wattles and stakes (1 stem per 0.5 to 1m spacing, planted along shorelines and creek edges)
  - plug stock comprised of Prickly Rose, Red Oiser Dogwood, and Black Twinberry planted (planting density of 15,000 to 20,000 stems/ha)
- Ground Cover Seed – Mixed species
  - 25% Mountain Brome
  - 25% Bluebunch Wheatgrass
  - 25% Blue Wildrye
  - 14.31% Rocky Mountain Fescue
  - 10% Native Red Fescue
  - 0.014% Fireweed
  - 0.68% Big Leaf Lupine

4.2.4 Offsetting Approach

As discussed in Section 4.1, it is expected that additional habitat will need to be provided to offset for the temporal loss of habitat use following the breach and before habitat remediation has been undertaken. This section presents the approach that is being taken to estimate the quantity of offsetting that will be needed, specifically, habitat equivalency analysis (HEA). Examples of these calculations are provided in Section 5.0. In some cases, the available data may not support an offsetting calculation, or it may not be feasible to construct in-kind habitat (e.g., deep lake benthic habitat) and therefore alternative approaches to deriving offsetting estimates are also provided in Section 5.0. Concepts for potential offsetting options are also discussed in Section 5.0.

HEA is a procedure initially developed by NOAA (1995) and provides a framework for determining the area required for compensatory restoration (i.e., offsetting) for temporary habitat disturbances (Kohler and Dodge 2006). The main assumption underlying HEA is that the losses of habitat resources can be compensated for (offset) by habitat replacement projects that provide additional resources of a similar type. The more commonly used methods apply subjective offsetting ratios. A key difference in this application of such ratios in land development scenarios is that the habitat loss is complete and permanent (e.g., where a shoreline area is filled in for construction of a land-backed wharf or a stream is covered by a structure), whereas the nature of habitat impact resulting from the breach event is a temporary disturbance and / or reduction in function (e.g., productivity, organism movement), provided that the loss has been rehabilitated. The HEA approach is thus a more appropriate means of estimating the amount of habitat that would offset such impacts because it recognizes the temporary nature of the “injury”. An illustration of the concepts behind HEA is provided in Figure 10.

1. **Productive capacity** - the maximum natural capability of a habitat to produce fish or to support aquatic organisms upon which fish depend, or in other words the physical area of substrate. Productive capacity remains even in the absence of an ecosystem function or productivity (see note 2), such as may result from contamination or temporary disruption to or alteration of physical habitat. For the purposes of this conceptual model, productive capacity is defined as the area of habitat available (m^2).
2. **Productivity** –the sum of production rates in a given area. Productivity integrates the contribution of primary production, food, cover and other habitat variables to producing fishery resources. For the purposes of this conceptual model, productivity is considered to be a nominal "output" per area (output/m^2). In the context of HEA, productivity may also be termed as "ecosystem services".
3. **Disturbance –** a disturbance to productivity, in the case of the Project involves changes to physical habitat or introduction of contaminants that affect productivity.
4. **Recovery –** recovery refers to a return of productivity and occurs where productive capacity (physical habitat) remains. The period of recovery is dependent on the ecosystem type. For example, lakebed sediments will recolonize with benthic organisms relatively rapidly, whereas replanted riparian vegetation make take multiple years to reach expected productivity.
5. **Lost productivity** – the production or ecosystem service lost following a temporary disturbance of the habitat. The productive capacity is assumed to remain.
6. **Habitat Equivalency Analysis** – HEA converts lost productivity (or ecosystem services) accumulated over time (if applicable) into an equivalent area (potential productive capacity)
7. **Equivalent compensatory habitat** – the area of habitat that can be constructed to offset lost productivity during a temporary disturbance.
8. **Compensatory habitat construction –** will increase productive capacity and in turn contribute productivity to offset losses experienced during a temporary disturbance.

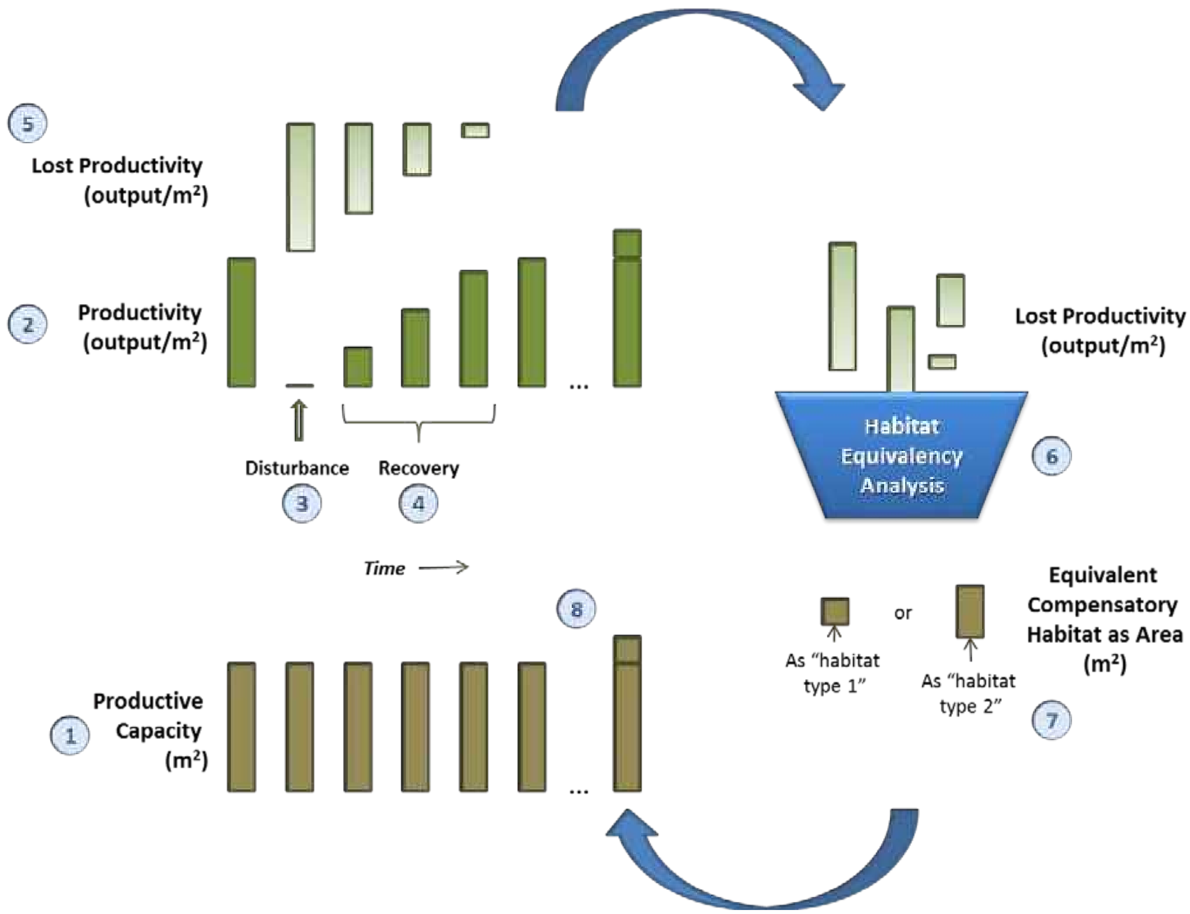


Figure 10: Illustration of Habitat Equivalency Analysis Concept

The HEA concept developed by NOAA (1995) is expressed as a complex equation:

$$J * V_j * \sum_{t=0}^{N+1}\left[(1+r)^{C-t} * \frac{b^J - 0.5\left(x_{t-1}^J + x_t^J\right)}{b^J}\right] + \left[\left(\frac{b^J - x_{t=N+1}^J}{b^J}\right) * \frac{1}{r} * (1+r)^{C-(N+1)}\right] =$$

$$P * V_p * \sum_{t=I}^{M+1}\left[(1+r)^{C-t} * \frac{0.5\left(x_{t-1}^P + x_t^P\right) - b^P}{b^J}\right] + \left[\left(\frac{x_{t=M+1}^P - b^P}{b^J}\right) * \frac{1}{r} * (1+r)^{C-(M+1)}\right]$$

Kohler and Dodge (2006) translated NOAA's equation into user-friendly software, Visual_HEA (with updates per Pioch et al. 2017), that requires the following input parameters:

- **Year of "claim".** This is the year in which the habitat damages/harmful disruption are made. The "claim" is an anchor point in time. The HEA calculations use the claim year as the reference point in calculating discounted service levels. The discount level at the time at which the damages were incurred is 1.0.
- **Service loss parameters from the habitat disruption.** This includes the size of the habitat damages/harmfully disrupted area and the time history of the loss of services at the disrupted site. In other words, it identifies the duration and level of service loss from time of disruption through habitat compensation.
- **Compensation ratio.** This parameter is the ratio of the area of disrupted habitat to the area of compensatory habitat. In this formulation of the Visual_HEA program, the compensation ratio is held constant throughout the analysis and was assumed to be 1:1 because of the system of monitoring and offset adjustment. The compensation ratio required by DFO for a given project is intended to qualitatively consider the length of time it takes for the habitat to become functional and/or for potential uncertainty in the habitat functioning as anticipated (DFO 2010). When there is uncertainty in the success of the new habitat, variance in the quality of habitat being replaced, and the lag time required for the new habitat to become functional DFO may request a higher ratio. HEA replaces arbitrary ratios with scientifically supportable estimates of recovery duration and in this RP, uncertainty in those estimates is accounted for through verification monitoring and adjustment of offsets owing.
- **Discount rate.** This default parameter incorporates the assumption that services provided sooner are more highly valued than those provided later. Because service losses and gains occur at different times, they should be adjusted to be compared. This adjustment is accomplished using a "discount factor" which decreases the value of future services and increases the value of past services to reflect the service benefits today. The incorporation of a discount factor therefore rewards the early construction of habitat and penalizes delays in constructing habitat. This discount rate is specified as a percentage rate per time unit; a default of 3% is commonly used as this is analogous to the common default inflation rate used for evaluating financial costs into the future. The discount rate does not consider potential short term economic fluctuations that may influence inflation.

- **Baseline levels of services.** These percentage values indicate the level of services being provided by the injury site prior to the habitat disruption and the level of services provided by the compensation site prior to any compensatory action. That is, in the case of the damaged or disrupted site, the baseline represents the level of services that would have been provided by the site had the disruption not occurred. For example, the baseline level of services of a habitat prior to disruption might be 100% (full services) or at some lower value depending upon the condition of the habitat. Conversely, the services level provided by the restoration site immediately upon restoration action might be 0% (no services such as would be the case upon immediate placement of a new substrate).
- **Pre-restoration service level**: This is the service level provided by the habitat during the period of disruption. In the case of Hazeltine Creek, this service level would be zero prior to build-out of a reach.
- **Service gain parameters from the compensatory action (restoration).** This includes the time history of service levels of the compensatory action.

4.3 Overview of Remedial Objectives by Area

Table 5 provides a summary of the remediation objectives by area and the work that has been carried out in those areas is summarized in Table 6. The focus of these objectives is to define the design basis for physical (structural) habitat that delivers the functions defined in those objectives. Protection of water and sediment quality is an overarching objective for the aquatic components of the project area and soil quality for the terrestrial components. As described in Section 4.1, water, sediment and soil quality are being risk managed and addressed through the CEMP as appropriate and, if monitoring demonstrates it to be needed, site-specific remediation work plans may be developed in the future to address potential risks to organisms from chemical stressors.

Table 5: Habitat Remediation Objectives by Area

Area	Area Name	Reach	Fish Habitat EU	Aquatic Objectives	Terrestrial Objectives
1	Tailings Storage Facility	NA	NA	NA	NA
2	Polley Flats	1	H1	■ Create rearing habitat for juvenile Rainbow Trout (primary objective) ■ Create spawning habitat for Rainbow Trout ■ Create overwintering habitat for Rainbow Trout	■ Establish self-sustaining riparian revegetation that provides cover, insect drop and eventually LWD to Hazeltine Creek ■ Establish riparian and adjacent forest vegetation that provides resistance of soils to erosion ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
3	Polley Lake	NA	Polley Lake	■ Restored benthic invertebrate community that contributes food organisms to fish that prey on emerging insects	■ Establish riparian revegetation along impacted shoreline of Polley Lake ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
4	Upper Hazeltine Creek	2	H1	■ Create spawning habitat for Rainbow Trout (primary objective) ■ Create rearing habitat for juvenile Rainbow Trout	■ Establish self-sustaining riparian revegetation that provides cover, insect drop and eventually LWD to Hazeltine Creek ■ Establish riparian and adjacent forest vegetation that provides resistance of soils to erosion ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
		3		■ Create spawning habitat for Rainbow Trout ■ Create rearing habitat for Rainbow Trout	
5	Hazeltine Canyon	4	NA	■ Rearing habitat for Rainbow Trout (minor)	■ Promote natural successional processes
6	Lower Hazeltine Creek	5	H2	■ Create spawning habitat for Coho, Sockeye and Kokanee ■ Create rearing habitat for Rainbow Trout and juvenile Coho Salmon ■ Create overwintering habitat for Rainbow Trout and juvenile Coho Salmon ■ Construct a stream channel that is connected to the floodplain and maintains natural flow of surface water and sediment ■ Identify post-remediation uses (objectives) for the sediment control ponds (HRWG)	■ Establish self-sustaining riparian revegetation that provides cover, insect drop and eventually LWD to Hazeltine Creek ■ Establish riparian and adjacent forest vegetation that provides resistance of soils to erosion ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
6	Lower Edney Creek	6	E2, E3	■ Restore and maintain passage from Quesnel Lake to Edney Creek watershed ■ Create spawning and rearing habitat for Coho Salmon and other species (including other salmonids) ■ Create rearing habitat for Rainbow Trout and Coho Salmon	■ Establish self-sustaining riparian revegetation that provides cover, insect drop and eventually LWD to Hazeltine Creek ■ Establish riparian and adjacent forest vegetation that provides resistance of soils to erosion ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
7	Edney Creek Mouth	6	E3	■ Maintain passage to and from the confluence of the two watercourses from and to the reaches of Edney Creek unaffected by the dam breach ■ Create rearing habitat for Rainbow Trout and Coho Salmon ■ Create shallow gravel shoal habitat	■ Establish self-sustaining riparian revegetation that provides cover, insect drop and eventually LWD to Hazeltine Creek ■ Establish riparian and adjacent forest vegetation that provides resistance of soils to erosion ■ Increase oxygen exchange with native soil ■ Create micro sites with suitable growing conditions for regenerating plants ■ Increase habitat complexity for riparian wildlife including amphibians
8	Quesnel Lake	Limnetic Zone	QL - Limnetic	NA	NA
		Littoral Zone	QL - Littoral	■ Restored access to Lower Edney Creek for spawning and rearing fish ■ Restored use of littoral zone for shoreline spawning and rearing ■ Create shallow shoreline habitat with conditions that promote the establishment of emergent and submergent vegetation.	■ Planting and assisting recovery of suitable riparian vegetation
		Benthic Zone	QL – Benthic	■ Restored benthic invertebrate community that contributes food organisms to fish that prey on emerging insects (e.g., Lake Whitefish)	NA
9	Quesnel River	NA	NA	NA	NA

HRWG – Habitat Remediation Working Group; LWD – large woody debris; NA – not applicable; QL – Quesnel Lake.

Table 6: Summary of Remediation Strategies and Treatments for Impacted Stream Reaches To 2018

Actions to Date	Remediation Area						
	1 (Polley Flats)	2 (Upper Hazeltine)	3 (Upper Hazeltine)	4 (Hazeltine Canyon)	5 (Lower Hazeltine)	6 (Lower Edney Creek)	NA (Edney Creek Mouth)
Site preparation (creating access, opening borrow areas, installing erosion-protection, etc.)	✓	✓	✓	✓	✓	✓	✓
Rough grading (filling in depressions and gullies, removing deposits of tailings, roughing in floodplain, stabilizing cut-banks, excavating channel)	✓	✓	✓	NA	✓	✓	✓
Initial armouring to stabilize channel and allow flows to be released from Polley Lake	✓	✓	✓	NA	✓	✓	✓
Placement of spawning gravels, woody debris, etc.	✓ (Oct 2016)[2]	✓ (Sep 2017)[3]	⊙	NA	⊙	✓ (Sep 2015)	✓ (Sep 2015)
Slope Grading	✓ (Oct 2015)	✓ (Oct 2015)	✓ (Oct 2015)	NA	✓ (Oct 2015)	✓ (Oct 2015)	✓ (Oct 2015)
Riparian planting[1]	✓ (Oct 2016)[2]	✓ (Oct 2017)[3]	⭘	NA	⭘	✓ (Oct 2015)	✓ (Oct 2015)
Re-grading of cut-banks	✓	✓	⭘	NA	✓	✓	✓
Construction of Settling Ponds	NA	NA	NA	NA	✓	NA	NA
Soil placed with coarse woody debris	✓	✓	⭘	✗	✓	✗	✗
Recontour with topsoil and coarse woody debris	✓	✓	✓	✗	✓	✓	*
Floodplain mounded with coarse woody debris	✓	✓	⊙	✗	✓	✓	✗
Floodplain ripped with coarse woody debris	✓	✓	✓	✗	✓	✗	✗
Grass seeding	✓	✓	✓	✓	✓	✓	✓
Wood chip mulch with coarse woody debris	✗	✗	✗	✗	✓	✗	✗

✓Complete; ⭘ Partially Complete (see notes below); ⊙ To Be Completed; ✗ Not Planned; NA Not Applicable.

Notes:

Reach 4 - Created access only.

Reach 3 - Some seeding and some planting has been done; however, more work will need to be done. Habitat work (placement of spawning gravels, woody debris, etc.) still to be completed and will disturb some of the planted areas.

- Regrading at cut banks complete except for the big blowout at 5,800 m.

Reach 5 - Some seeding and some planting has been done; however, more work will need to be done. Habitat work (placement of spawning gravels, woody debris, etc.) still to be completed and will disturb some of the planted areas.

[1]Riparian planting consisted of planting staked live wattles of willow and black cottonwood, prickly rose, black twinberry, red osier dogwood, Sitka alder and conifers as well as a custom locally collected multispecies seed blend.

[2] Parts of Polley Flats remediated in 2017

[3] Remediation work completed in Reach 1 in 2016 extended down into Reach 2 to chainage 1+265 m in progress October 2017.

4.4 Remedial Approach by Area

The following sections present background on the physical characteristics requiring remediation, the work that has already been carried out, the options considered, and the preferred conceptual remediation approach.
The options analysis for work that has already proceeded (e.g., in Hazeltine Creek) was undertaken at the time the work was being planned and implemented and those options included the input of external advice through the HRWG. The resulting work incorporated that advice.

The focus of the following section is on aquatic habitat remediation because the objectives differ by reach. Terrestrial remediation is also necessary but the objectives have some commonalities such as riparian function along all reaches (and lakeshores), provision of habitat complexity for riparian wildlife, including amphibians and regeneration of soil structure. These are outlined in Table 5.

4.4.1 Tailings Storage Facility / Area 1 (Dam Breach Re-engineering)

The TSF breach in the perimeter embankment has been repaired and considerably upgraded with buttressing as described below and MPMC has since received permits enabling the operation of the TSF within the parameters of those permits.

- The 4 August 2014 breach of the TSF Perimeter Embankment was about 100 m long, although damage occurred to an approximately 400 m length of the embankment. A temporary upstream rockfill berm was constructed between August and September 2014 to control the release of tailings.
- A Freshet Management Embankment was constructed at the breach zone between November 2014 and June 2015 to allow capture and temporary storage of the 2015 freshet flows and prevent release of tailings to the downstream environment. The Freshet Management Embankment was constructed with rock-fill, crushed rock aggregate and sandy tailings to an elevation of 950 m. A cut-off wall was then constructed through the Freshet Management Embankment by mixing the crushed rock aggregate with cement and bentonite slurry.
- The Freshet Management Embankment was raised in 2016 and 2017 to elevation 963 and 966 m, respectively. A compacted till core was used as the low permeability element to raise the cut-off wall of the Freshet Management Embankment. Rock-fill, crushed rock aggregate and sandy tailings were placed upstream and downstream to support the till core. A buttress was built downstream of the Freshet Management Embankment in 2016 and 2017. The Freshet Management Embankment, raises and buttress were constructed using non-potentially acid generating (NAG) materials.
- A Perimeter Embankment Buttress was constructed downstream of the Perimeter Embankment in 2015, and the Main Embankment Buttress was constructed downstream of the Main Embankment in 2016. The Buttresses were constructed using NAG rockfill. The buttresses were constructed with a downstream slope of 3H:1V. The Perimeter Embankment Buttress was extended in 2016.

4.4.2 Polley Flats / Area 2 (Reach 1)

Using the classification system of the HRWG, this area corresponds to Ecological Unit H1. Polley Flats / Reach 1 represents the outlet channel of Polley Lake and encompasses approximately 70 ha of the TSF breach area. The natural stream alignment flowing out of Polley Lake had been historically (late 1800s to early 1900s) directed into a manmade, diversion channel for the first 775 m (Golder 2015b) as part of the water supply for hydraulic mining in the area (Figure 11). This channelized outlet ran along the east side of what was historically a vegetated, meandering flood plain. The pre-breach channel connected with a beaver pond which also received input from Bootjack Creek. Polley Flats and Area 2 extended a short distance (~300 m) past this stream convergence, part way into Reach 2 where the stream channel became better defined but still incorporated some beaver dam ponds and side channel meanders (Golder 2015b).

Figure 11: Historic Photo of Polley Lake Cut for Hydraulic Mining (CCHMC, undated, ca. 1900)

Channel, floodplain and vegetation characteristics in Area 2 were significantly altered by the TSF breach. However, with active channel and floodplain remediation integrated with a comprehensive revegetation strategy, there is a high potential for recovery. Limiting factors for Area 2 included large deposits of tailings and associated material, along with scouring and poor, post-breach soil substrate fertility. Overall ecological risk was considered low-moderate for Area 2 (Golder 2017b). As of the end of 2018, approximately 350,000 metric tonnes of tailings have been removed from Polley Flats and a small area in Reach 2. Area 2 aquatic remediation efforts have advanced considerably, with initial armoured channel and creation of complex aquatic habitat completed in 2017. Planting in the riparian zone has also occurred. Remediation activities in Reach 2 are further described in Section 4.6.

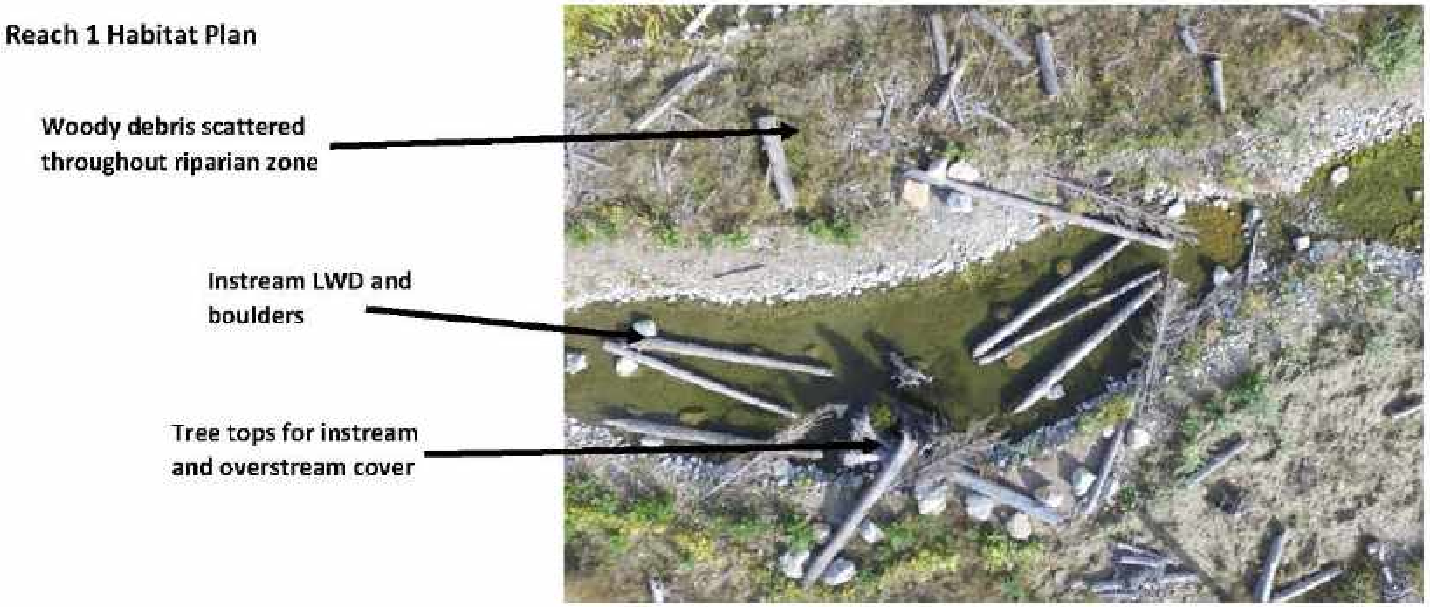
A summary of the current remediation actions conducted to date in Area 2 (Reach 1) is summarized in Figure 12 and Table 6.

Primary objectives for aquatic habitat in Area 2 (Reach 1 or Ecological Unit 1) are to provide rearing, spawning and overwintering habitat for rainbow trout. This includes establishing a moderate sinuosity, moderately entrenched, and confined stream type with coarse gravel and small cobble substrate. The channel bed morphology includes riffle-pool morphology with irregularly spaced scour pools. Pools are formed and maintained by large woody debris structures associated with outside meander bends, boulders and eventually, vegetation. Aquatic habitat objectives also include providing a heterogeneous mix of components such as depth, velocity substrate, cover, and pools that support populations of trout and other aquatic organisms. Aquatic habitat construction in Area 2 was carried out in 2017 with ongoing monitoring.

Objectives for terrestrial sites in Area 2 include rehabilitating the floodplain to target ecosystems representing a diverse mosaic of shrubs and trees of varying age classes. Hydrogeomorphic and other disturbance processes will affect the development of the riparian and floodplain ecosystem, ultimately determining the spatial pattern and successional development of riparian vegetation. A mosaic of riparian conifer forest, cottonwoods, aspen and riparian shrubs would be present within the future floodplain depending on topography, disturbance patterns, and morphology. Terrestrial habitat objectives also aim to provide shade, nutrients and small organic debris (SOD) to support riparian ecological functions (Koning and Wendell, 1999). This in turn would support wildlife use in Area 2 and maximise the wildlife habitat features present in the system.

Terrestrial remediation efforts are ongoing with a focus on site preparation and planting. Mounding and ripping as a site preparation method, has helped alleviate compaction and helped liberate the original topsoil over 14.5 ha (20%) of Area 2. This site preparation also creates atmospheric connectivity which increases oxygen exchange and promotes soil fauna and microbial communities. Additional site preparation methods include placing imported soil over 19 ha to bring in needed nutrients and improve growing medium structure. Woody debris has been placed over all the site preparation areas to promote structural heterogeneity and to provide microsites for establishing plants. Remediation efforts such as these, improve the physical and structural properties of the soil, and facilitate re-establishment of vegetation. Upland and riparian plantings have been initiated over 35.6 ha (50%) of the disturbance zone in Area 2.

Reach 1 Habitat Plan



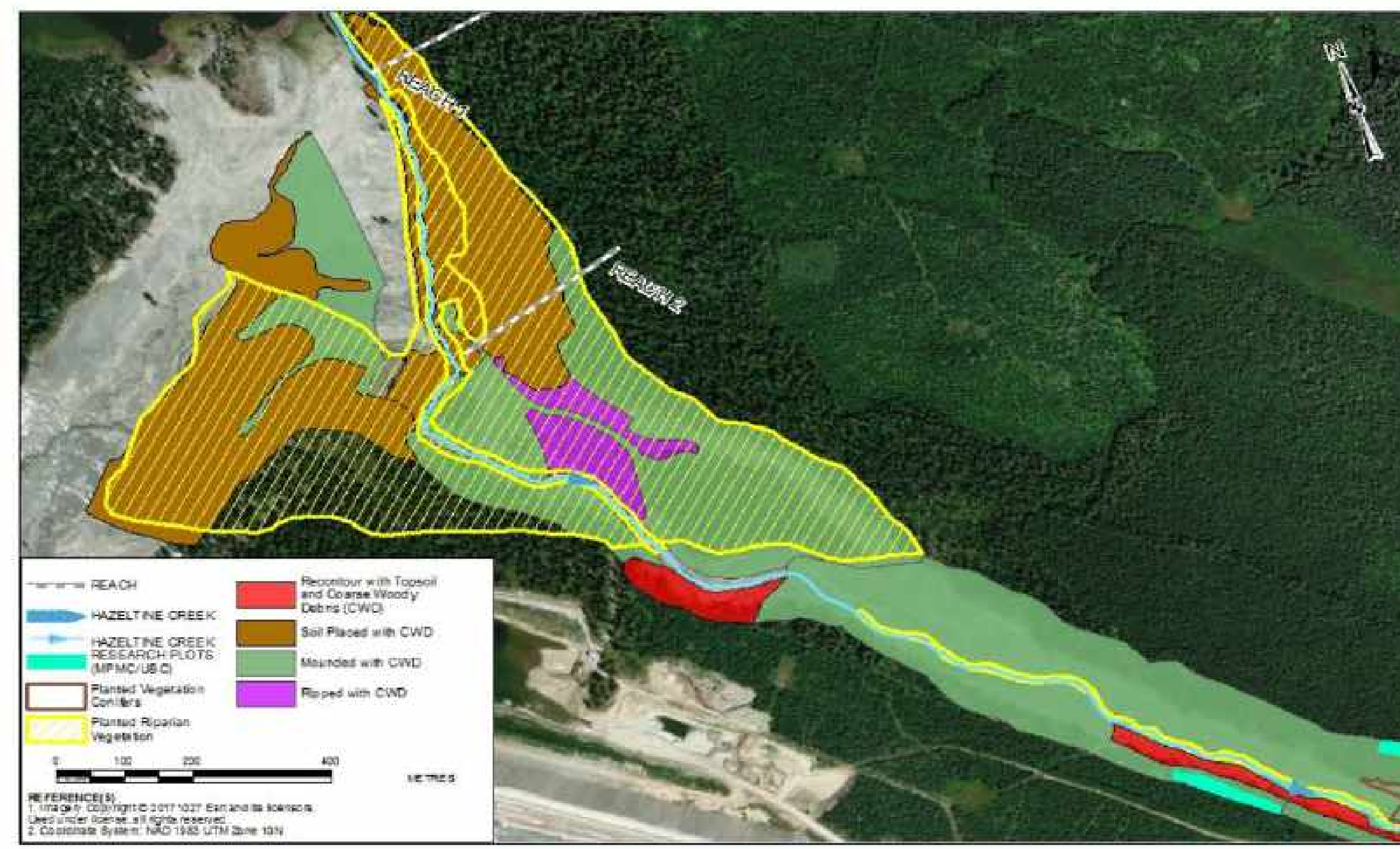


Figure 12: Polley Flats / Area 2 (Reach 1) Description and Current Remediation and Rehabilitation Status

4.5 Polley Lake / Area 3

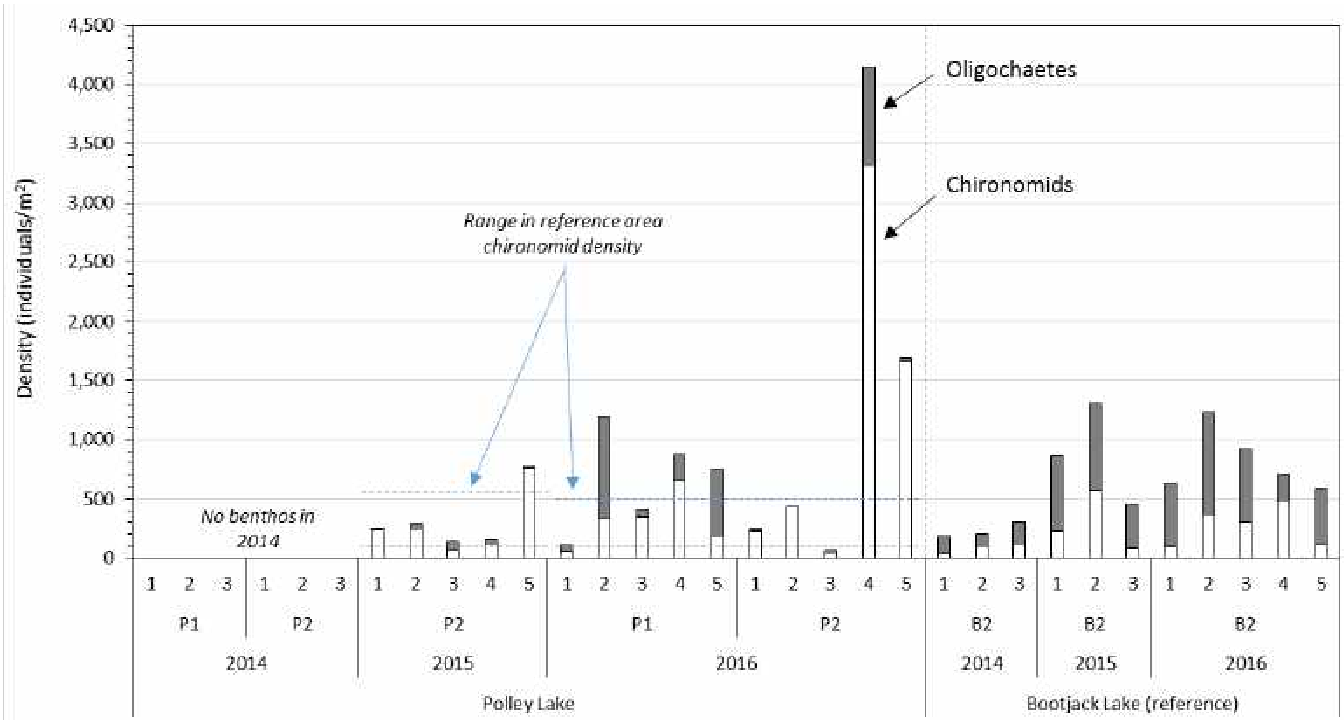
Using the classification system of the HRWG, this area is one EU – Polley Lake. Polley Lake is situated adjacent to the Mount Polley Mine and has a long (6.17 km), narrow (0.65 km) configuration. The lake has a pre-breach mean depth of 18 m and maximum depths of 35 m in the south basin and 33 m in the north basin. The main inflow to the lake is from the Frypan Lake sub-watershed to the northwest and the estimated hydraulic residence time of the lake is approximately 16.2 years (MPMC 2015a). The lake was previously used to supply water for hydraulic placer operations (see for example Figure 11). Polley Lake is dimictic and mixes from the surface to the lake bottom twice each year. Thermal stratification occurs in summer with the thermocline typically forming at a depth between 5 and 15 m (Minnow 2014). Hypoxic (low oxygen) conditions generally occur at depths greater than 20 m, with dissolved oxygen (DO) concentrations less than 5 mg/L, including before the breach (Minnow 2014). The trophic status of the lake reportedly 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. Tailings inundated a wetland at the outlet of Polley Lake and deposited heterogeneously throughout the lake itself (MPMC 2015a). As well, a thick deposit of tailings and other debris (known as the “Plug”), blocked water from flowing out of Polley Lake and into Hazeltine Creek. Immediately following the event, the water level in Polley Lake increased by approximately 1.7 m and turbidity increased in the deeper waters of the lake below the thermocline. In mid-October 2014, 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 (Golder 2016a).

The deposit of material at the outlet of Polley Lake affected spawning and rearing areas for Rainbow Trout and Longnose Sucker both in the lake as well as downstream of the outlet in Upper Hazeltine Channel. In addition, shortly after the TSF breach a fish fence and flow control structure was installed at the outlet of Polley Lake to Hazeltine Channel. This fish fence had (until April 2018) prevented Rainbow Trout in Polley Lake from accessing historical spawning habitat in Upper Hazeltine Creek during ongoing reconstruction and remediation of Hazeltine Creek. As demonstrated in the age frequency distribution for Rainbow Trout, in 2016 there were a greater number of older fish and an apparent absence of year-1 and -2 individuals compared to the distribution for 2014 (Minnow 2017a).

The deposit of tailings and outwash material in Polley Lake temporarily reduced the density (number of individuals per a given area) of benthic invertebrates. Benthic invertebrates, such as chironomids (the aquatic larvae of midges) and oligochaetes (freshwater worms), are eaten by fish and their abundance provides an indication of habitat quality for rearing and overwintering fish. Chironomid density is particularly relevant to the fish population of Polley Lake as both Rainbow Trout and Longnose Sucker feed on the aquatic stage of this insect group, although they can also be opportunistic and feed on other taxa (MPMC 2015a).

Figure 13 shows the density of chironomids and oligochaetes in deep areas of the lake and Figure 14 shows the density in mid-depth areas of the lake in Polley Lake and in the reference area, Bootjack Lake, for 2014, 2015, and 2016. No benthic invertebrates were found in the deep area of Polley Lake in 2014 and in the mid-depth zone, the numbers were lower than found in Bootjack Lake. In the year after the breach, the deep benthic community was recolonizing the substrate and chironomid density in all but two replicates was within the range observed in reference Bootjack Lake. By 2016, the mid-depth benthic community had a higher density than that of Bootjack Lake (Figure 14). Subsequent sampling of Polley Lake has not been undertaken.



Note: Bars show individual replicates. Source of data: Golder (2017c).

Figure 13: Spatial and Temporal Variability in Benthic Invertebrate Density in Polley Lake Deep Areas, 2014, 2015, and 2016

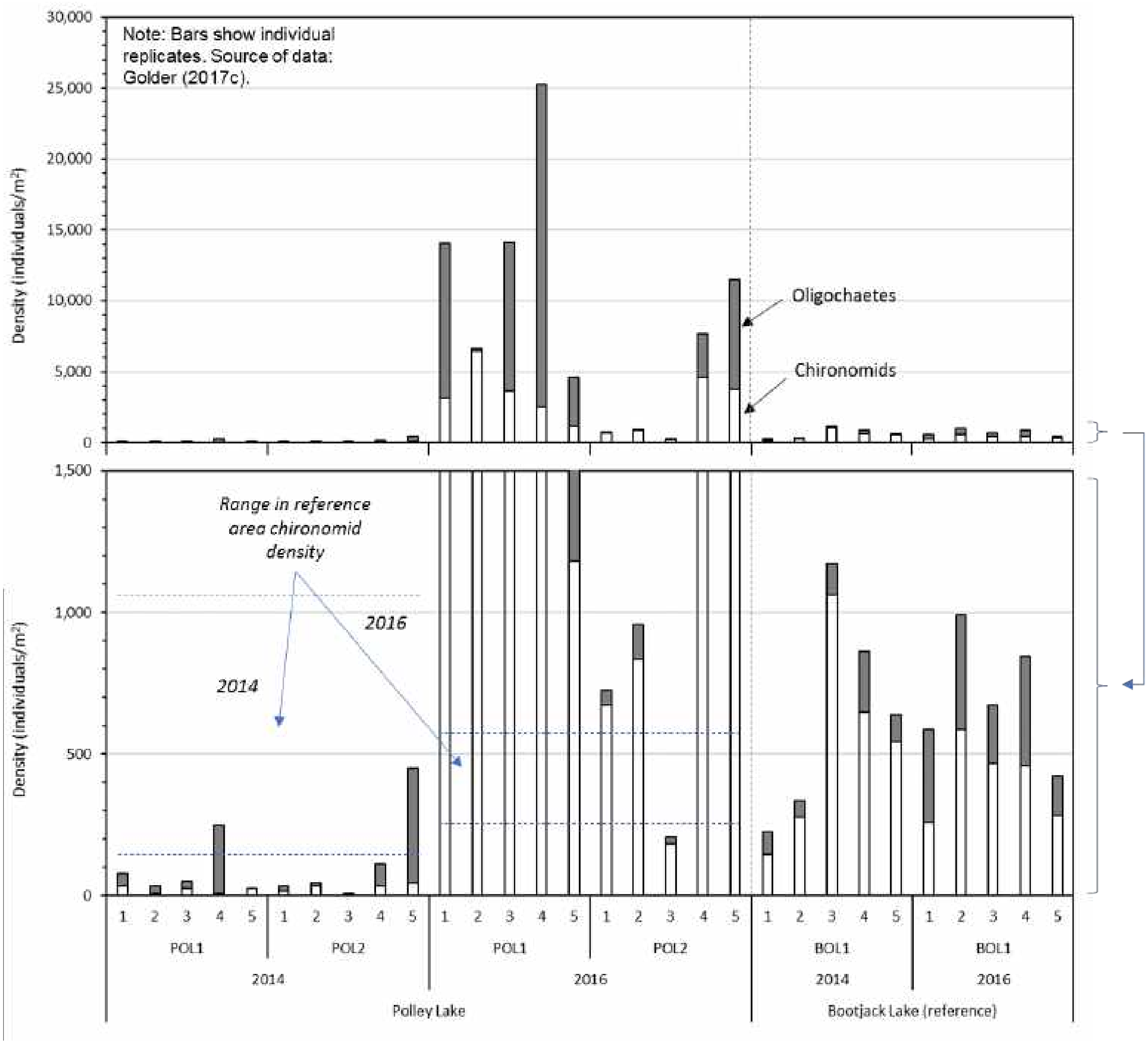


Figure 14: Spatial and Temporal Variability in Benthic Invertebrate Density in Polley Lake Mid-depth Areas, 2014 and 2016

There is some uncertainty regarding the suitability of Bootjack Lake as a reference over the longer term given a recent amendment to the waste discharge authorization which now allows the discharge of seep water to Bootjack on a contingency basis. As of writing, there has not been a discharge. Nonetheless the Polley Lake monitoring data show a trend in increasing abundance of benthic invertebrates and the temporary disruption to this food source for these species did not appear to have affected either Rainbow Trout or Longnose Sucker, as measured by condition factor (calculated from fish length and weight) which was similar for both species between 2014 and 2016. Should the permitted Springer Pit seep discharge be utilized, the study design will need to be re-evaluated as part of the CEMP update process.

4.5.1 Remediation Activities to Date

Reconstruction of the Hazeltine Creek channel has largely restored the connection between Polley Lake and upper Hazeltine Creek, except for a flow control structure which was constructed at the mouth of Polley Lake to control flows during reconstruction of the Hazeltine Creek channel. The outflow control structure (or weir) can impound water in the lake, for example during freshet or at times when water flows would impede habitat construction works. The weir also allows for the discharge of water at a controlled rate to control erosion as reconstructed areas of Hazeltine Creek stabilize as planted vegetation grows. An additional benefit of the weir is that it can allow for a more moderate hydrograph, providing extended flow durations in Hazeltine Creek which have historically (pre-breach) been low in the summer months. While it has yet to be decided by the HRWG, the weir may form part of habitat offsets. The weir was recently (2018) also equipped with a fish ladder allowing fish to successfully move between Polley Lake and upper Hazeltine Creek.

From the time the weir was constructed until April 2018, Polley Lake Rainbow Trout, which use upper Hazeltine Creek for spawning and rearing, were excluded by a fish fence from using that habitat while the channel reconstruction was underway. Based on the findings of an evaluation of flows, habitat availability, and water quality (Golder 2018b), a fish bypass structure was installed beside the flow control structure which will remain in place, and Rainbow Trout now have access to Upper Hazeltine Creek. Monitoring of the re-introduction effort demonstrated high utilization by Polley Lake Rainbow Trout adults, estimated to number 4,890 and an estimated recruitment of 18,064 juvenile Trout were produced in this lake outlet. The adults returned to Polley Lake following spawning and most of the juveniles also returned to Polley Lake as new recruitment to that population (Connors et al., 2018).

Planting of the riparian area adjacent to Hazeltine Creek was also carried out by MPMC (see details in Table 6).

4.5.2 Remediation Plan

The potential pathways of effect for the identified ecological functions for Polley Lake (rearing, overwintering, spawning, migration) were deposition of material, alteration of habitat structure, loss of riparian vegetation and exclusion from habitat by temporary fencing (Table 3). The remediation objectives for this area are summarized in Table 5.

As illustrated above (Figure 13 and Figure 14), the deposition of material initially caused a reduction in the benthic invertebrate community (e.g., a reduction in food organisms for fish) which, based on more current data appears to be approaching recovery. In Polley Lake, unlike Quesnel Lake, the TSF Breach outwash materials mixed with soils and sediments of Polley Lake which retained organic carbon in the settled material. As discussed in Section 4.11.3.3, potential remediation options identified for deposited material in Quesnel Lake were: dredging, addition of organic carbon (unlikely to provide benefit for Polley Lake), thin-layer capping, and monitored natural recovery (MNR). The evaluation of those options is considered in detail in the remedial options evaluation for Quesnel Lake. Some of the principles of that evaluation for Quesnel Lake have similarities to the situation of Polley Lake. While dredging in Polley Lake would have less logistical implications than Quesnel Lake (see below), dredging would be similarly disruptive and would not provide a clear benefit given the signs of recovery observed in Polley Lake, which has similar abundance and diversity of benthic organisms when compared with the reference lake (Figure 14). For the bottom of Polley Lake, the selected remedial option is therefore MNR, which is described in further detail in Section 4.11.3.4, in the context of Quesnel Lake.

Polley Lake benthic invertebrate monitoring study design will be addressed in the CEMP so that consistent and appropriate techniques are used to support MNR.

4.6 Upper Hazeltine Creek / Area 4 (Reach 2 & 3)

The EU for aquatic habitat in the area are provided in Table 2, remediation objectives for Upper Hazeltine Creek are in Table 5, and the current remediation actions conducted to date in Area 4 (Reaches 2 and 3) are summarized in Figure 15 and Table 6. Using the classification system of the HRWG, this area corresponds to EU H1. Section 4.5 describes how the breach event affected the area.

Reach 2 extends downstream from Polley Flats to the Gavin Lake road crossing. This reach is a relatively low gradient with a wide floodplain between Hazeltine Creek flows from Polley Lake to the start of Hazeltine Canyon. The habitat objectives for Reach 2 are to provide both rearing and spawning habitat for Rainbow Trout (Table 4). The hydraulic grade of Reach 2 is modest, with an average grade of approximately 0.9%. Typical flow velocities at this grade are conducive to spawning by Trout. Primary, secondary and tertiary meanders occur throughout Reach 2. The channel was designed to facilitate spawning by Trout at points of downwelling and upwelling along the meanders of both the low flow and MAF channels. Spawning habitat was also provided within gravel platforms associated with the upstream end of v-notch weirs constructed to create pools within the design alignment of the MAF channel. These weirs are fish passable. The upstream ends of the pools are fitted with boulder weirs to facilitate scour of the pools (to minimize the accumulation of sediments) and to mitigate head-cutting. The channel (apart from the weirs) and the pools have been complexed with boulders, logs and tree tops to provide instream and overstream cover for fish. The interaction of flows with these features will sustain and/or create runs, small riffles and small pools along the design alignment of the low flow channel and will facilitate mixing throughout the water column of the pools. It is this complexity that will sustain rearing habitat for juvenile Trout.

Provision of spawning habitat for Rainbow Trout and rearing habitat for juvenile Rainbow Trout are the primary objectives for Reach 3 (Table 4). The hydraulic grade of Reach 3 is relatively steep, with an average grade of approximately 2.3%. Flow velocities are at about the upper limit of those associated with spawning by Trout. The secondary meander represented by the MAF channel is absent. It is expected that spawning by Trout will occur at points of downwelling and upwelling along the meanders of the low flow channel. Boulders weirs are a common feature of the MAF channel due to the steepness of the channel; they will mitigate head-cutting. They are also instrumental in maintaining the meander of the low flow channel; without the weirs, the low flow channel would eventually straighten due to the relatively high flow velocities, facilitating laminar flow and hindering downwelling and upwelling, and decreasing habitat values for Trout. Large v-notch weirs occur within the design alignment of the MAF channel to create ponds. These weirs are at about the steepest grade associated with passage by Trout; passage is facilitated (through turbulent flow) by a meander in the v-notch and a dense aggregation of boulders orientated in a haphazard pattern. The upstream ends of the pools are fitted with boulder weirs to facilitate scour of the pools (to minimize the accumulation of sediments) and to mitigate head-cutting.

The remainder of Reach 3 and the pools have been complexed with boulders, logs and tree tops to provide instream and overstream cover for fish. It is expected that the pools will provide rearing habitat for juvenile Trout. The interaction of flows with complexing features will enhance turbulence, important in creating hydraulic refugia for both adult and juvenile Trout. This will mitigate the ‘flushing’ and downstream ‘losses’ of Polley Lake fish through the canyon and into Quesnel Lake.

Trout access into upper Hazeltine Creek was facilitated by removing the fish fencing between Polley Lake and Hazeltine Creek. At the same time, new fish fences were installed at the lower range of constructed habitat in Hazeltine Creek. The recent use of the area by Rainbow Trout is described in Section 4.5.1. Monitoring carried out (Connors et al. 2018) identified that the desired habitat functions appear to have been achieved. Habitat monitoring will continue as the remainder of Hazeltine Creek habitat is built-out.

Monitoring data collected in 2015 and 2017 indicated that the reconstructed streambed has been colonizing with benthic invertebrates and periphyton (Minnow 2018c). In 2017, the abundance of invertebrates (collected by kicknetting for a specified time) was in the range of 10,000 organisms per sample, comprised of mayflies (Ephemeroptera), caddisflies (Trichoptera), chironomids (Chironomidae), and oligochaetes (Oligochaeta). Periphyton biomass (as chlorophyll *a*) ranged from 5 to 21 mg/m^2.

Overall, remedial activities to date appear to be successful. Monitoring for attainment of intended ecological functions and water quality monitoring will need to continue as part of MPMC's long term commitments (Figure 8).

Reach 2 and 3, Upper Hazeltine Creek (Area 4) receives input from Polley Lake via Polly Flats and flows into the start of Hazeltine Canyon. It consists of a 60 to 200 m disturbance zone surrounded by second growth hybrid white spruce forest stands. The rehabilitation strategy involves creating a stable channel morphology with an armored base lined with a 75mm minus spawning gravel. Mean Annual Flow (MAF) channel width varies between 4.5 m and 7.7 m and the lower floodplain averages 20 m wide.

Primary aquatic habitat objectives for this area are to provide rearing and spawning habitat for Rainbow Trout by creating step pool channels with interspersed riffles and rapids. Large woody debris and boulders have been added to meander points and channel margins to introduce aquatic habitat and cover for trout and other aquatic organisms. These weirs are fish passable and while they are not intended for spawning they help maintain spawning substrate in other areas. The upstream ends of the ponds are fitted with boulder weirs to facilitate scour of the ponds (to minimize the accumulation of sediments) and to mitigate head-cutting. In 2018, upper Hazeltine Creek supported spawning by and estimated 4,890 adult trout.

Terrestrial objectives in Reach 2 and 3 include improving soil conditions and reducing long term sediment load into Hazeltine Creek, as well as improving structure and function of habitat by introducing coarse woody debris and surface roughness via mounding and ripping. Revegetation efforts to date consist of grass seeding with an erosion mix and allowing natural ingress from nearby seed sources. The establishment of shrubs and deciduous trees mature is expected to be gradual and be replaced by dense stands of conifers. Channel conditions should continue to evolve into productive trout habitat with nutrient inputs from the surrounding vegetation.

Typical status of Reach 2 channel on 31 July 2018 (A) and Reach 3 channel on 17 September 2018 (B)

Upper Hazeltine Creek Plan

Aerial View of Reach 2 (17 October 2018)

Figure 15: Reach 2 and 3, Upper Hazeltine Creek (Area 4) Description and Current Remediation and Rehabilitation Status

4.7 Hazeltine Canyon / Area 5 (Reach 4)

Hazeltine Canyon has not been assigned an EU and remediation work for the canyon is not prescribed. The remediation objectives for the area are summarized in Table 5 and the current remediation actions conducted to date in Area 5 are summarized in Table 6.

Reach 4, Hazeltine Canyon (Area 5) is approximately 1.3 km in length and extends from the lower end of Upper Hazeltine Creek, at chainage 6+600 m, to the upper end of Lower Hazeltine Creek, at chainage 7+900 m. The canyon averages 50 m wide, with incised channel walls, and is the steepest reach with an average slope of 5%. The steep banks and the high longitudinal gradient create a narrow, structurally controlled valley or canyon that prevents upstream passage of fish. The upper edge of the canyon is lined with coniferous forest and there is limited floodplain development within this section. Some rearing (minor) of Trout is expected to occur in the Hazeltine Canyon area.

The high flows associated with the canyon provides little potential for fish habitat, therefore, remediation of fish habitat was not planned for Reach 4. Site preparation in the area has consisted of creating access and limiting erosion potential only. The fish habitat objective for this reach is controlling erosion and maintaining water quality for downstream habitats.

Terrestrial objectives in Reach 4 were limited to promoting natural successional processes. Remediation to date in Hazeltine Canyon has consisted of grass seeding to provide short term erosion protection and assist natural ingress of local vegetation.

4.8 Lower Hazeltine Creek / Area 6A (Reach 5)

Using the classification system of the HRWG, this area corresponds to EU H2. The EU and potential pathway of effects for aquatic habitat in Lower Hazeltine Creek are provided in Table 2 and the remediation objectives for the area are summarized in Table 5. The current remediation actions conducted to date in Area 6A (Reach 5) are provided in Figure 17 and Table 6.

Lower Hazeltine Creek / Reach 5 extends from the downstream end of Hazeltine Canyon to the Edney Creek confluence. The reach crosses over an alluvial fan that has formed at the outlet of the canyon (including pre-breach). The streambed in this reach has a low gradient of approximately 1.8%.

The lower Hazeltine Creek Area, extending to the shore of Quesnel Lake has been the location of considerable site preparation, addition of organic carbon (wood mulch) and multispecies planting as part of both habitat remediation work and erosion control. The physical habitat construction of Hazeltine Creek in Reach 5 has not yet concluded and additional planting is expected after the physical remediation and erosion control works are finished. Stream remediation designs for lower Hazeltine Creek have not yet been developed. However, a number of design concepts were discussed at November 2018 HRWG meeting. The consensus view was that the preferred option was that Hazeltine Creek and Edney Creek would be joined into a single creek, as it was pre-breach (Figure 16). The ponds will be decommissioned though specific details of that decommissioning have not yet been decided. However, their connection to the creek was not viewed as a desired design element.

Monitoring data collected in 2015 and 2017 indicated that the reconstructed foundational stream channel has been colonizing with benthic invertebrates and periphyton (Minnow 2018c). In 2017, the abundance of invertebrates (collected by surber sampling) was on the order of 5,000 organisms per m^2. This density is lower than observed in 2007; however, the community in 2017 was comprised of similar taxa as observed previously (i.e., mayflies, stoneflies (Plecoptera), caddisflies, non- chironomids (Chironomidae), true files (Diptera)). Periphyton biomass (as chlorophyll *a*) was on average 5 mg/m^2. Creek habitat substrates and habitat complexity features have not yet been constructed in lower Hazeltine Creek and the final creek alignment will differ from that assessed.

Figure 16: A 2008 Photo of the mouth of Hazeltine and Edney Creeks. Prior to the breach, these streams were combined in a single channel. (Photo Courtesy MPMC).

The primary aquatic objective for Reach 5 (Area 6a) is to provide both rearing and spawning habitat for Sockeye salmon Rainbow Trout and Coho salmon. The overall channel remediation of Hazeltine Creek includes the lower floodplain, the Mean Annual Flow (MAF) channel, and the low flow channel. The primary meander pattern is exhibited by the lower floodplain; this part of the overall floodplain is engaged by flows associated with freshet. Armouring was undertaken to minimize erosion of the materials underlying the channel. Pockets of tailings and breach outwash materials were removed from the footprint of the constructed channel and from the footprint of any fill materials placed in the floodplain. Flow velocities in Reach 5 are conducive to spawning by both rainbow trout and Coho salmon. Grades were deeply incised by the release event and cuts into adjacent slopes to achieve relatively elaborate meanders were minimized as this would exacerbate existing cuts, resulting in further impacts to treed woodlands.

Instream habitat features resemble those defined for Reach 2. The v-notch weirs constructed to create ponds within the design alignment of the MAF channel are slightly steeper than those of Reach 2, at about 3.0 percent compared to 2.5% for Reach 2. These weirs are fish passable. The upstream ends of the ponds are fitted with boulder weirs to facilitate scour of the ponds (to minimize the accumulation of sediments) and to mitigate head-cutting.

The remainder of Reach 5 will be complexed with boulders, logs and tree tops to provide instream and overstream cover for fish. The interaction of flows with these features will sustain and/or create runs, small riffles and small ponds along the design alignment of the low flow channel and will facilitate mixing throughout the water column of the ponds. The features will enhance turbulence, important in creating hydraulic refugia for both adult and juvenile fish. It is this complexity that will sustain rearing habitat for juvenile trout. To date, soil rehabilitation efforts have reduced long-term sediment load flow into Hazeltine Creek by removing tailings and increased oxygen exchange with native soil. Ripping and mounding, along with Coarse Woody Debris (CWD) placement, have created micro sites that foster regenerating plants increase habitat complexity in this reach. Of the 29 ha in this area, 22 ha have been roughened and planted with riparian species while over 6 ha have been recontoured with imported soil and complexed with CWD. In addition, wood chip mulch has been spread over 5 ha to control erosion and reduce soil moisture loss.

Reach 5 on 17 September 2018 (A) and 31 July 2018 (B)

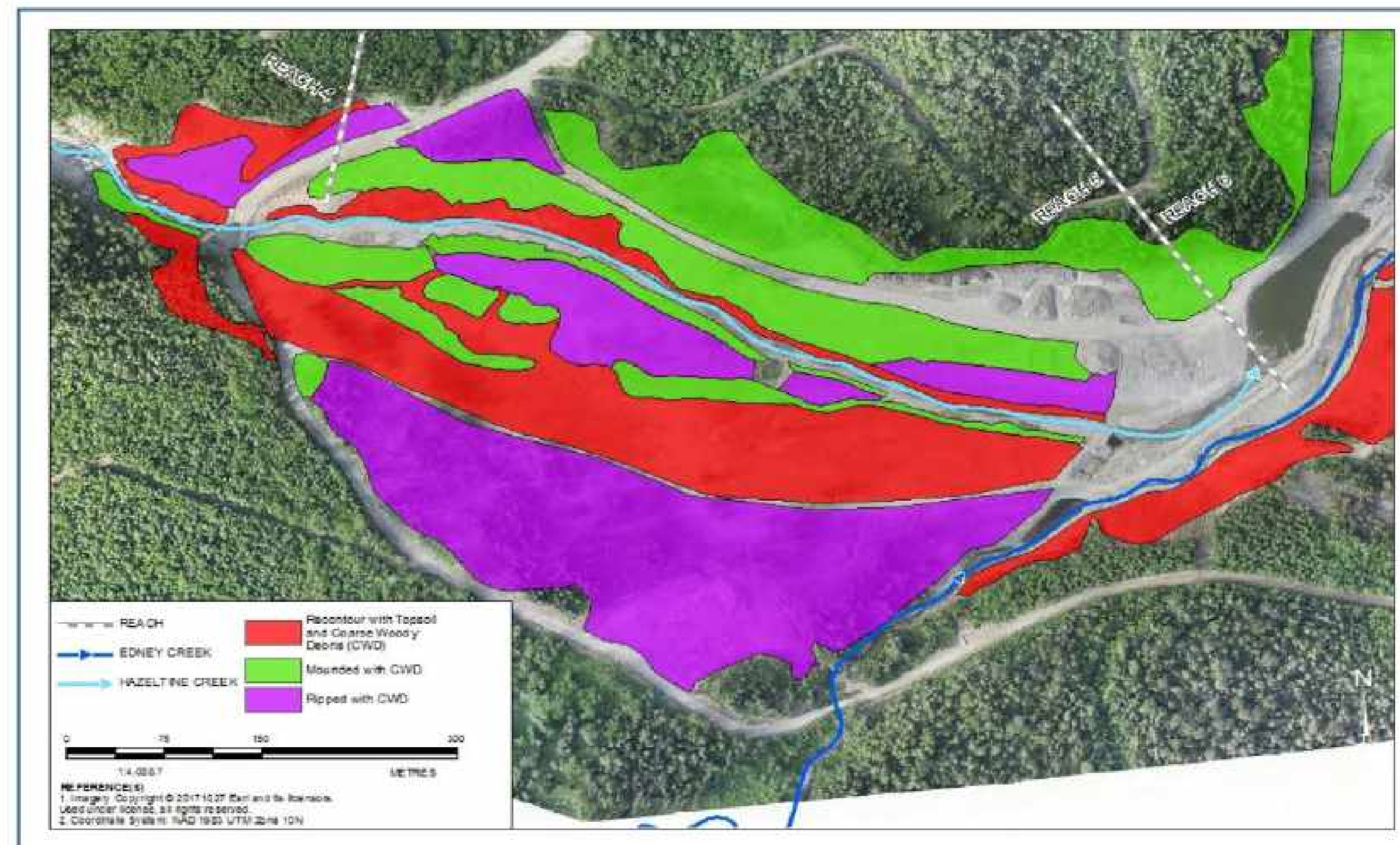


Figure 17: Reach 5, Lower Hazeltine Creek (Area 6a) Description and Current Remediation and Rehabilitation Status

4.9 Lower Edney Creek / Area 6b (Reach 6)

Using the classification system of the HRWG, this area corresponds to EU E3. The ecological units and potential pathway of effects for aquatic habitat in Lower Edney Creek are provided in Table 2 and the remediation objectives for the area are provided in Table 5. The current remediation actions conducted to date in Area 6b (Reach 6) are summarized in Figure 18 and Table 6.

This section is the furthest downstream reach and extends from the confluence of Hazeltine Creek and Edney Creek to the outlet into Quesnel Lake. Currently (as of fall 2017), the two creeks were separated in order to control outflow from Hazeltine Creek and facilitate fish passage and habitat remediation in Edney Creek. Hazeltine Creek now flows into two temporary settling ponds before discharging into the lake through a temporary diversion. Edney Creek follows its natural route with a secondary overflow channel that splits from the main channel less than 100 m from Quesnel Lake. Typical MAF channel width is approx. 7.1 m with a minimum lower floodplain width of 35 m. The hydraulic grade of Reach 6 is approximately 1.0%.

Sampling carried out (Minnow 2018a) has found that the habitat constructed is being used by the same species as were documented in the creek before the breach. Twelve fish species were captured from Edney Creek in 2016, including juvenile Rainbow Trout, and Coho and Chinook Salmon, confirming that the connection between Edney Creek and Quesnel Lake is functioning. Other species observed were: Kokanee, Mountain Whitefish, Northern Pikeminnow, Burbot, Largescale Sucker, Longnose Sucker, Bridgelip Sucker, Longnose Dace, Peamouth Chub, and Redside Shiner. Rainbow Trout and Longnose Dace were the most abundant fish.

Monitoring data collected in 2015 and 2017 indicated that the reconstructed streambed has been colonizing with benthic invertebrates and periphyton (Minnow 2018c). In 2017, the abundance of invertebrates (collected by surber sampling) was on the order of 5,000 organisms per m^2, comprised of mayflies, stoneflies (Plecoptera), caddisflies, non- chironomids (Chironomidae), true files (Diptera), and oligochaetes (Oligochaeta). Periphyton biomass (as chlorophyll *a*) was on average 5 mg/m^2.

4.10 Edney Creek Mouth / Area 7

Using the classification system of the HRWG, this area corresponds to EU E3. At the pre-breach confluence of Edney Creek and Hazeltine Creek, Edney Creek channel was scoured resulting in a drop of approximately 2 m in elevation, resulting in a barrier to the free movement of fish from Quesnel Lake to Edney Creek. The upper reaches of Edney Creek provided good fish habitat that was not impacted by the breach event and restoration of its connectivity to Quesnel Lake was identified as a priority action and was the first section of habitat to be constructed as part of the breach response program (Bronsro et al. 2016). The connection of Edney Creek to Quesnel Lake was constructed by February 14, 2015.

The mouth of Edney Creek was designed to distribute flow from the mouth of Edney Creek and create two channels. The low flow channel connects to Quesnel Lake under all flow conditions while the higher flow channel distributes the flow during moderate and higher flows. The shoreline design at the mouth of Edney Creek incorporates a large area of shallow gravel shoal habitat that is accessible to fish under a wide range of lake levels. The installation of the habitat features for the lower section of Edney Creek were constructed September 2015. Modification of portions of lower Edney Creek are expected as the flows of Hazeltine Creek and Edney Creek will be combined per consensus reached at the November 2018 HRWG meeting.

Primary aquatic habitat objectives for Area 6b (Reach 6) are to provide spawning habitat for Sockeye Salmon, Kokanee Salmon, Coho Salmon and Rainbow Trout, and rearing habitat for Coho salmon and rainbow trout. This will be achieved by re-establishing a non-erodible engineered channel, and re-establishing fish and riparian habitat.

In 2015, boulder weirs were placed throughout the MAF channel. Strategically placed boulders were placed to work with the weirs to 'train' the low flow channel such that it did not straighten during high flows. Off channel ponds were constructed to associate with the secondary channel. Channels and ponds were complexed with boulders, logs and tree tops to provide instream and overstream cover for fish. These features were placed such that the interaction of flows with these features will sustain and/or create runs, small riffles and small ponds along the design alignment of the low flow channel, and will facilitate mixing throughout the water column of the ponds. The features will enhance turbulence, important in creating hydraulic refugia for both adult and juvenile fish. It is this complexity that will sustain important rearing habitat for juvenile trout.

In 2017, over 31 ha of the Lower Edney Creek area has been planted and plots indicate >10,000 stems/ha of *Populous trichocarpa* in some areas. MPMC have also collected a custom seed mix from the site that includes Sitka Alder, Red Elderberry, Willow Spp., Pink Spirea, Yarrow and Cow Parsnip. . Terrestrial objectives in Reach 6 include improving soil conditions, creating micro sites with suitable growing conditions for regenerating plants, providing habitat structure and increased habitat complexity by incorporating Coarse Woody Debris (CWD), and assisting recovery of plant communities appropriate for the local conditions. Sections of Reach 6 were re-contoured with topsoil and CWD (3.7 ha) and mounded with CWD (9.9 ha).

In 2018, a tree planting program for ongoing revegetation include live staking with willow and poplar in riparian areas to assist ingress of conifer seedlings and establish an erosion control grass cover in the upper floodplain was put down.

Reach 6 on 31 July 2018 (A and B)

Figure 18: Lower Edney Creek /Area 6b (Reach 6) Description and Current Remediation and Rehabilitation Status

4.11 Quesnel Lake / Area 8

4.11.1 Lake Characteristics

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 Quesnel Lake remediation area consists of the West Basin area between Cariboo Island and the Quesnel River, a relatively shallow (pre-breach, 113 m maximum depth) portion of the lake that is separated from the rest of the lake by an approximately 35 m deep sill near Cariboo Island (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 weakest. In the deeper portions of the lake, seasonal overturn 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 (Laval et al. 2008). Water chemistry data indicate that the lake is slightly alkaline, has low sensitivity to acid inputs, and is oligotrophic, with phosphorus being the limiting nutrient (Nidle et al. 1994; Shortreed et al. 2001).

As summarized in Section 3.2.4, the ecological risk assessment found that residual effects due to alteration of water quality for organisms associated with the water column (plankton, pelagic fish) were low. In comparison, physical habitat and benthic invertebrate communities were altered from the effect of scouring along the lake side wall adjacent to the outlet of Hazeltine Creek and deposition of that scoured material as well as material from the Hazeltine corridor and the TSF on to the lake bed below the 100-m contour. The remainder of this section focusses on physical/benthic habitat in the littoral and benthic zones of the lake.

4.11.2 Littoral Zone

4.11.2.1 Overview of Effects

Using the classification system of the HRWG, this area corresponds to Ecological Unit QL-Littoral. The littoral zone in the Hazeltine Creek delta was scoured by the debris flow, affecting approximately 2.1 km and 94 ha of shoreline (approximately 5.8% of the shoreline length and 6.5% of the littoral area in the West Arm). The effect of the event was a reduction in the benthic invertebrate community and the alteration of shoreline rearing and spawning habitat. The event also blocked access to unimpacted upper reaches of Edney Creek, which is discussed above in Section 4.10.

The scouring of the Quesnel Lake shoreline also temporarily reduced the density (number of individuals per a given area) of benthic invertebrates. Benthic invertebrates such as chironomids (the aquatic larvae of midges), non-chironomid Diptera (e.g., the aquatic larvae of black flies), oligochaetes (freshwater worms), amphipods, EPT taxa (the aquatic larvae of mayflies, stoneflies, and caddisflies), and molluscs (snails and clams) are found in the littoral zone and can be eaten by fish. The abundance of these types of benthic invertebrates provides an indication of habitat quality for rearing and overwintering fish. Chironomid, amphipod, and EPT taxa density is particularly relevant to the fish population of Quesnel Lake as the fish that occupy the littoral zone feed on these groups.

Benthic invertebrate community sampling in September 2014 showed that the density of organisms in the West Arm of the lake adjacent to the mouth of Hazeltine Creek was significantly lower than observed at a reference area in the North Arm of the lake and at a far-field station in the West Arm near the outlet to Quesnel River (Figure 18). Reference areas of the lake were dominated by chironomids, amphipods, molluscs, and EPT taxa and these taxonomic groups were affected primarily in the immediate vicinity of the Hazeltine Creek mouth. The data also show that the density of benthic invertebrates is variable in Quesnel Lake and the degree of effect was variable through the West Arm. For example, chironomid, amphipod and EPT density was lowest at the stations immediately adjacent to Hazeltine Creek whereas the station closest to the Quesnel River had a greater density of chironomids than at Horsefly, suggesting lesser effect there.

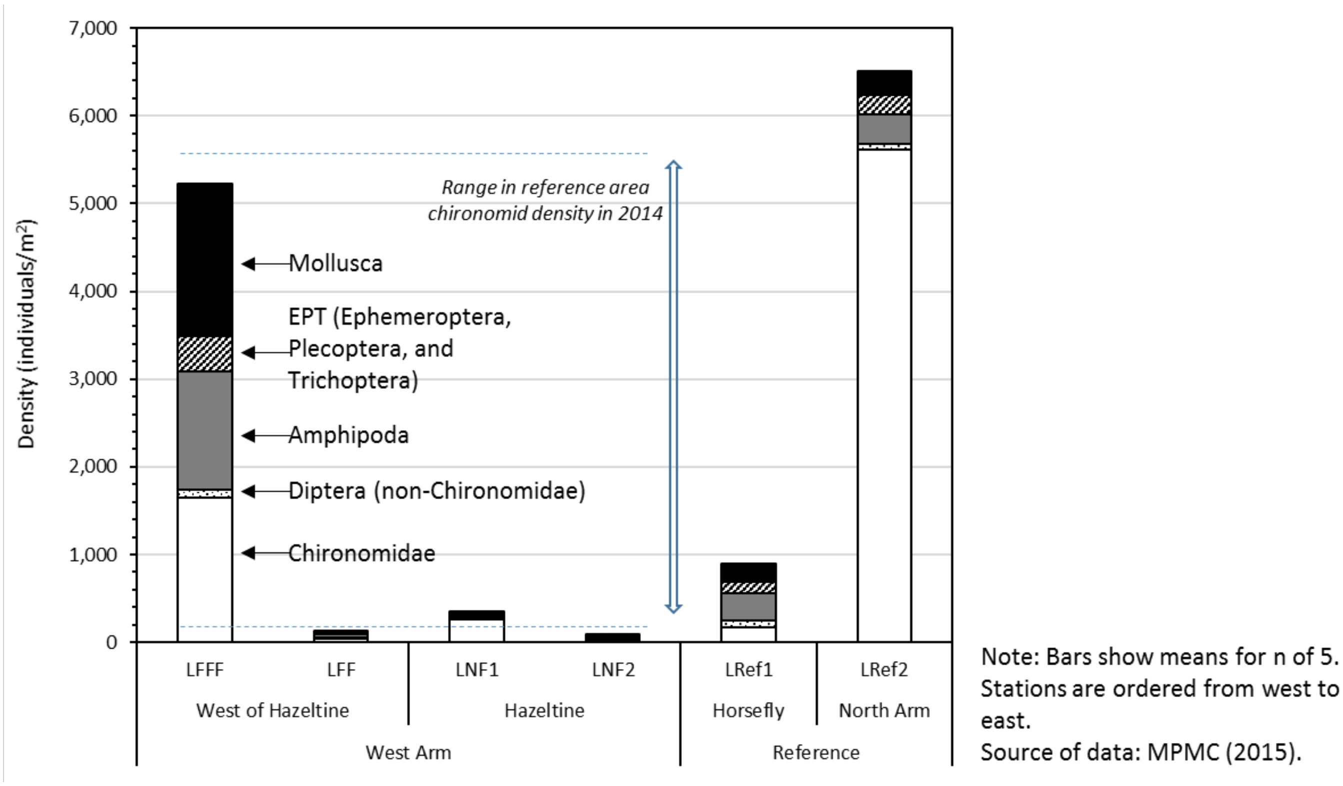
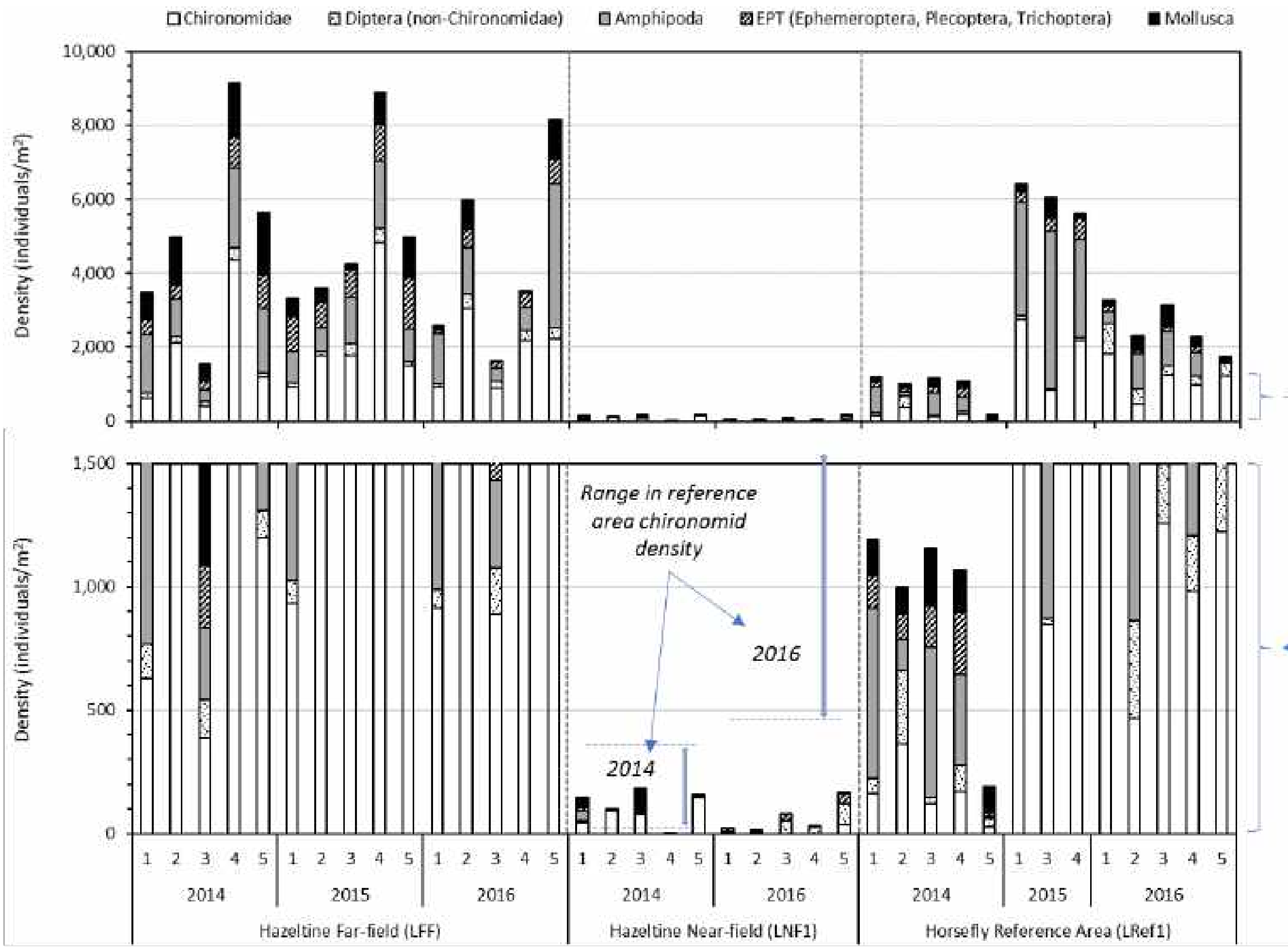


Figure 19: Spatial Variability in Benthic Invertebrate Abundance in the Quesnel Lake Littoral Zone in September 2014

Data from subsequent sampling indicate that benthic invertebrate density of the Hazeltine shoreline was still lower in 2016 than observed at the far-field station in the West Arm and in the reference area at Horsefly (Figure 20). A follow-up sampling event was undertaken in 2017, but the sampling methods were changed between 2016 and 2017 and it is therefore not possible to undertake a quantitative comparison of the data (Minnow 2018c). As well, additional habitat reconstruction activities are planned, which may disrupt the recovery of the benthic community.



Note: Bars show results for individual replicates (numbered from 1 to 5 except where noted). LNF1 not sampled in 2015.
Source of data: Golder (2017c).

Figure 20: Spatial and Temporal Variability in Benthic Invertebrate Density in the Quesnel Lake Littoral Zone, 2014 and 2015

The actual contribution of the affected area of littoral zone to fish productivity is not known; however, the available data suggest that the decrease in benthic invertebrate prey items have not resulted in a decrease in condition factor of forage fish, Lake Trout, or Burbot captured in the littoral zone (Figure 21).

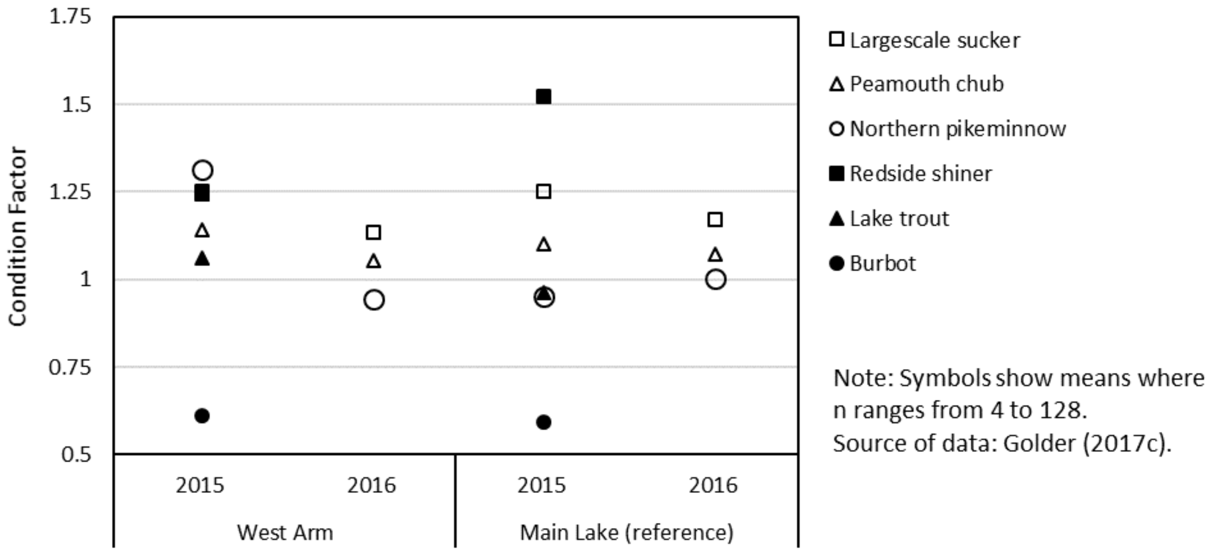


Figure 21: Spatial and Temporal Variability in Condition Factor for Fish Species Potentially Using Littoral Zone Habitat, 2015 and 2016

4.11.2.2 Remediation Activities to Date

MPMC has been implementing a remediation strategy over the last two years that resulted in the removal of tailings from the Hazeltine Channel bed and surrounding areas, reconstruction of the Hazeltine and Edney Creek channels, and restoration of the connection of Edney Creek with Quesnel Lake through the littoral zone (Section 4.10). The lower area of Edney Creek was reconstructed on a prioritized basis to stop erosion and restore fish access (completed February 2015), with instream habitat features subsequently added (initial work August 2015). In the littoral areas adjacent to the Edney Creek channel, material has also been placed to help manage erosion.

Fish access to Hazeltine Creek from Quesnel Lake is still restricted at this time due to ongoing remediation activities but Quesnel Lake is connected to Edney Creek.

4.11.2.3 Remediation Plan

The HRWG has not finalized the remediation objectives for the littoral zone of Quesnel Lake; however, based on the pathways of effect (Table 4) that are still considered operable, it is expected that the objectives will focus on habitat suitability for spawning and rearing, in particular around structure and riparian vegetation. This remediation work will tie into work that is underway in Lower Hazeltine Creek or has already been completed in Edney Creek.

The Quesnel Lake littoral zone benthic invertebrate monitoring study design will need to reflect the requirements to monitor recovery using consistent (over time) techniques to support the evaluation of the efficacy of the remediation to address uncertainties in the risks associated with residual sediment contamination. The monitoring study design will be included in an updated CEMP.

It is anticipated that productivity losses during the period of loss will be addressed through the development of habitat offsets as noted in Section 5.3.1.8.

4.11.3 Benthic Zone

4.11.3.1 Overview of Effects

Using the classification system of the HRWG, this area corresponds to Ecological Unit QL-benthic. The benthic zone[6] below the 100 m contour was impacted by outwash materials across an area of 1.81 km^2. This material covered benthic substrate and invertebrate organisms, and as demonstrated by benthic invertebrate community sampling in September 2014, the density of benthic invertebrates in the West Arm of the lake adjacent to the mouth of Hazeltine Creek was significantly lower than observed at a reference area near Horsefly River as well as other reference areas of the lake (Figure 22). Reference areas of the lake were dominated by chironomids and oligochaetes and both of these taxonomic groups were affected in the West Arm, primarily in the vicinity of Hazeltine. The data also show that the density of benthic invertebrates is variable in Quesnel Lake and the degree of effect was variable through the West Arm. For example, chironomid density was lowest at the stations immediately adjacent to Hazeltine Creek whereas the station closest to the Quesnel River had a similar density of chironomids as observed at the North Arm reference station, suggesting lesser effect there. The density of chironomids is particularly relevant to fish such as Mountain Whitefish and Lake Trout as these fish tend to eat these insects as they hatch and rise up through the water column to the surface of the lake.

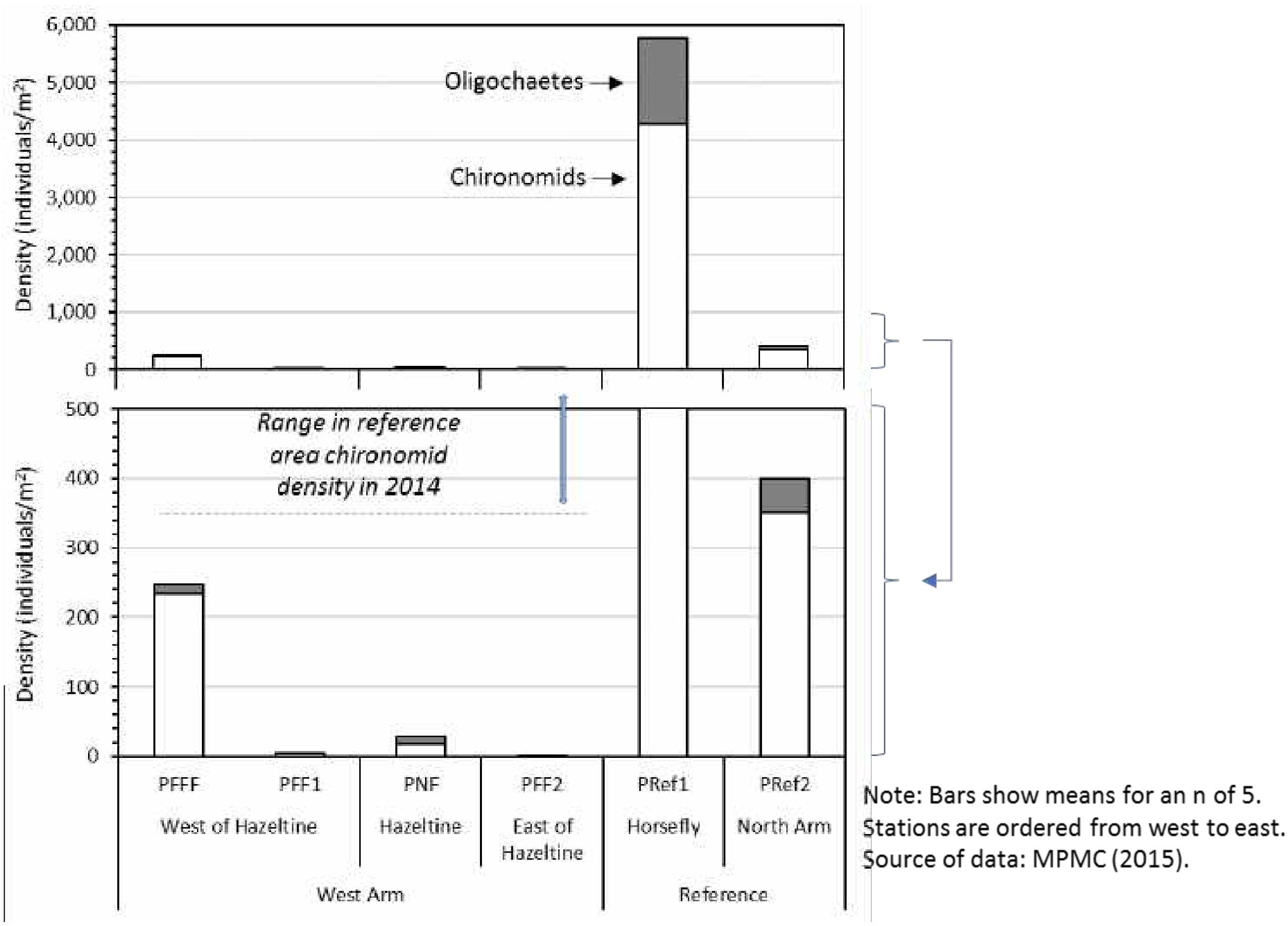


Figure 22: Spatial Variability in Benthic Invertebrate Abundance in Quesnel Lake Benthic Zone in September 2014

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[6] also called the "profundal" zone in some of the Quesnel Lake studies

Benthic invertebrate data collected in 2015 and 2016 show that the benthic invertebrate community has started to recover in the vicinity of Hazeltine Creek (Section 3.2.4). Samples were also collected in 2017 but as of the time of writing, results are not yet available. Figure 23 shows the density of chironomids and oligochaetes in individual replicates for the Horsefly reference station and the Hazeltine affected station for 2014, 2015, and 2016. The communities were dominated by oligochaetes and chironomids, and spatially variable at both stations. The significantly higher number of oligochaetes at the reference station in 2015 appears to be related to an influx of tubificids (one of the types of oligochaete worms in that area), potentially from the Horsefly River itself or the shorelines of the lake. Although a positive (increasing) trajectory of recolonization is apparent in the data (Figure 23), those data are based on only three seasons of sampling events and verification of such a trajectory is required. As only three annual sampling events (2014 to 2016) have been conducted to date and in limited areas of the lake bottom, the trajectory of recolonization requires confirmation.

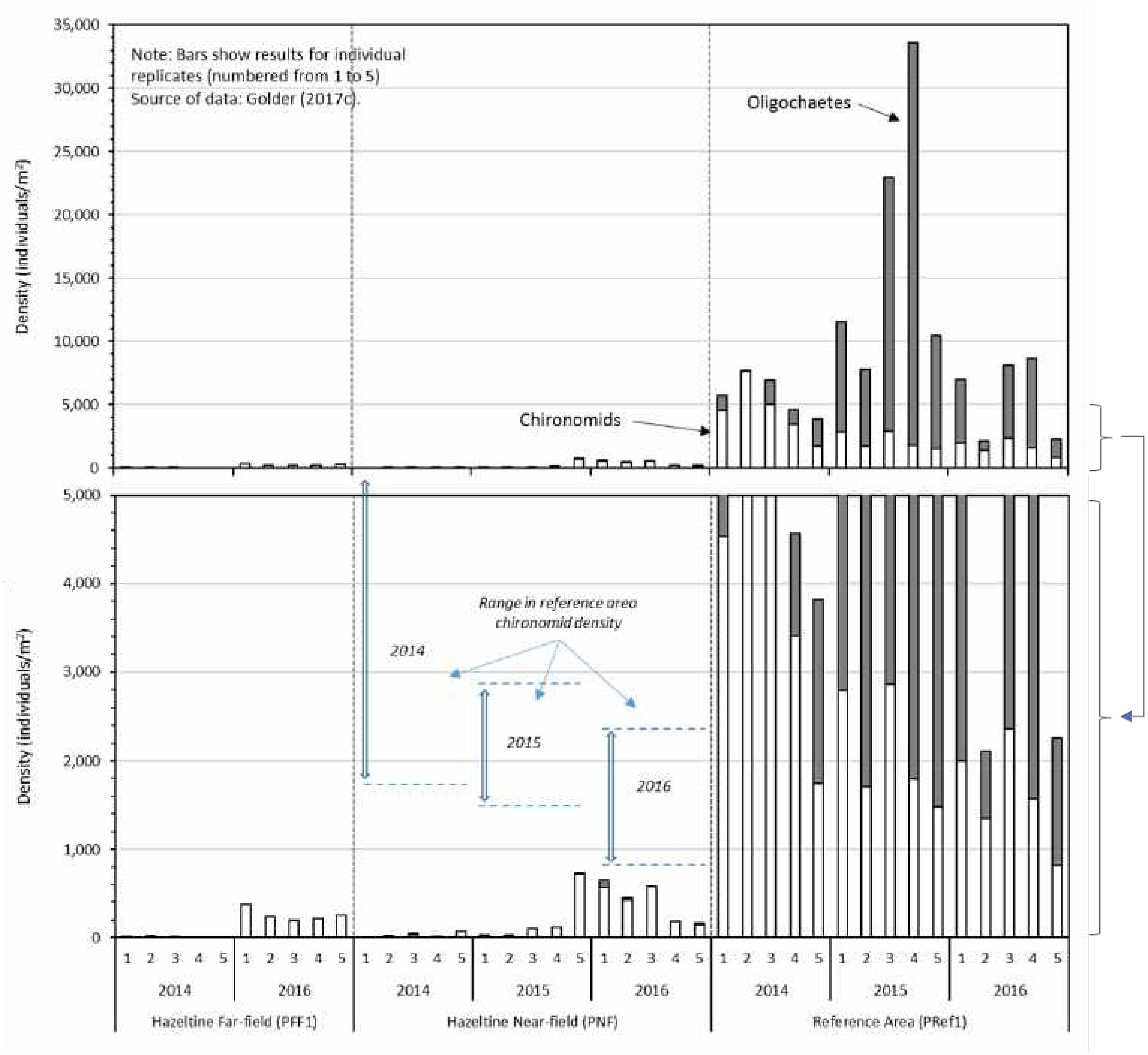

Figure 23: Spatial and Temporal Variability in Benthic Invertebrate Abundance in Quesnel Lake Benthic Zone in 2014, 2015, and 2016

The ERA suggested that the physical structure, more specifically the low organic carbon content of the sediments, is affecting the recolonization of those sediments. In laboratory-based sediment tests, it was found that in low organic carbon sediments dominated by outwash materials that are low in organic carbon, growth was reduced. However, adding organic carbon to those sediments resulted in normal organism growth. Figure 24 illustrates the spatial and temporal variability of total organic carbon (TOC) in the sediments of the West Arm and in references areas at Horsefly and in the North Arm. In 2014, sediments collected adjacent to Hazeltine had relatively low TOC (<0.5%). Subsequent sampling indicated that TOC was higher in 2015 and 2016, and while not at the average TOC content observed in the reference areas, TOC was within the range of reference samples. Thus, it appears that natural processes are contributing organic carbon to the sediments. This is a reasonable inference based on the TOC content of sediments collected in sediment traps at the West Arm far field station (towards Quesnel River; 2.3 to 4.3%) and the Horsefly reference station (2 to 3.5%) between 2014 and 2015. The increasing TOC in the sediments at Hazeltine could in turn be related to the increasing density of benthic invertebrates observed in the West Arm.

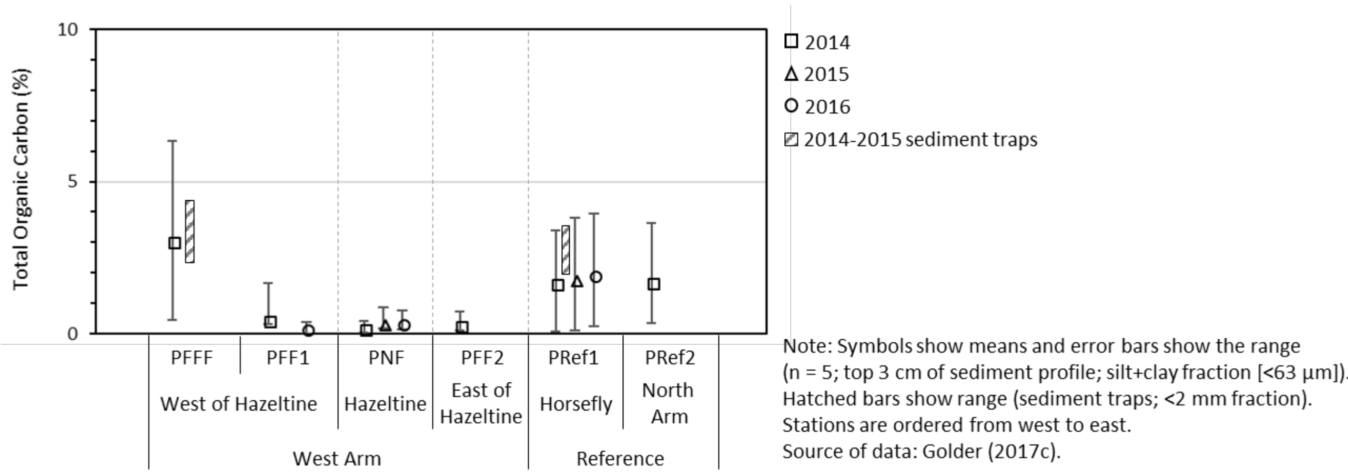

Figure 24: Spatial Variability in Total Organic Carbon in Quesnel Lake Benthic Sediments in 2014, 2015, and 2016

A literature review was undertaken to identify factors that influence succession and recolonization of disturbed sediments in lake environments. Little useful information was found as studies regarding succession and recolonization of disturbed benthic substrates have focussed on marine areas which are:

- dredged or received disposal of dredged material (e.g., Oliver et al. 1977, Van Dolah et al. 1984, Bolam and Rees 2003, Cruz-Motta and Collins 2004)
- have become organically enriched (e.g., Holte and Oug 1996; Norkko and Bonsdorff 1996; Nilsson and Rosenberg 2000)
- have received tailings (e.g., Kathman et al. 1984; Ellis and Hoover 1990; Olsgard and Hasle 1993; Burd 2002; Hughes et al. 2015)

The literature review also sought studies of British Columbia lakes that are known to have received operational (i.e., deliberate and permitted) deposits of tailings (Table 7). For these locations, studies were either only done prior to the commencement of tailings deposits, or, where post-discharge studies were available, they were conducted decades after the fact and therefore did not provide an indication of either recovery rates or recovery of benthic invertebrate communities in the near-term (e.g., MEMPR 1991; Mudroch et al. 1993). The potential use of data from the available studies is also confounded by the fact that the tailings from the mines studied were acid generating, unlike Mount Polley tailings (Kennedy et al. 2016), and the contaminants of primary concern were different (e.g., mercury, arsenic, zinc). Nonetheless, although the profundal (deep) zone of Benson Lake was devoid of benthic invertebrates when the Benson Lake Coast Copper Mine stopped discharging tailings in 1973, the follow-up study, which wasn't undertaken until some 17 years later "found that Benson Lake showed little evidence of the fact that it was the recipient of mine waste" (MEMPR 1991). The authors of that study suggested that the organic layer that had accumulated on the lake bed may have prevented the further flux of metals (e.g., zinc) from the underlying tailings.

Table 7: Mines in British Columbia That Deposited Tailings to Lakes

Area	Waterbody	Mine	Type	Active Period
Central BC	Jack of Clubs Lake	Cariboo Gold Quartz Mine	gold	1933 to 1964
Vancouver Island	Benson Lake	Benson Lake Coast Copper Mine	copper	1962 to 1973
	Buttle Lake	Myra Falls/Lynx Mine	zinc, copper, gold	1966 to 1984
Northwest BC	Tom MacKay Lake Albino Lake	Eskay Creek Mine	gold	2002 to 2008
	Brucejack Lake	Brucejack Mine	gold	Commenced in 2017

Although studies from the marine environment provide a positive indication that disturbed sediments can and will start to recolonize relatively quickly after the initial disturbance, they are not direct analogues for deep lakes. This is because dispersal of organisms is influenced by movement of the water column, which is typically greater in the tidal marine environment than in lakes where water movement at the bed of deep lakes tends to be relatively low by comparison. However, the principle that colonization sequence and speed are dependent on dispersal mode/abilities (i.e., how they move) of a given taxonomic group and size of area disturbed are also true for freshwater environments (e.g., Cañedo-Argüelles and Rieradevall 2011).

The primary taxonomic groups found in the profundal area of Quesnel Lake are chironomids and oligochaetes. The predominant chironomid species found in Quesnel Lake tend to be clingers or burrowers/tube dwellers that feed on detritus (e.g., *Phaenopsectra* sp., *Heterotrissocladius* sp.; Merritt and Cummins 1978). *Procladius* sp. is another chironomid species present that "sprawls" or stays on the surface of the sediment. Regardless of the mode of existence (burrower versus sprawler), because benthic in-faunal chironomids are the aquatic larval stage of flying insects, they reach the lake bed as eggs deposited on the surface of the lake or eggs/larvae flushed from the littoral zone or tributary streams rather than via lateral "migration" at the lake bed. Once in deep lakes, chironomid development can take a longer period of time than for the same species in shallower areas (Wallace and Anderson 1995). This suggests the possibility (but not certainty) that in the initial year after disturbance of a deep lake bed, a majority of the organisms in the sediments may be small enough that they are not retained in a sediment sieve. In subsequent years, the retained organisms may be the more developed larvae that were deposited in prior years.

In comparison, the oligochaete species present in Quesnel Lake (Lumbriculidae and Tubificidae) spend their entire life cycle in the aquatic environment. They therefore colonize lake bed sediments either by *in situ* reproduction or via discharge from tributary streams (Pennak 1978). Aquatic oligochaetes tend to burrow into the sediments and lateral movement would be slow relative to the dispersion of a species that does not burrow.

That the dispersal processes described above are naturally successful is supported by the fact that sediment in other areas of Quesnel Lake are colonized by chironomids and oligochaetes. The hypothesis that the sediments in the West Arm will recolonize naturally is also supported by data from a sediment transplant study conducted in 2015 with the objective of identifying potential constraints to recolonization of the West Arm sediments (Minnow 2016a). The study involved collection and taxonomic analysis (identification and enumeration) of sediment from:

- The lakebed near Hazeltine and transplant of that material to the reference area in buckets that were retrieved after seven weeks (“transplanted exposed sediment”).[7]
- The profundal zone in the West Arm and reference areas in August and October (“*in-situ* sediment”). These data illustrate the change in the benthic community during the transplant period.
- The littoral zone in the West Arm and reference areas in August (“littoral sediment”). These data provide an indication of the benthic invertebrate community in adjacent shallow areas which may be a source of colonizing organisms.

Figure 25 shows the density (number of organisms per m^2) for the dominant taxonomic groups that occur in the deep lake sediments: three chironomid taxa (*Phaenopsectra* sp., *Procladius* sp., and *Heterotrissocladius* sp.) and two oligochaete taxa (Tubificidae and Lumbriculidae). The upper graphs show the full range of density (up to 35,000 organisms/m^2) and the lower graph shows density up to 7,500 organisms/m^2 to highlight the dominant taxa in the Hazeltine sediments. The stations are organized to show the littoral zone results next to the *in situ* benthic zone results for the West Arm location, and the littoral zone, *in situ* benthic zone, and transplanted West Arm sediments at the reference location.

As shown in Figure 25, sediment from the benthic zone of Quesnel Lake adjacent to the mouth of Hazeltine Creek transplanted to the reference area had a greater density of benthic invertebrates than did the sediments *in situ* at Quesnel Lake near Hazeltine. The benthic invertebrate density and composition in two of the transplanted sediment replicates was also similar to that observed in two of the in situ reference sediments as of October when the sediment buckets were retrieved. The benthic community in the transplanted sediments after the seven-week deployment was dominated by the oligochaete Tubificidae and the chironomids *Phaenopsectra* sp. and *Procladius* sp., which were also observed in the littoral zone at Horsefly. In comparison, the *in situ* sediments at Hazeltine were dominated by the chironomid *Heterotrissocladius* sp., which was the dominant chironomid in the littoral zone. These data suggest that the recolonization of the sediments in the West Arm may be more dependent on proximity to a source of colonizing organisms than on the quality of the sediment itself.

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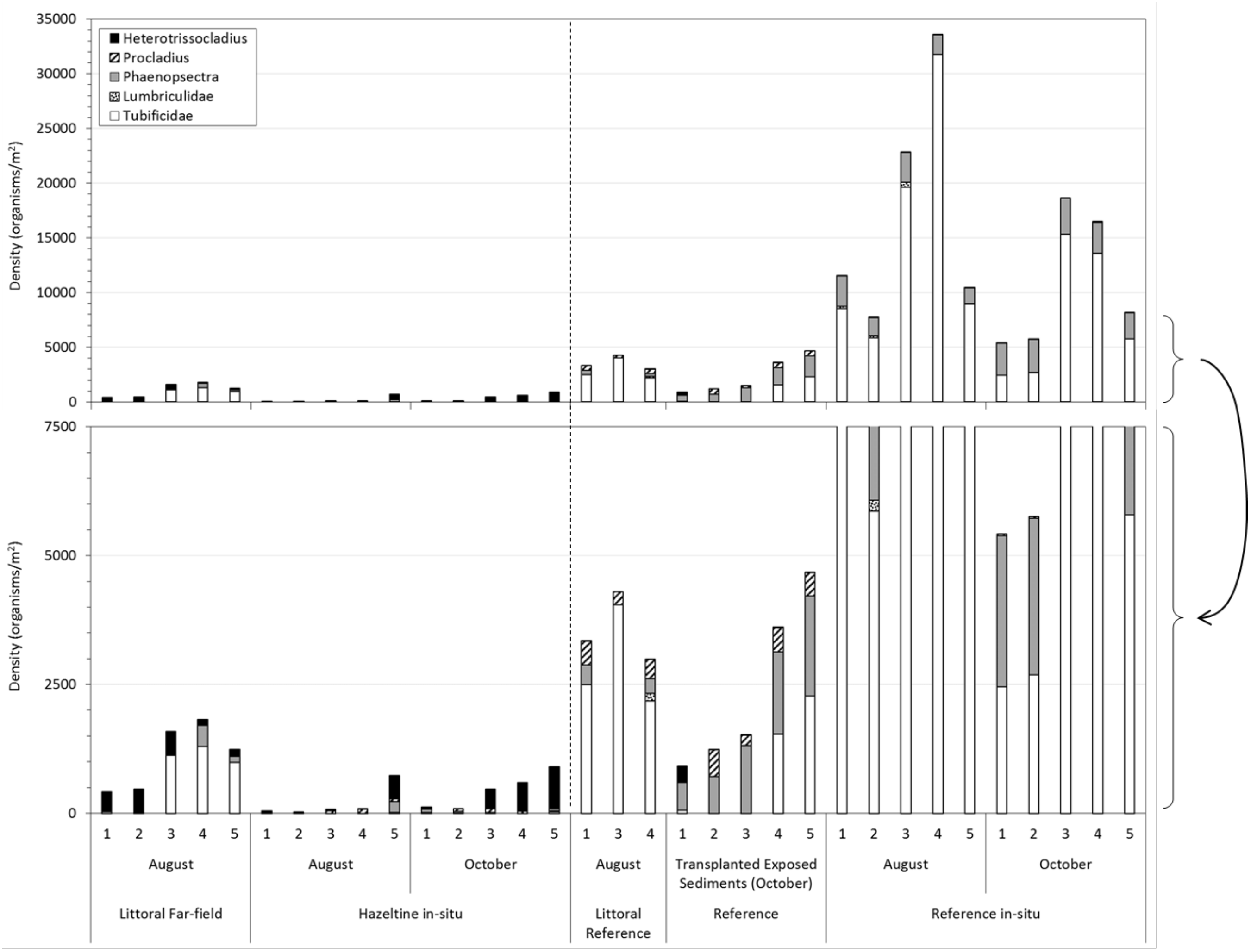
[7] The sediments were transplanted with and without a carbon amendment. The results for the amended sediments were not significantly different from the un-amended sediments therefore the data for the amended sediments are not shown here.



Note: Bars show results for individual replicates (numbered from 1 to 5 except where noted).
The upper graph shows the full range of density and the lower graph shows density up to 7,500 organisms/m².
The month indicates when the samples were collected for taxonomic analysis. The transplanted sediments were deployed for seven weeks.
Source of data: Golder (2017c).

Figure 25: Chironomid and Oligochaete Density in Transplanted and *In Situ* Sediments (2015)

4.11.3.2 Remediation Activities to Date

To date, the focus on the Quesnel Lake benthic zone has been testing, monitoring and evaluation of data through the aquatic ecological risk assessment to identify appropriate remedial decisions. Remedial actions with regards to the Quesnel Lake benthic zone have consisted of actions to stop the further release of particulate materials into the lake from erosion of Hazeltine Creek (Bronsro et al. 2016).

4.11.3.3 Remediation Plan

Based on the identified ecological function of rearing (Table 4) and the effect of the event on the benthic invertebrate community as illustrated above, the remediation objective for the Quesnel Lake benthic zone is a benthic invertebrate community that is similar to that occurring in other, unaffected areas of the lake, and which contributes food organisms to fish. The benthic community would be used as an indicator for fish productivity because there is a poor understanding of the contribution from profundal benthic communities to fish productivity (for example Figure 23) whereas the density of benthic organisms can be directly measured.

Overview of Net Environmental Benefit Analysis

Net environmental benefit analysis (NEBA) is a method developed to identify and compare alternative site management options, often for contaminated sites or for oil spill clean-up (Efroymson et al. 2003). The focus of this methodology is net environmental benefit, which is the balance of the environmental benefit achieved from a management option with the environmental costs associated with the option (e.g., habitat disruption). “Environmental benefit” addresses a range of natural resource “services” from habitat that supports ecological function (water quality, fish habitat, bird nesting), direct human uses (e.g., recreation, fisheries), and passive values (e.g., existence value, aesthetic value). Environmental costs and benefits are therefore considered in a broad context. NEBA was undertaken for the Quesnel Lake portion of the RP because (unlike Hazeltine Creek) the remedial options have not been evaluated by the HRWG. NEBA provides context for the evaluation of those options.

As a result of physical smothering from the settled breach outwash materials, the environmental services of the lakebed have been disrupted and low organic carbon content has been identified as a potentially limiting factor for benthic invertebrate community recovery. NEBA is therefore, conceptually, a useful tool for identifying and comparing potential management options for addressing the Quesnel Lake remediation area. A framework for undertaking NEBA is illustrated in Figure 26.

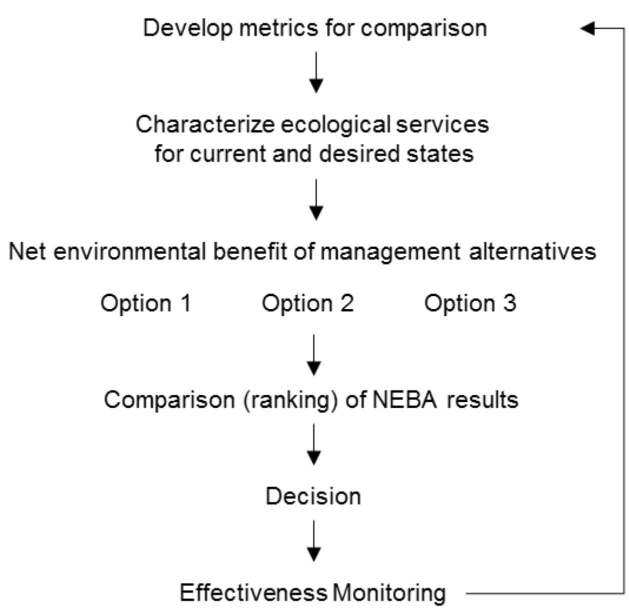


Figure 26: Framework for Net Environmental Benefit Analysis (adapted from Efroymson et al. 2003)

The focus of the remainder of this section is to identify alternative remediation (action) options, selection of metrics for comparing those options, and the ranking of the options based on their respective net environmental benefit in the context of the remedial objectives of (re) establishing a benthic invertebrate community that is similar to that occurring in other, unaffected areas of the lake, and which contributes food organisms to fish.

Identification of Conceptual Remedial Options for Quesnel Lake

The three general remedial options typically considered in a NEBA are (Efroymson et al. 2003):

- Monitored Natural Recovery
- physically, chemically, or biologically remediate the site – this may mean, in the context of sediments, physical dredging of the material or the addition of materials to amend the sediment (e.g., organic carbon)
- improve the ecological value of the site through remediation and restoration

A combination of the above may also be appropriate depending on site specific considerations. For the Quesnel Lake remediation area, the more specific remedial options that could be applied are as follows:

- monitored natural recovery (MNR), together with productivity offsets for interim losses
- physical remediation in the form of dredging
- chemical/biological remediation in the form of sediment amendment with organic carbon
- chemical/biological remediation in the form of thin-layer capping

The options evaluation starts by considering each of these four options and considering, at a conceptual level (i.e., not including engineering design, costing), how each of these options might be implemented under the a priori assumption that the options are technically and financially feasible. Given these implementation scenarios, factors that would influence environmental costs and benefits, in the broad sense described above, are considered so that there is a basis for evaluating the remedial options on that basis. Simple categorical ranks were applied to those variables to evaluate the net environmental benefits.

Table 8 provides an overview of each of these remediation options as well as variables that need to be taken into consideration in the planning and implementation of the options. Habitat offsets are not included in Table 8, however, they are recognized in environmental policy as a remedial method and offsets are the proposed means of addressing service losses over the period of recovery and are discussed further in Section 5.4.2.

Table 8: Overview of Considerations for Remediation Options for Quesnel Lake Profundal Benthic Zone

Variable	Dredging	Amendment or Chemical Stabilization	Thin-layer Capping	Monitored Natural Recovery
Description				
Overview	Physical removal of lakebed substrates that were contributed by the deposit of outwash material, debris and tailings during the event. Estimated volumes to be removed are 1.81 km^2 x 10 m in depth (some consolidation of those materials will have occurred making the consolidated thickness of deposits less). Although depth would be variable and this may overestimate deposit, it is a plausible planning basis to account for over-dredging and bulking of dredged materials. Deposited material is at water depths greater than conventional dredging equipment, which is designed for enabling vessel navigation. Clam shell dredging would be feasible but turbidity would be very difficult to control and material handling would involve heavy truck traffic throughout the area. Depths exceed conventional suction dredging depths though unconventional equipment may be modifiable. Dredged material would need to be dewatered at a rate proportional to production and with suction dredging, large water volumes would be involved.	Involves (in this case) the addition of organic matter into lakebed substrates to provide an initial food source to enhance recovery of benthic invertebrate community. This approach has been proposed, though not operationalized, for submarine tailings placement areas in Norway (Kvassnes et al. 2009). Possible sources of organic carbon include: ■ bio char (e.g., burned wood) – may not have organic carbon in a form that is metabolically accessible by benthic organisms ■ unburned coal – may not have organic carbon in a form that is metabolically accessible by benthic organisms ■ compost or biosolids – likely to have organic carbon in a bioaccessible form This option is considered experimental at the scale necessary. Research has been conducted at other locations on the delivery mechanism, different types of organic carbon, and thickness of the layer of amendment material needed to be successful. These studies have been conducted in relatively shallow water and most commonly for remediation of organic contaminants such as petroleum hydrocarbons and PCBs over limited spatial scales. Reports on studies regarding a lack of organic carbon at water depths similar to that of Quesnel Lake were not found; therefore, the success of organic carbon amendment as a remediation tool is uncertain, and a site-specific trial study would be needed to develop an appropriate design. Quesnel Lake is used as a drinking water source, thereby limiting the forms of organic carbon that would be acceptable and this may include most commercially sourceable forms that are also bioaccessible for benthic organisms.	Involves the addition of a thin layer (e.g., 1 to 10 cm depth) of material to the surface of the lakebed substrates to separate the colonizing biota from the deposited tailings. The material may be inert geological material (e.g., sand, clay) or may be composed of a mixture of geological material and components intended to bind with contaminants, such as activated carbon, as described for the amendment/chemical stabilization option. Where capping material consists of an inert geological material and is not amended with a carbon source such as activated carbon, capping may not address the lack of carbon that has been identified in toxicity testing as a potential limitation to re-colonization. Conversely, when a carbon source is included, a greater impact on the existing benthic community may occur that if an inert geologic material is used (e.g., Samuelsson et al. 2017). Depending on the area to be capped and the desired depth of the capping layer, the volume of material that would need to be imported and placed on the lake bottom could range from 150,000 to 1,500,000 m^3.	Involves allowing natural processes (e.g., sinking of diatoms and plankton, particulate organic matter from tributary streams) to contribute organic carbon to sediments. There is no specific provincial guidance but parallels can be drawn to Monitored Natural Attenuation (MNA) of groundwater contaminants which is addressed by Technical Guidance 22 (MOE 2014), which identifies specific factors that must be in place for MNA to be considered feasible.
Constructability				
Equipment availability	Deep-sea mining has been done at 200 m depth by purpose-built vessels with cutter suction dredge (CSD) heads that cannot be transported intact to Quesnel Lake. A shipyard would be needed on the shore of Quesnel Lake to assemble and/or construct vessels and dredge units. Suction dredging units with proven capability at -70 m are available; it is possible that they could be custom-modified to work at the ~110-m depth that would required Clam-shell dredging through 110 m of water column could be conducted but would require the construction of a work platform on site. A fleet of dredge scows would need to be constructed on site. The required equipment is not readily available and would need to be procured, fabricated, and assembled.	Different methods for amending sediments have been used: ■ surface dumping from a split-hull barge ■ pumping a mixture of sand and carbon through a down pipe to a few meters above the substrate – usually in waters shallower than 100 m ■ "Injection" and rotor-tilling directly into the bedded sediment usually in waters shallower than 100 m The selection of the equipment would dictate the precision of the placement of the organic carbon material. For any of the scenarios listed above, the required equipment is not readily available or not easily transportable to the site; it could take years to procure/fabricate/assemble.	Different methods for amending sediments have been used: ■ surface dumping from a split-hull barge ■ pumping a mixture of sand and carbon through a down pipe to a few meters above the substrate – usually in waters shallower than 100 m The selection of the equipment would dictate the precision of the placement of the capping material. For any of the scenarios listed above, the required equipment is not readily available or not easily transportable to the site; it could take years to procure/fabricate/assemble.	N/A

Variable	Dredging	Amendment or Chemical Stabilization	Thin-layer Capping	Monitored Natural Recovery
Staging/work areas	A work area would be needed to: ■ Construct dredge platforms and scows. ■ Launch equipment into the lake and for offloading of dredged material from the dredger to a pump station or trucks, which would then transfer the material to the disposal site (notionally a disused pit or enlarged TSF. ■ If suction dredged, a floating umbilical with booster stations at 700 to 1,000,m intervals would extend from dredging unit to a single shore point (several km depending on the location of the dredge assembly). ■ If materials to be pumped, a pipeline would need to be constructed. An additional pipeline would need to be constructed for dewatering in the case of suction dredging.	A work area would be needed to launch equipment into the lake and for loading of the vessel that would place the amendment material on the lake bed. This may require the construction of a ramp and/or jetty along the lake shore as well as removal of trees.	A work area would be needed to launch equipment into the lake and for loading of the vessel that would place the amendment material on the lake bed. This may require the construction of a ramp and/or jetty along the lake shore as well as removal of trees.	N/A
Water management (treatment and disposal)	Hydraulic dredging produces volumes of water at a 1:6 to 1:10 ratio of solids to water that would require management. For a dredged material volume of 32.4 M m^3, 194 approximately to 324 M m^3 of dredged slurry would be generated. This water would need to be conveyed from the lake bottom, across the lake and up to the disposal location where solids would be removed. The clarified water would then need to be returned to the lake. Clam-shell dredging re-suspends sediments into the water column. For typical, nearshore construction dredging projects, this type of work is conducted with in a turbidity curtain. A turbidity curtain would be operationally infeasible deeper than about 10 m. Therefore, if this type of equipment were used, active turbidity control would not be possible. Clam shell dredged material would need to be loaded to a barge and dewatered at that location, in Quesnel Lake.	N/A – Water requiring treatment would not be handled.	N/A – Water requiring treatment would not be handled.	N/A
Safety Considerations	Health and safety planning to address operation of: ■ water-based equipment ■ transport of equipment ■ potential interaction with recreational users of Forest Service Roads Navigational risks to recreational boaters from a 24/7 operation and potentially several km long “umbilical” slurry line on the water surface – even with navigational lights, this would pose a risk, particularly to non-local boaters	Health and safety planning to address operation of: ■ water-based equipment ■ transport of equipment ■ potential interaction with recreational users of Forest Service Roads and Quesnel Lake boaters	Health and safety planning to address operation of: ■ water-based equipment ■ transport of equipment ■ potential interaction with recreational users of Forest Service Roads and Quesnel Lake boaters	Health and safety planning to address operation of a sampling vessel similar to a typical recreational vessel as operated on Quesnel Lake
Access to Site	Potential need to upgrade access roads to accommodate size of equipment that would need to be brought to the lakeshore Clearing of staging area(s) along Quesnel Lake shoreline	Potential need to upgrade access roads to accommodate size of equipment that would need to be brought to the lakeshore	Potential need to upgrade access roads to accommodate size of equipment that would need to be brought to the lakeshore	N/A. Existing infrastructure can be used.
In-water footprint	Estimated at a minimum of 1.81 km^2 with additional allowance for over-dredging (controllability of suction dredging unit at 110m depth may be a challenge).	Up to 1.81 km^2	Up to 1.81 km^2	No incremental amounts beyond the initial impact

Variable	Dredging	Amendment or Chemical Stabilization	Thin-layer Capping	Monitored Natural Recovery
Conceptual Schedule				
Planning, Engineering and Permitting	2 to 4 years	2 to 4 years + study durations for small scale trials	2 to 4 years + study durations for small scale trials	N/A. Available data indicates that the process of natural recovery is already occurring (Section 4.11.3)
Procurement and/or construction of equipment	5+ years	5 years	5 years	N/A
Implementation	At 4,000 m^3/day (convention clam-shell dredging using four spreads) to 6,000 m^3/day (deep-sea cutter suction dredging, assuming that it were feasible) and assuming 6-months of production during ice-free season and suitable weather conditions, dredging of 32.4 million m^3 would take 30+ years.	One to two open water seasons (depending on method of placement) with potential need to repeat application of amendments	One to two open water seasons (depending on method of placement) with potential need to repeat application of amendments	N/A
Certainty in Outcome	Dredging would remove the deposited material, but there is uncertainty as to whether the material at the dredge cut depth would have sufficient organic carbon to support benthic invertebrate recolonization. It would not be possible to have a dredge cut that is at the former mud line and therefore, it is unlikely that the newly exposed material would have organic carbon levels similar to reference conditions. There is not a clear risk reduction benefit that would occur by removing the deposited materials.	Option is experimental, based on benchtop laboratory testing; there is low certainty that application to a large area on the lake bed would improve recolonization over and above MNR, given that mechanisms of colonization (Section 4.11.3) would be the same as for MNR.	Option is experimental, based on laboratory and field-scale testing to determine the applicable material type and layer thickness. There is low certainty that application to a large area on the lake bed would improve recolonization over and above MNR, given that mechanisms of colonization (Section 4.11.3) would be the same as for MNR.	Recolonization by benthic invertebrates has already been observed *in situ* in the West Arm and in transplanted sediment to other parts of Quesnel Lake. Natural processes are expected to be successful. Monitoring is required to verify this expectation and attainment of diversity and abundance similar to other areas in Quesnel Lake.
Considerations				
Geotechnical				
Slumping of lake walls	■ Removal of material at toe of lake wall could destabilize the submerged slope and cause further scouring and deposition of material, and subsequent effects to water quality.	■ The mass of material anticipated for placement is unlikely to affect slopes.	■ The mass of material anticipated for placement is unlikely to affect slopes.	N/A
Compaction of lake bed	■ Depending on the removal method, the remaining sediment at the dredge cut depth could be compacted, thus creating additional conditions that affect benthic invertebrate recolonization or would require more “aggressive” dredging equipment.	■ Placement of a layer of material could potentially result in compaction of underlying materials, thus creating additional conditions that affect benthic invertebrate recolonization. However, it is expected that organic carbon amendment would be a thin layer.	■ Placement of a layer of material could potentially result in compaction of underlying materials, thus creating additional conditions that affect benthic invertebrate recolonization. However, it is expected that the cap would be a thin layer.	N/A
Aquatic Habitat				
Fish	■ Dredging for a long time frame would continually displace fish from the area of work and disrupt food sources for benthic-feeding fish as they are disturbed while the work progresses.	■ Application of amendment may temporarily displace fish in the immediate work area. ■ Food sources during implementation would be disrupted, to the extent that those sources come from the benthos.	■ Application of capping material may temporarily displace fish in the immediate work area. ■ Food sources during implementation would be disrupted, to the extent that those sources come from the benthos.	N/A

Variable	Dredging	Amendment or Chemical Stabilization	Thin-layer Capping	Monitored Natural Recovery
Offsetting/rehabilitation costs	■ Additional offsetting might be needed to address time lag in benthic habitat recovery as a result of the ongoing disturbance.	■ Additional offsetting might be needed to address time lag in benthic habitat recovery; however, both the extent of loss and the time lag would be expected to be smaller than the initial impacts of the event.	■ Additional offsetting might be needed to address time lag in benthic habitat recovery; however, both the extent of loss and the time lag would be expected to be smaller than the initial impacts of the event.	N/A
Terrestrial Habitat				
Riparian vegetation	■ Creation of sufficiently large staging area(s) might require removal of shoreline vegetation.	■ Creation of sufficiently large staging area might require removal of riparian vegetation.	■ Creation of sufficiently large staging area might require removal of riparian vegetation.	N/A
Birds	■ Creation of staging area could disrupt bird habitat, although site selection and timing would likely be able to address such disruption.	■ Creation of staging area could disrupt bird habitat, although site selection and timing would likely be able to address such disruption.	■ Creation of staging area could disrupt bird habitat, although site selection and timing would likely be able to address such disruption.	N/A
Wildlife	■ Creation of staging area could disrupt wildlife habitat.	■ Creation of staging area could disrupt wildlife habitat.	■ Creation of staging area could disrupt wildlife habitat.	N/A
Water Quality				
Induced turbidity	■ Clam shell dredging would induce turbidity. Given the clear water characteristics of Quesnel Lake, it is likely that this would result in visible turbidity in the lake. A clamshell would move turbid waters across the thermocline. ■ Hydraulic dredging would have much reduced turbidity generation compared to mechanical (clamshell) dredging, but some induced turbidity would occur. ■ With depths involved it would not be possible to have a barrier/turbidity curtain in place to contain induced turbidity using either method.	■ Where application of amendment is via surface or near surface dumping, amendment material would cause turbidity. ■ Bottom substrates may be disturbed as amendment material reaches lake bed; computational or empirical approaches could assist in quantifying whether that would be significant. ■ With depths involved it would not be possible to have a barrier/turbidity curtain in place to contain induced turbidity.	■ Where application of capping material is via surface or near surface dumping, the material would cause turbidity. ■ Bottom substrates may be disturbed as capping material reaches lake bed; computational or empirical approaches could assist in quantifying whether that would be significant. ■ With depths involved it would not be possible to have a barrier/turbidity curtain in place to contain induced turbidity.	N/A
Contaminant dispersion	N/A	■ N/A, although the organic carbon may disperse into the water column during application.	■ N/A, although the capping material may disperse into the water column during application.	N/A
Introduction of foreign substances and potential breakdown products	■ N/A. Dredging does not involve introduction of foreign materials. ■ As with the use of machinery around water generally, there is always some risk of loss of fuel and lubricants to the water, despite exercise of precaution.	■ The addition of an organic carbon amendment would be experimental and the optimal application rate is unknown at this time. If too much organic carbon was added to the lake bed, breakdown products such as sulphides and ammonia could be released, and dissolved oxygen could be consumed, creating anaerobic conditions in the sediment, which would retard colonization by communities compared to reference locations.	■ Depends on the material selected for the cap. A geologically inert material would not be expected to contain foreign substances.	N/A.
Navigation / Recreation				
Boat passage	■ Large work platform (50 x 100 m) and safety zone (100-m radius) around work area would restrict usage of portions of lake. ■ With suction dredging, a floating slurry pipeline would have an uninterrupted span of potentially up to 10 km or more depending on dredged material disposal location and dredging rigs. Diesel booster pumps would operate every 0.5 to 1 km.	■ Potentially large work platform and safety zone (100 m radius) around work area would restrict usage of portions of lake although that would likely be minor.	■ Potentially large work platform and safety zone (100 m radius) around work area would restrict usage of portions of lake although that would likely be minor.	N/A. Typical recreational boat operation.

Variable	Dredging	Amendment or Chemical Stabilization	Thin-layer Capping	Monitored Natural Recovery
Fisheries	■ Large work platform (50 x 100 m) and safety zone (100 m radius) around work area would restrict usage of portions of lake for fishing.	■ Potentially large work platform and safety zone (100 m radius) around work area would restrict usage of portions of lake by fishermen although that would likely be minor.	■ Potentially large work platform and safety zone (100 m radius) around work area would restrict usage of portions of lake by fishermen although that would likely be minor.	N/A. Typical recreational boat operation.
Noise and Air Quality / Nuisance				
Construction noise and lighting	■ Some noise generated through operation of equipment (motors, metal upon metal, vessels, verbal communication). ■ During seasonally allowable periods, the operation would likely operate 24/7, necessitating lights in the work zones, booster stations would have lights and diesel-powered pumps.	■ Some noise generated through operation of equipment (motors, metal upon metal).	■ Some noise generated through operation of equipment (motors, metal upon metal).	N/A.
Air quality	■ Typical emissions from construction equipment and from trucks transporting dredged material to the mine site. ■ If the material is dewatered near the lake and transported by truck, local dust could be an issue.	■ Typical emissions from construction equipment. ■ Potential dust generation from stockpiles. ■ Nuisance odors may be associated with the organic carbon amendment.	■ Typical emissions from construction equipment. ■ Potential dust generation from stockpiles.	N/A.
Traffic				
Import of equipment and materials	■ Additional traffic through adjacent communities to bring equipment and construction materials to site. ■ Municipal and regional by-laws may have restrictions on truck routes and schedules, which may have an influence on the overall schedule.	■ Additional traffic through adjacent communities to bring equipment and construction materials to site. ■ Municipal and regional by-laws may have restrictions on truck routes and schedules, which may have an influence on the overall schedule.	■ Additional traffic through adjacent communities to bring equipment and construction materials to site. ■ Municipal and regional by-laws may have restrictions on truck routes and schedules, which may have an influence on the overall schedule.	N/A. Typical recreational boat operation.
Export of dredged material	■ Not expected with suction dredging and hydraulic transport of slurry. ■ If clamshell dredging is used, material would need to be brought to shore, dewatered sufficiently for safe truck transport. ■ Municipal and regional by-laws may have restrictions on truck routes and schedules, which may have an influence on the overall schedule.	N/A	N/A	N/A.

Studies Needed to Support Remediation Planning

Depending on the remediation option selected, additional studies may be required to support the planning and assessment of the remediation, for example, if the option of dredging were selected:

- Geotechnical evaluation (e.g., to support design of shoreline infrastructure such as ramps and docks; to understand the potential for dredging to destabilize the lakeshore) for the dredging option.
- Evaluation of mine roads to determine if upgrades would be necessary to support additional truck traffic that may be required to transfer dredged material to the mine site for disposal, if trucks are selected for this purpose.
- Evaluation of a new pipeline route and detailed pipeline engineering to support engineering of a new pipeline to transfer dredged material if direct pumping is selected for this purpose.
- Dredged material dewatering and dewatering effluent treatment and disposal; location selection for dredged material and volumes of water that can be practicably treated, which would govern dredging production rates.
- Optimal dredging methods, equipment availability, vessel sizing requirements.
- Bench-scale and in situ pilot testing to evaluate the potential efficacy of a remediation option (e.g., tests to determine the preferred material for carbon amendment and dosing rates, or material for thin-layer capping).

NEBA Metrics

Table 8 identified a number of considerations regarding potential options that could be implemented to meet the remediation goals for the benthic zone of Quesnel Lake. The primary indicator metrics selected from those considerations for inclusion in comparing the net environmental benefit of the potential remediation options (i.e., gains versus losses) are as follows and discussed further below. “Environmental Benefit” is considered broadly. While the main biological measure of gains and losses is invertebrate production, environmental benefits in this case also include use of the environment of Quesnel Lake and effects on the human environment (aesthetics).

- net benthic invertebrate productivity – gains from the action less the losses from those actions
- effects on water quality – including all uses of Quesnel Lake water (e.g., aquatic life, drinking water, etc.)
- effects on adjacent terrestrial areas
- effects on air quality
- effects on recreational activities (e.g., boating, swimming)
- effects on aesthetics (noise, traffic)

Net Benthic Invertebrate Productivity

The ultimate remediation goal is that the benthic invertebrate community recover to a level that is similar to adjacent areas. As the data show, this recovery has started (Section 4.11.3) and therefore this variable is intended to capture how physical or other perturbations associated with a remediation option may affect productivity over time due to that additional disturbance. This means that if an additional perturbation is to be beneficial, the productivity gain needs to be greater than the loss from the perturbation for there to be a net benefit. Net benthic invertebrate productivity is thus defined as follows: Productivity of desired stated minus the initial loss from TSF breach and the incremental additional loss or gain from implementation of a remediation activity.

Although the data are not sufficient at this time to quantify the overall recovery trajectory and when the density of chironomids, in particular, will be consistently within the range of natural variability of reference areas, a qualitative comparison of potential additional productivity loss can be identified. For example, Figure 27 illustrates the conceptual time scale at which recovery reaches the range of natural variability. The amendment and dredging options are expected to result in a second disruption to the benthic community and therefore additional lost productivity, following a period of detailed planning, site preparation, and procurement of equipment. The dredging option is expected to take the longest time to implement with continual disruption to the lake bed where dredging is occurring at a given time. The amendment option is expected to take less time than dredging and cause a lesser effect on productivity initially than dredging because the sediments are not being “excavated”. In comparison, monitored natural recovery allows for the recolonization of the sediments to continue its current trajectory without a second disruption to productivity. Based on the timeline illustrated in Figure 27, the net benthic productivity of the three remediation options is therefore ranked from highest to lowest as:
MNR > amendment > dredging.

It should be noted that Figure 27 is a conceptual figure and the dotted lines are notional projections. It is possible that the impacts of dredging, in particular, could be reduced somewhat through project planning with recovery starting as the dredge works its way across Quesnel Lake. However, given the depth of the design dredge cut being upwards of 10 m, it is possible that such a depth would need to be achieved through multiple passes. A 10 m deep cut would be filled by inwards collapse of the uncut sidewalls and such events would generate turbidity at depth which may be available for surface water turbidity at lake overturn. Therefore, while the absolute losses notionally depicted in Figure 27 may be greater than achievable in a well-designed dredging program, in relative terms, the figure nevertheless depicts the concept of extended duration perturbations to the benthic community should the dredging option be pursued. There is no evidence available to suggest that following dredging, benthic productivity would be higher than it would otherwise be with MNR. Accordingly, dredging scores poorly on net environmental benefits, whether considered in the broad context as described above or in the narrower context of non-human biological metrics.

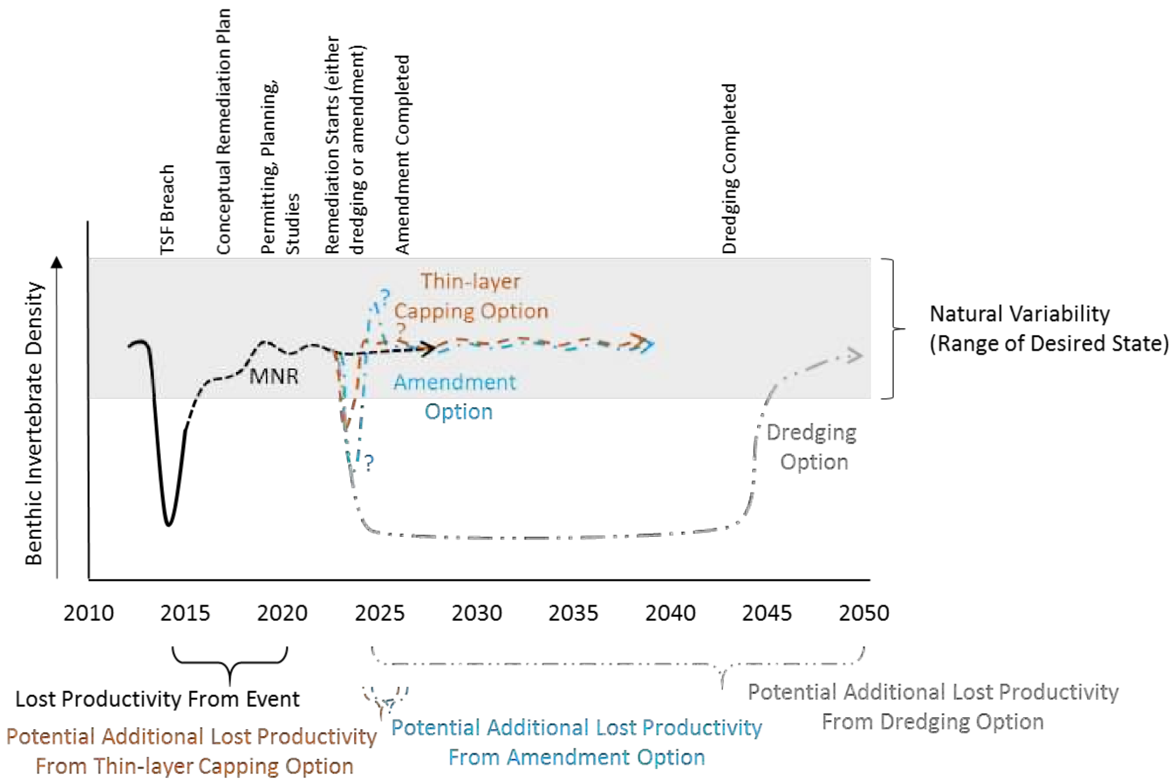


Figure 27: Conceptual Comparison of Influence of Remediation Option on Net Benthic Invertebrate Productivity (Not Based on Actual Data from Quesnel Lake)

Effects on Water Quality

Two of the remediation options (dredging and carbon addition) may have an effect on water quality, which may in turn affect productivity of the water column or the safety of the water for human consumption, specifically:

- Dredging has the potential to introduce suspended sediments into the water column. This re-suspension of sediments would occur throughout the duration of dredging, which is estimated to be six months per year for > 30 years. The degree to which sediment may be re-suspended during dredging is dependent on the equipment used. Mechanical dredging (i.e., with a clam shell bucket) introduces a considerably greater amount of solids into the water column than hydraulic dredging. As well, a temporary water treatment system with effluent discharge back to the lake may be needed, depending on the dredging method selected. For example, hydraulic dredging generates six parts of water to each part of solids. At a dredging rate of 6,000 m^3 solids per day and assuming an 8:1 water:solids ratio (the middle of the notionally expected range), 48,000 m^3 of dewatering effluent would need to be treated to remove solids and this treated effluent would then be discharged back into the lake. Additional turbidity may be generated using either method depending on the depth of the dredge cut at a given location. A dredge cut with a 10 m mud wall adjacent to that cut would be infilled by slumping and the force of that slumping would generate considerable turbidity at depth. To prevent this, dredging would need to be carried out as "shaved" layers, which would then result in further delays to recovery over a wider area.

- Capping the sediments would necessarily involve introducing a substance to the lake (inorganic sediment), which may become entrained in the water column depending on the placement method. This water quality effect is expected to be relatively short-term compared to dredging. None of the data so far suggest a benefit or need for thin-layer capping.
- Amending the sediments would necessarily involve introducing a substance to the lake (organic carbon), which may become entrained in the water column depending on the placement method, or may result in degradation products being released as the carbon breaks down on the lake bed. These water quality effects are expected to be relatively short-term compared to dredging.

In comparison, monitored natural recovery is not expected to have any water quality effects because the sediments are both physically (Tetra Tech 2017) and chemically (Kennedy at al. 2016) stable at the bottom of the lake. Physical stability will be re-evaluated if and when university data and methods become available for review.

In summary, from least to greatest negative impact on water quality, the remediation options are ranked as follows: MNR < capping < amendment < dredging.

Effects on Terrestrial Areas

Given the magnitude of the lakebed area that would need to be actively remediated, considerable infrastructure and staging areas may be needed for the following logistic needs for the dredging and, to a lesser extent, capping and carbon addition methods:

- Constructing and storing equipment – the type and size of equipment (e.g., barges) that would be needed are not readily available in the Cariboo Region and/or may not be transportable to the site due to physical size and weight. Therefore, it may be necessary to transport raw materials (e.g., sheet metal) or sections to the site and construct the needed equipment along the Quesnel Lake shore.
- Operation of booster pumps if the transfer of dredged sediment from the lake to the pit is done via direct pumping. The booster pumps would be needed approximately every 0.5 to 1 km and would need to be placed in a relatively flat area that is easily accessible for maintenance. Several booster pumps would be needed for the section of slurry pipeline that would be floating on Quesnel Lake.
- Construction of ramps and wharves for launching equipment and facilitating trans-loading of materials. For example, material to be applied to the lake bed would need to be transferred from trucks to the floating platform from which it will be placed on the lake bed. In the event that dredged sediment is transferred to the disposal area via truck, the material would need to be transferred from a dredge scow to a processing area for dewatering and then to trucks.

The area required for staging is not yet defined, but it would likely involve the removal of vegetation and reconfiguration of land forms along the shoreline and adjacent upland areas. Following completion of the remediation, these areas would then also need to be remediated.

In comparison, monitoring of natural recovery can be done using a vessel that can be trailered and launched at an existing ramp.

In summary, from least to greatest effect on terrestrial areas, the remediation options are ranked as follows: MNR < capping < amendment < dredging.

Effects on Air Quality, Light, and Noise

Air quality and light and noise levels may be affected by the operation of equipment (e.g., engines on excavators, generators, metal on metal contact):

- The duration of dredging is conceptually estimated to be, in aggregate, six months per year for approximately 30 years, with operations occurring 24 hours per day. The dredging could potentially occur at a faster rate by having more dredge rigs deployed to the lake; however, production rates may be limited based on the ability to dewater the slurry and treat the return water to acceptable levels. Further engineering design would be required, should this option be selected. The dredging season would coincide with the greatest period of recreational use of Quesnel Lake because weather windows suitable for dredging would occur over the spring to fall timeframe. Noise and light effects would occur during this time on a 24/7 basis. Additional booster pumps (lights and noise) would be needed at the shoreline and potentially every 0.5 to 1 km to direct pump dredged material to the mine if that is the transfer option selected. The other potential transfer method would be the use of heavy haul trucks, which could be loaded by excavator and introduces the possibility of metal-on-metal contact which induces noise.
- The application of capping or amendment material to the lake bed would also involve heavy machinery, although it is expected that less equipment would be operating at a given time and the duration is expected to be considerably shorter.
- Monitored natural recovery would involve the intermittent operation of a recreational-type boat, during daylight hours only

In summary, from least to greatest effect, the remediation options are ranked as follows: MNR < capping < amendment < dredging.

Effects to Recreational Activities

Recreational use on Quesnel Lake could include boating (power boats, canoes), fishing, and swimming. These activities could be affected as follows:

- During dredging, the work would be done from one or more mobile “spreads” consisting of a dredge barge and potentially hopper barges which could impede lake and shoreline-based activities. As noted previously, this equipment could be on the lake 6 months per year for >30 years. For mechanical dredging, the hopper barges would transit between the dredge barge and the shore-based trans-loading area. For hydraulic dredging, the most efficient delivery method is via direct piping from the dredging location to the shore. This is done via a floating pipe with booster pump stations potentially every 1 km. For health and safety purposes, exclusion zones would be established around the equipment. Shoreline work areas would also have exclusion zones set around them.

- The carbon addition option would also involve the use of relatively large work platforms with exclusion zones, but for a lesser amount of time, potentially within a single season depending on the specific requirements of such application.

In summary, from least to greatest effect, the remediation options are ranked as follows:
MNR < capping < amendment < dredging.

Effects to Aesthetics (Visual)

As described above, dredging and carbon amendment involve large work platforms that would be on the lake and visible from the shoreline. This would be ongoing potentially for 6 months per year for >30 years if the dredging option were selected, and a lesser period of time if the carbon amendment option is selected. Both options may also involve construction of shoreline staging areas and thus temporary loss of treed areas.

Quesnel Lake is a clear water system and in numerous public and other meetings, the local community has been clear about how much they value this (and other) aspects of Quesnel Lake. If turbidity induced by dredging were to come to the surface either through seasonal overturn or through clamshell dredging, even a minor increase in turbidity of a few NTUs would likely be noticeable by local community members.

In comparison, monitored natural recovery would involve sampling from a vessel similar to those used by recreational boaters and would not involve the installation of shoreline facilities or the generation of turbidity. Carbon addition could potentially result in some minor turbidity but with further design efforts may not result in significant (visible) turbidity.

In summary, from least to greatest effect, the remediation options are ranked as follows:
MNR < capping < amendment < dredging.

4.11.3.4 Recommended Remediation Option

The options were categorically ranked relative to one another without weighting one variable more strongly than the other (Figure 28). Based on the metrics for comparison of the net environmental benefits associated with each conceptual remediation option, dredging has the greatest potential to have higher environmental costs and would result in the lowest net environmental benefits (benthic invertebrate productivity) because dredging would result in extended perturbations at the bed of Quesnel Lake. Given the observations of a recovering lake bed – species richness is similar to the unimpacted lake bed station and abundance is increasing though not yet within the range of natural variability – the time benefit of recovery between the initial impact of the event and the initiation of dredging would be reversed. There is also no basis from which to expect that the post-dredged lake bed would be more highly productive. The addition of carbon is a concept that comes from laboratory tests where carbon was added and restored growth to pre-impact conditions. This does not mean that it would result in certainty of benefit if scaled up from lab to field, especially given that organic carbon in the sediments is increasing as a result of natural processes (Figure 24) and there would be a time delay to develop this remedial option from concept to final design.

Monitored natural recovery is expected to result in the greatest net benthic invertebrate productivity and is not expected to cause further environmental effects (beyond those caused by the event itself). As with all three options, performance verification of MNR would be a necessary component of the CEMP.

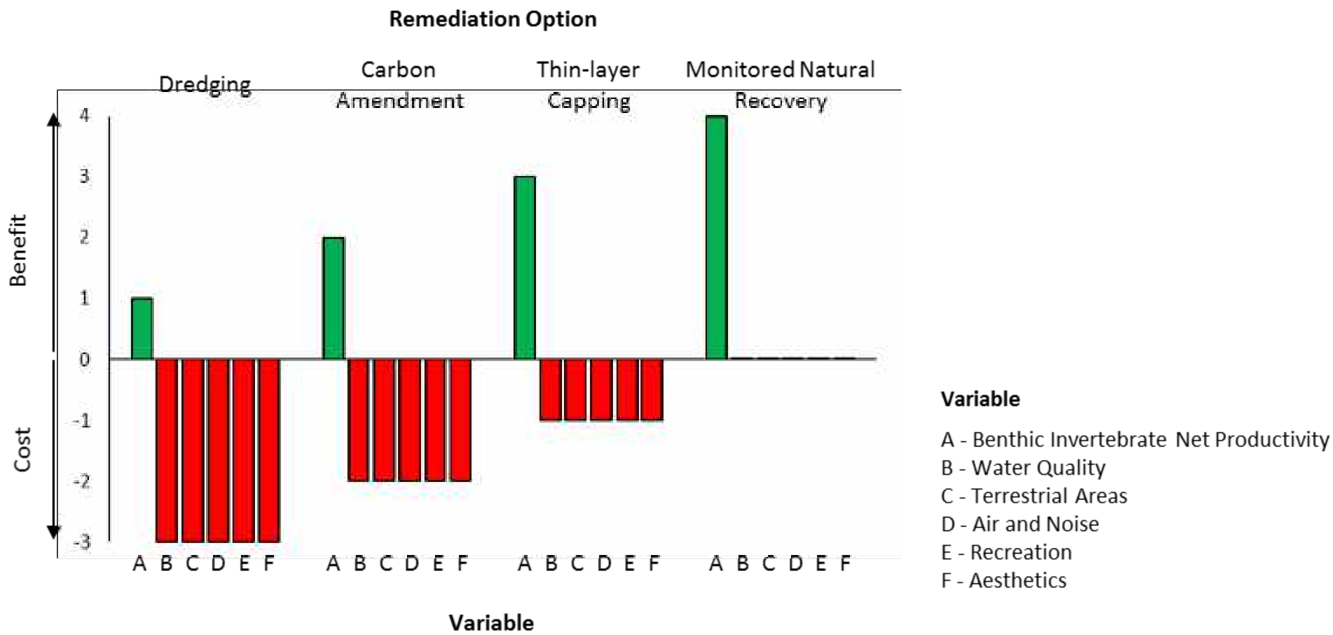


Figure 28: Net Environmental Benefit Analysis of Dredging Versus Carbon Amendment versus Thin-layer Capping versus Monitored Natural Recovery

The recommended remedial option is MNR. As noted in Table 6, there is no specific provincial guidance but parallels can be drawn to guidance respecting Monitored Natural Attenuation of groundwater contaminants (Technical Guidance 22; TG-22; MOE 2014). Table 9 provides an adaption of factors from TG-22 that are applicable to the Quesnel Lake benthic zone and how the conditions are met. Based on this guidance, MNR is feasible as a remediation option.

Table 9: Overview of Factors for Monitored Natural Recovery to be Feasible (Adapted from TG-22 [MOE 2014])

Factor	How this Condition is Met
1) MNR is to be performed in the context of a risk assessment that indicates an absence of significant risks to human health or the environment.	The human health risk assessment did not identify risks. The aquatic ecological risk assessment showed that although abundance of benthic invertebrates was lower in the West Arm, species richness was similar between the West Arm and reference areas and that recolonization in sediment from a reference area transplanted to the West Arm was not impaired. The main risks are associated with the nutrient (organic carbon) poor nature of the sediment and organism growth was restored with its addition. Sediment organic carbon has increased (Figure 24) and while it is within the range of reference stations, the average concentration is still reduced.

Factor	How this Condition is Met
2) A long term performance monitoring and validation program can be and will be put in place	MPMC conducts regular monitoring in accordance with their CEMP. Monitoring components to validate that the benthic invertebrate community is continuing to recover are part of the CEMP. The CEMP is part of MPMC's permit and the execution of the CEMP is therefore compelled by regulatory instrument.
3) The use of MNR will result in the remediation goals being met within a reasonable time.	Based on the currently available data (i.e., from 2014 through 2016), the benthic invertebrate community is continuing to recover. Species richness and diversity is already similar between the West Arm and reference areas. In 2016, the density of benthic invertebrates was still lower in the West Arm than in the reference area; however, the trajectory is one of continuous improvement. Based on the current trajectory, it is expected that the benthic community in the West Arm will be similar to that in reference areas within a reasonable time frame. An additional round of sampling was conducted in 2017 and once the data are available, this trajectory can be verified. Monitoring in future years (frequency to be determined based on data) is an expected part of MNR.
4) A contingency plan that includes defined implementation triggers for identifying when the remedial goals are not being met.	The CEMP will include a response framework that identifies triggers for potential additional remediation activities.

4.11.3.5 Addressing Residual Impacts Post-remediation

Even with the selected remediation option for Quesnel Lake benthic zone remediation (MNR), as a result of the event there was a loss of benthic invertebrate productivity and quantifying that lost productivity is part of the objective of identifying and quantifying productivity offsets. Figure 29 illustrates the conceptual offsetting requirements for the initial impact with MNR (and other options). Estimated remediation duration for MNR is approximately 5 years based on estimates from literature plus a reduced rate of colonization in year one as turbid materials were settling out. There is uncertainty in this estimate. Residual impacts and offsets for Quesnel Lake are discussed in Section 5.4.2.

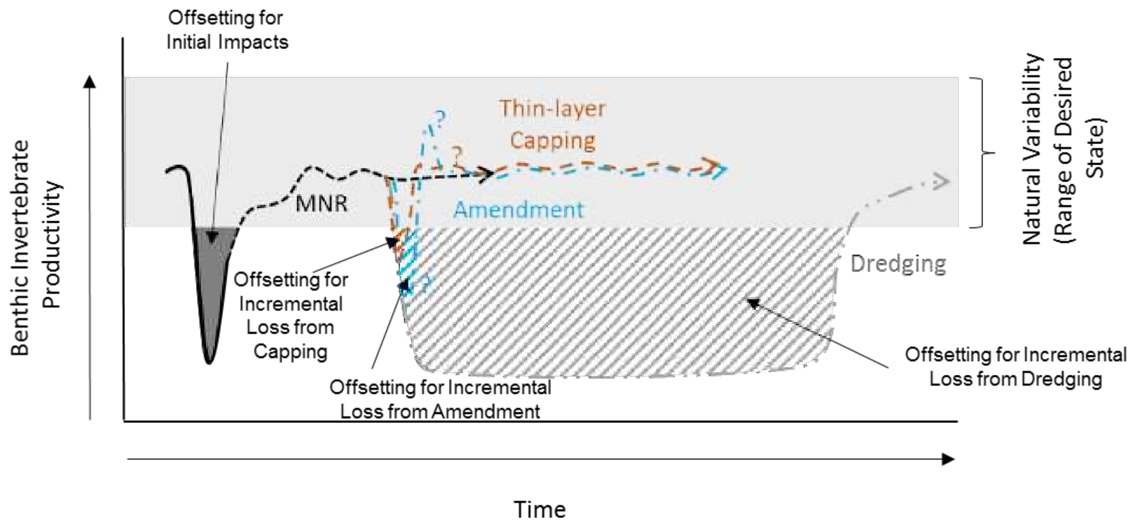


Figure 29: Conceptual Illustration of Offsetting Needs Post-Remediation

4.12 Quesnel River / Area #9

Using the classification system of the HRWG, this area corresponds to EU-Quesnel River. 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. Following the TSF breach, 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. 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 2015a). That amount of material represents 12% or less of the river's annual sediment load. Daily average and *in situ* turbidity concentrations in Quesnel River have shown an overall progressive decrease over time throughout 2015 (Golder 2017c). Turbidity measurements continue to be low.

Objectives for Quesnel River are directly related to stability of benthic sediments in the West Basin of Quesnel Lake and maintenance of downstream water quality (related to the breach).

4.13 Public Safety Risks

4.13.1 "Edney Flats"

Potential public safety risks were identified in the flat sediment area near the mouth of Edney Creek as well as general risks along the Hazeltine Creek corridor.

The WSA Engineer requested that a safety evaluation be carried out of the deposited materials with regard to persons or human occupied vehicles becoming stuck. A geotechnical evaluation was carried out (Golder 2019) using hand augers and Dynamic Cone Penetrometer (DCP) testing at 5 stations across the area of concern. Hand augers were advanced to depth ranging from 0.4 to 2.9 m below ground surface and DCP tests were advanced between 1.3 and 2.9 m below ground surface. Soil cuttings collected from the hand auger were visually logged and classified in the field and representative samples were collected for further visual classification and geotechnical index testing in Golder's laboratory, including moisture content determinations, gradation analyses and Atterberg limits. Field observations indicated that groundwater level is hydraulically connected to and controlled by the water level of Quesnel Lake and seasonal fluctuation, including inundation can therefore be expected.

Based on findings of the study and the strength gain since deposition, the loose/soft ground hazard at Edney Flats was concluded to not present a life safety concern. Observations of vehicle tracks were also noted. However, given the variable nature of the material and inferred fluctuations in groundwater level, especially at times of flooding, the area may become untrafficable. For this reason, Golder recommended that signage be erected around the perimeter of the site, cautioning users of the potential soft ground conditions and MPMC will be erecting that signage in 2019 once weather and ground conditions allow. No additional remediation for safety purposes was recommended.

4.13.2 Sediment Ponds, Lower Hazeltine Creek

The sediment ponds at lower Hazeltine Creek were built as temporary structures with relatively steep side walls and, if retained in their present form, would present a public safety hazard. Life rings are placed near the ponds and signage is in place indicating the steep slope and open water at present. However, remediation of Hazeltine Creek habitat will involve the decommissioning of those ponds based on the consensus decision reached at the HRWG meeting in November 2018. While current habitat design concepts do not include the ponds in whole or in part, should they be retained, public safety considerations will need to form part of engineering design.

4.13.3 Public Safety Issues Along Hazeltine Creek

Some of the changes that occurred because of the TSF breach included a steepening of the banks of Hazeltine Creek and deposition of tailings material among the trees along the Hazeltine Creek corridor. The deposited tailings resulted in conditions that caused a die-back of some of the affected trees (Golder 2015a). A danger tree assessment was carried out by MPMC in 2018 and most danger trees in any area where the public would access were removed. MPMC crews also re-sloped most of the steep banks so that they were not a drop off. There remains an area above Hazeltine Canyon that has not been re-sloped as this slope provides habitat for bank swallows in its current form. MPMC will need to consider whether bank swallow habitat is to remain (in consultation with wildlife specialists) and means of restricting access to the tops of those slopes.

5.0 RESIDUAL EFFECTS, OFFSETS AND COMPENSATION

This section describes the residual effects (current to March 2019) to fish populations, instream fish habitat, riparian habitat, and upland terrestrial habitat from the event (Section 5.3), as well as the current determination of compensation and offsets required to counterbalance these residual effects (Section 5.4). Proposed and potential on-site and off-site offset and compensation options are also described in Section 5.4. Some local opportunities are tabulated in Appendices B and C; however, projects will be evaluated and prioritized by the HRWG.

5.1 Ecological Units, Ecological Functions, and Indicators

DFO guidance on offsetting (DFO 2013) articulates the view that effective offsets are those that prioritize benefit for the specific fish populations and areas that were affected. In that context, the HRWG divided the affected areas from the event into ten EUs, identified the CRA fish species present pre-event, and described the ecological functions for each of these fish species (Table 10). The HRWG then developed indicators and metrics (vis-à-vis Loughlin and Clark 2014) for each EU to compare the difference between pre- and post-event effects to fish and fish habitat and to use these comparisons to estimate the residual effects and determine whether offsets are required.

Increasing fisheries productivity is the key objective of offsetting activities under the *Fisheries Act* (Bradford et al. 2016). Fisheries productivity can be measured directly through measurement of production rates of fish species of interest, or indirectly through measurement such as catch per unit effort, biomass, or fishing yield (Minns 1997). Fish population indicators (i.e., fish abundance, fish age class structure, fish condition factor) are the HRWG's preferred indicators for estimating residual effect. Fish habitat suitability and availability indicators (e.g., habitat function metrics, mesohabitat type, microhabitat features) are a less direct surrogate for assessing fisheries productivity - they measure productive capacity – which does not directly translate to fish abundance, community structure or health (Bradford et al. 2016). As such, the HRWG put greater weight on fish population indicators compared to fish habitat suitability and availability indicators. Indicators are listed in priority order against each EU in Table 10.

Table 10: Ecological Units, Ecological Functions, and Indicators Selected to Determine Residual Effect

Ecological Unit (EU)	CRA Species	Ecological Functions	Indicator (in Priority Order) *
Upper Edney Creek (E1)	Rainbow Trout	S; M	▪ Rainbow Trout Abundance ▪ Rainbow Trout Age Class Structure
Middle Edney Creek (E2)	Rainbow Trout; Coho Salmon; Chinook Salmon; Sockeye Salmon; Mountain Whitefish; Burbot	S; R; O; M	▪ Rainbow Trout Abundance ▪ Rainbow Trout Age Class Structure ▪ Habitat Function Metrics**
Polley Lake	Rainbow Trout	S; R; O; M	▪ Rainbow Trout Abundance ▪ Rainbow Trout Age Class Structure ▪ Rainbow Trout Condition Factor

Ecological Unit (EU)	CRA Species	Ecological Functions	Indicator (in Priority Order) *
Upper Hazeltine Creek (H1)	Rainbow Trout	S; R; O; M	■ Rainbow Trout Abundance ■ Rainbow Trout Age Class Structure ■ Habitat Function Metrics**
Lower Hazeltine Creek (H2)	Rainbow Trout; Coho Salmon; Chinook Salmon; Sockeye Salmon; Kokanee; Mountain Whitefish; Burbot	S; R; O; M	■ Rainbow Trout Abundance ■ Rainbow Trout Age Class Structure ■ Habitat Function Metrics**
Lower Edney Creek (E3)	Rainbow Trout; Coho Salmon; Chinook Salmon; Sockeye Salmon; Mountain Whitefish; Burbot	S; R; O; M	■ Rainbow Trout Abundance ■ Rainbow Trout Age Class Structure ■ Habitat Function Metrics**
Quesnel Lake – Limnetic Zone	Rainbow Trout; Coho Salmon; Chinook Salmon; Sockeye Salmon; Mountain Whitefish; Bull Trout; Kokanee; Lake Trout; Lake Whitefish; Pygmy Whitefish; Burbot	R; M	■ Limnetic Zone Fish Relative Abundance ■ Limnetic Zone Fish Condition Factor ■ Turbidity ■ Phytoplankton and Zooplankton Biomass
Quesnel Lake - Littoral Zone	Rainbow Trout; Coho Salmon; Chinook Salmon; Sockeye Salmon; Mountain Whitefish; Bull Trout; Kokanee; Lake Trout; Lake Whitefish; Pygmy Whitefish; Burbot	S; R; M	■ Littoral Zone Fish Relative Abundance ■ Littoral Zone Fish Condition Factor ■ Littoral Habitat Area ■ Potential Shoreline Spawning Habitat Area ■ Habitat Features by Area ■ Submergent and Emergent Vegetation by Area ■ Benthic Invertebrate Relative Abundance and Diversity
Quesnel Lake - Benthic Zone	Rainbow Trout; Bull Trout; Lake Trout; Mountain Whitefish; Pygmy Whitefish; Lake Whitefish; Burbot	R	■ Total Benthic Area Smothered ■ Benthic Zone Fish Relative Abundance ■ Benthic Zone Fish Condition Factor ■ Benthic Invertebrate Relative Abundance and Diversity
Quesnel River	Coho Salmon; Chinook Salmon; Sockeye Salmon; Rainbow Trout; Bull Trout; Mountain Whitefish; Burbot; Kokanee	S; R; O; M	■ Turbidity

S = Spawning; R = Rearing; O = Overwintering; M = Migration.

*FHWRG Habitat Objectives Tables 2015 ** Metric criteria for diagnostics of habitat function are outlined in reference Table 1, adapted from Johnston and Slaney 1996 Technical Circular.

5.2 Pathway of Effect

Pathways of Effects are used in DFO's Fisheries Protection Policy Statement (DFO 2013) to describe the types of cause-effect relationships that are known to exist for specific activities or events and the mechanisms by which these actions ultimately lead to effects in the aquatic environment. Each cause-and-effect relationship is represented as a pathway, connecting the activity to a potential stressor, and the stressor to an effect on fish or fish habitat. Each pathway represents connections where mitigation measures could be applied to break the connection and reduce or eliminate the effect. When mitigation measures are not or can not be applied or are not fully effective, the remaining effect is referred to as a residual effect that will require offsetting to balance the impact on fisheries productivity.

Because the event affected fish populations and fish habitat differently among the EUs, the HWRG developed Habitat Objectives Tables that included the main "pathways of effect" associated with the event for each EU and these are presented against each EU by ecological function in Table 11. For example, the HWRG identified one "pathway of effect" to Upper Edney Creek (E1) – the potential effect to spawning and migration functions from the "potential downstream disruption of access for returning adult spawners". While, the HWRG recognized a greater number and different types of "pathways of effect" of the event on Middle Edney Creek (E2) – for example, the potential effect to spawning, rearing, overwintering and migration functions from the "deposition of material", and "instream streambed scour and removal of structure".

Table 11: Pathway of Effect of the Event on each Ecological Unit by Ecological Function

Pathway of Effect	Ecological Unit (EU)									
	E1	E2	E3	H1	H2	Polley Lake	QL - Benthic	QL - Limnetic	QL - Littoral	Quesnel River
Potential downstream disruption of access for returning adult spawners	S; M									
Deposition of material		S; R; O; M	S; R; O; M	S; R; O; M	S; R; O; M	S; R; O; M	R		S; R	
Instream streambed scour and removal of structure		S; R; O; M	S; R; O; M	S; R; O; M	S; R; O; M					
Riparian habitat alteration associated with deposition of material		S; R	S; R	S; R	S; R	R			R	
Riparian clearing associated with channel remediation work		S; R	S; R		S: R					
Removal of natural channel morphology, mesohabitat proportions		S; O; M	S; O; M	S; O; M	S; O; M					
Removal of critical and important fish habitat		S; O	S; O	R	S; R; O					
Removal of spawning gravel and hydraulic features that create and maintain high quality spawning gravels		S	S	S	S					
Instream removal of structure		R	O		R					
Removal of structure						S; O				
Alteration of structure						S; O	R		S; R	
Decrease in channel length and sinuosity		R	R	R	R					
Alteration of natural channel morphology (width, depth, gravel/boulder substrates), and mesohabitat proportions		R	R		R					
Alteration of Water Quality (pH, hardness, TDS, metals)		O	R; O	R; O	R; O	R; O	R	R; M	S; R; M	
Alteration of Water Quality (turbidity)		R; O	R; O	R; O	R; O	O				S; R; O; M
Alteration of flow (Hazeltine not connected)			R; O							
Reduction of hydraulic features (riffles, instream LWD, meander helical flows) that create and maintain high habitat			R	R	R; O					

Source: Habitat Objectives Tables HRWG 2015. S = Spawning; R = Rearing; O = Overwintering; M = Migration.

5.3 Residual Effects, Compensation and Offset Determination

Effects to each EU have been quantified both spatially (i.e., geographical area) and temporally (i.e., the time lag between the event occurrence [August 2014] and remediation). This is because the event has caused different effects to each area, and for different periods of time. For example, Lower Edney Creek remediation work was conducted within nine months of the event, whereas Lower Hazeltine Creek remains in the design stage, with no habitat remediation (beyond the foundational channel for erosion control) undertaken since the event (i.e., as of writing, approximately 4.5 years).

Residual effects have been determined for each indicator, for each EU, using pre- and post-event monitoring data (Sections 5.3.1.1 to 5.3.1.10 and Table 12 to Table 21). Residual effects from the event have also been quantified for riparian habitat (Section 5.3.1.11;Table 22) and upland terrestrial habitat (Section 5.3.2).

Residual effect values have been used to calculate the requirement for offsets for each EU (Sections 5.3.1.1 to 5.3.1.10). The residual affected area (i.e., the “spatial balance”), and the time lag to remediation (i.e., the “temporal balance”), for each EU represents a specified loss of habitat productivity. The spatial and temporal balances for each indicator have been incorporated into offset calculations for each EU and the riparian habitat, and compensation for upland terrestrial habitat (Sections 5.3.1.1 to 5.3.2).

5.3.1 Aquatic Habitat

5.3.1.1 Upper Edney Creek (E1)

In Upper Edney Creek (E1), no habitat was directly altered, and therefore there was no spatial loss of Rainbow Trout productivity. There was potential for the event to cause a blockage in the lower sections of Edney Creek that could have obstructed access for spawning Rainbow Trout migrating from Quesnel Lake to Upper Edney Creek. The event occurred in August of 2014 after the spawning migration of Rainbow Trout. Remediation work in the lower sections of Edney Creek restored access to Upper Edney Creek (E1) from Quesnel Lake prior to the 2015 spawning migration of Rainbow Trout and therefore it is not expected that there was a temporal loss of Rainbow Trout productivity in Upper Edney Creek (E1; Table 12).

Abundance of Rainbow Trout in Upper Edney Creek was higher post-event compared to pre-event conditions and the age class structure of Rainbow Trout in Upper Edney Creek (E1) was similar pre-and post-event (Table 12). Based on these indicators, negative effects on the functionality of habitat in Upper Edney Creek (E1) were not likely.

As the event caused no direct physical effects to Upper Edney Creek (E1), and there were no measured negative effects to the indicators, no offsetting is required for Upper Edney Creek (E1).

Determination**: No Offsetting**

Table 12: Upper Edney Creek (E1)

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	Spawning; Migration	Rainbow Trout CPUE (# fish per minute by electrofishing) in 2007 (August) was **0.67** in Upper Edney Creek (UEC-1) (Minnow 2016b).	Average CPUE (# fish per minnow trap day) for Rainbow Trout in 2016 (April to October) was **0.429** (Minnow 2016b) and in 2017 (May to November) was **1.09** (Minnow 2018a).	Rainbow Trout CPUE was higher in 2017 than 2016 indicating they successfully migrated upstream to E1 (Minnow 2016b, 2018). Overall spatial balance **= Positive**	(-) 9 months Fish passage from Quesnel Lake to Edney Creek watershed was restored 9 months post-event (i.e., prior to Rainbow Trout migration) Overall temporal balance **= Neutral**
Rainbow Trout Age Class Structure	Spawning; Migration	Rainbow Trout age class structure data for 2007 (August) show **79%** of Rainbow Trout were **Young of Year** (YOY [age "0"]; Minnow 2007; SNC 2015a). There is limited pre-event juvenile salmon abundance data. There is no pre-event salmon spawner escapement data (except some limited observations).	Rainbow Trout age class structure data for 2016 (April; August/September; October) and 2017 (April; October; November) show most Rainbow Trout were **YOY** (i.e., <3.5 to 12 cm), with some **Age 1 or 2** fish, in both years (Minnow 2018a). No Rainbow Trout spawners were observed in spring 2016 or 2017 (Minnow 2018a).	Rainbow Trout age class structure post-event (2016/2017) and pre-event (2007) were comparable (Minnow 2007, 2018a; SNC 2015a). Overall spatial balance **= Neutral**	(-) 9 months Fish passage from Quesnel Lake to Edney Creek watershed was restored 9 months post-event (i.e., prior to Rainbow Trout migration) Overall temporal balance **= Neutral**

Sources: Minnow 2007, 2016b, 2018a; SNC 2015a.

5.3.1.2 Middle Edney Creek (E2)

In Middle Edney Creek (E2), approximately 1,350 m^2 of high-quality spawning, rearing, overwintering, and migratory habitat was altered for one year, resulting in a temporal loss of fish productivity. Approximately 1,553 m^2 of instream habitat was remediated, resulting in a spatial net gain of high-quality habitat (Table 13).

The reconstructed habitat features were assessed and rated good (Table 3) for the following metrics: bankfull-width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency, and holding pools (Table 13). A higher abundance of Rainbow Trout was observed in 2017 compared to 2016, as was a similar age class structure pre- and post-event. Based on these indicators, negative effects on the functionality of habitat in Middle Edney Creek (E2) were not likely.

HEA calculations were undertaken for Middle Edney Creek (E2; Appendix D). The HEA calculation resulted in a required offset of units (Table 23). Because a greater amount of habitat has been remediated (1,553 m^2) than needed for offsetting (1,499 m^2), no further offsetting is required.

Determination: **No Offsetting**

Table 13: Middle Edney Creek (E2)

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	Spawning; Rearing; Overwintering; Migration	1,350 m^2 of total instream habitat was altered.	1,553 m^2 of total instream habitat was remediated.	Balance of +203 m^2 total instream habitat. Overall spatial balance **= Positive**	1 to 2 years Overall temporal balance **= Negative**
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	Spawning; Migration	There is no pre-event Rainbow Trout CPUE data for Middle Edney Creek.	Average CPUE for Rainbow Trout in Lower and Middle Edney in 2016 (21 April to 22 October) was **0.119** CPUE (# fish per trap day) with minnow traps and **0.054** CPUE (# fish per minute) with electrofishing (Minnow 2016b; Minnow 2018a). Average CPUE (# fish per trap day) for Rainbow Trout in Lower and Middle Edney in 2017 (28 May to 4 November) was **0.419** (Minnow 2018a). Survey method was minnow trapping (Minnow 2018a). Rainbow Trout CPUE in Lower and Middle Edney increased between 2016 and 2017 (Minnow 2016b, 2018).	The different in Rainbow Trout abundance in Middle Edney Creek pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of pre-event data; this indicator has not been used in determination of residual effects.**	1 to 2 years (spawning) <9 months (migration) Overall temporal balance **= Negative**
Rainbow Trout Age Class Structure	Spawning; Migration	The size and age of Rainbow Trout in Middle and Lower Edney Creek have been related historically, with reported mean/median fork lengths during August sampling events of 5.4 to 5.8 cm for **YOY**, 9.1 to 11.3 cm for **Age 1** fish and 12.1 to 13.6 cm for **Age 2** fish (HKP 1997; Minnow 2009). Rainbow Trout age class structure in Middle and Lower Edney in 2007 (21 to 28 August) ranged from **YOY to Age 3** fish (Minnow 2007; SNC 2015a). There is limited juvenile salmon abundance data. There is no salmon spawner escapement data (except some limited observations).	Most Rainbow Trout individuals measured in Middle and Lower Edney in 2016 were **YOY** (i.e., between 5 and 8 cm; Minnow 2018a). No Rainbow Trout spawners were observed in spring (21 April to 24 April), summer (28 August to 1 September), and fall (19 to 22 October) of 2016 (Minnow 2018a); however, the 2016 data indicates successful spawning in spring 2016. Rainbow Trout individuals measured in Middle and Lower Edney Creek in 2017 ranged from **YOY to Age 2** fish (i.e., between 7 and 13 cm; Minnow 2018a). No Rainbow Trout spawners were observed in spring (5 April) and fall (24 to 29 October and 4 November) 2017 (Minnow 2018a); however, the 2017 data indicates successful overwintering of the 2016 juveniles and successful spawning in spring 2017.	Rainbow Trout age class structure in Middle Edney Creek post-event (i.e., 2017) and pre-event (i.e., 2007) were comparable (Minnow 2007, 2018a; SNC 2015a). Overall spatial balance **= Neutral**	1 to 2 years (spawning) <9 months (migration) Overall temporal balance **= Negative**
Habitat Function Metrics*	Spawning; Rearing (Mesohabitat Type by Area) Overwintering (Mesohabitat Type by Area and Quality) (Microhabitat Features)	Pederson (1998) classified Middle and Lower Edney Creek as having a cascade-pool morphology dominated by cobble substrates, with functioning LWD as the most prevalent aquatic cover type. Fish habitat value was rated as high (SNC 2015a). Middle Edney Creek was observed to be ponded just upstream from its confluence with Hazeltine Creek due to the presence of a beaver dam (SNC 2015a).	Habitat functionality of Middle and Lower Edney Creek were assessed together. The habitat objectives for E2 was to create access and rearing habitat for juvenile salmonids including rainbow trout. Habitat parameters achieving quality ratings of good were: bankfull width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency (mean pool spacing), and holding pools (adult migration). Habitat parameters achieving quality ratings of fair were: LWD pieces per channel length and percent wood cover in pools (Golder 2017e). The habitat was not designed to prioritize spawning habitat and as such the substrate was more suitable for rearing but less so for spawning. Evaluation of habitat preferences and suitability criteria for the spawning / incubation life stage indicated the presence of some functional spawning habitat. Evaluation of habitat preferences and suitability criteria for the juvenile/rearing life stage indicated that habitat is suitable (relative to the reference site). However, dissolved oxygen was identified as being less suitable to Rainbow Trout. Additional cover (additional of large woody debris) could help moderate temperatures in the area (Golder 2017e). Current length of channel and channel configuration are different from prior to the event. Beaver activity near confluence had increased pool habitat (dynamic system; Golder 2017e).	Habitat function metrics in Middle Edney Creek was rated as high quality both pre-event and post-event Overall temporal balance **= Neutral**	1 to 2 years (spawning, rearing and overwintering) Overall temporal balance **= Negative**

Sources: HKP 1997; Golder 2017e; Minnow 2007, 2009, 2016b, 2018a; Pederson 1998; SNC 2015a.

* Metric criteria for diagnostics of habitat function are outlined in reference Table 1, adapted from Johnston and Slaney 1996 Technical Circular.

5.3.1.3 Lower Edney Creek (E3)

In Lower Edney Creek (E3), approximately 1,158 m^2 of high-quality spawning, rearing, overwintering, and migratory habitat was destroyed, with remediation occurring over the span of one year, resulting in a temporal loss of fish productivity. Approximately 3,795 m^2 of instream habitat was remediated, resulting in a spatial gain of high-quality habitat (Table 14).

Other indicators to suggest a recovering functional creek habitat for Rainbow Trout include an increase in abundance of Rainbow Trout between 2016 and 2017, and a similar age class structure pre- and post-event. The reconstructed habitat features were assessed and rated good for the following metrics: bankful-width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency, and holding pools (Table 14).

An HEA was not undertaken for Lower Edney Creek (E3) because this section of stream did not exist prior to the event. The construction of this section of creek contributes 2,643 m^2 of habitat credit.

Determination**: No Offsetting**

Table 14: Lower Edney Creek (E3)

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	Spawning; Rearing; Overwintering; Migration	1,158 m² of total instream habitat was destroyed.	3,795 m² of total instream habitat was remediated.	Balance of +2,637 m² total instream habitat. Overall spatial balance **= Positive**	1 to 2 years Overall temporal balance **= Negative**
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	Spawning; Migration	There is no pre-event Rainbow Trout CPUE data for Lower Edney Creek.	Average CPUE for Rainbow Trout in Middle and Lower Edney in 2016 (21 April to 22 October) was **0.119** CPUE (# fish per trap day) with minnow traps and **0.054** CPUE (# fish per minute) with electrofishing (Minnow 2016b; Minnow 2018a). Average CPUE (# fish per trap day) for Rainbow Trout in Middle and Lower Edney in 2017 (28 May to 4 November) was **0.419** (Minnow 2018a). Survey method was minnow trapping (Minnow 2018a). Rainbow Trout CPUE in Middle and Lower Edney increased between 2016 and 2017 (Minnow 2016b, 2018).	The difference in Rainbow Trout abundance in Lower Edney Creek pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of pre-event data; this indicator has not been used in determination of residual effects.**	1 to 2 years (spawning) <1 year (migration) Overall temporal balance **= Negative**
Rainbow Trout Age Class Structure	Spawning; Migration	The size and age of Rainbow Trout in Middle and Lower Edney Creek have been related historically, with reported mean/median fork lengths during August sampling events of 5.4 to 5.8 cm for **YOY**, 9.1 to 11.3 cm for **Age 1** fish and 12.1 to 13.6 cm for **Age 2** fish (HKP 1997; Minnow 2009). Rainbow Trout age class structure in Middle and Lower Edney Creek in 2007 (21 to 28 August) ranged from **YOY to Age 3** fish (Minnow 2007; SNC 2015a). Limited juvenile salmon abundance data. There is no salmon spawner escapement data (except some limited observations).	Most Rainbow Trout individuals measured in Middle and Lower Edney Creek in 2016 were **YOY** (i.e., between 5 and 8 cm; Minnow 2018a). No Rainbow Trout spawners were observed in spring (21 April to 24 April), summer (28 August to 1 September), and fall (19 to 22 October) of 2016 (Minnow 2018a); however, the data indicates successful spawning in spring 2016. Rainbow Trout individuals measured in Middle and Lower Edney Creek in 2017 ranged from **YOY to Age 2** fish (i.e., between 7 and 13 cm; Minnow 2018a). No Rainbow Trout spawners were observed in spring (5 April) and fall (24 to 29 October and 4 November) 2017 (Minnow 2018a); however, the 2017 data indicates successful overwintering of the 2016 juveniles and successful spawning in spring 2017.	Rainbow Trout age class structure in Lower Edney Creek post-event (i.e., 2017) and pre-event (i.e., 2007) were comparable (Minnow 2007, 2018a; SNC 2015a). Overall spatial balance = **Neutral**	1 to 2 years (spawning) <1 year (migration) Overall temporal balance **= Negative**
Habitat Function Metric*	Spawning; Rearing (Mesohabitat Type by Area) Overwintering (Mesohabitat Type by Area and Quality) (Microhabitat Features)	Pederson (1998) classified Middle and Lower Edney Creek as having a cascade-pool morphology dominated by cobble substrates, with functioning LWD as the most prevalent aquatic cover type. Fish habitat value was rated as high.	Habitat functionality of Middle and Lower Edney Creek were assessed together. The habitat objectives for E2 was to create access and rearing habitat for juvenile salmonids including rainbow trout. Habitat parameters achieving quality ratings of good were: bankfull width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency (mean pool spacing), and holding pools (adult migration). Habitat parameters achieving quality ratings of fair were: LWD pieces per channel length and percent wood cover in pools (Golder 2017e). The habitat was not designed to prioritize spawning habitat and as such the substrate was more suitable for rearing but less so for spawning. Evaluation of habitat preferences and suitability criteria for the spawning / incubation life stage indicated the presence of some functional spawning habitat. Evaluation of habitat preferences and suitability criteria for the juvenile/rearing life stage indicated that habitat is suitable (relative to the reference site). However, dissolved oxygen was identified as being less suitable to Rainbow Trout. Additional cover (additional of large woody debris) could help moderate temperatures in the area (Golder 2017e). Current length of channel and channel configuration are different from prior to the event. Beaver activity near confluence had increased pool habitat (dynamic system; Golder 2017e).	Habitat function metrics in Lower Edney Creek was rated as high quality both pre-event and post-event Overall temporal balance = **Neutral**	1 to 2 years (spawning) 1 year (rearing and overwintering) Overall temporal balance **= Negative**

Sources: HKP 1997; Golder 2017e; Minnow 2007, 2009, 2016b, 2018a; Pederson 1998; SNC 2015a.

* Metric criteria for diagnostics of habitat function are outlined in reference Table 3, adapted from Johnston and Slaney 1996 Technical Circular.

5.3.1.4 Upper Hazeltine Creek (H1)

Rainbow Trout in Upper Hazeltine Creek (H1) is an important contributing population/stock to overall Rainbow Trout recreational fishery in Polley Lake (Lirette 2015).

In Upper Hazeltine Creek (H1), 44,650 m^2 of fair quality fish habitat was destroyed. The pre-event habitat was rated as fair due to well documented anthropogenic alteration of Reach 1, ponding associated with beaver dams in Reaches 1 and 2, reasonable rearing habitat, and poor spawning substrate (comprising mostly fines) in Reaches 1 and 2. Overall, Reach 3 was rated as high-quality habitat pre-event.

In the fall of 2015 and 2017, remediation work within Reaches 1, 2, and 3 resulted in the creation of 15,266 m^2 of high-quality habitat. In Reaches 1 and 2, habitat was improved from its pre-event state by the addition of spawning gravels, course woody debris, and enhancing the channel complexity. Remediation work on Reach 3, is not complete. The reconstructed habitat features in Reaches 1 and 2 were assessed and rated good for the following metrics: bankful-width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency, LWD pieces per channel length, percent wood cover, and spawning substrate. Reaches 3, 4 and 5 of upper Hazeltine Creek have not been remediated and are thus lacking many habitat features (e.g., spawning gravels, course woody debris; Table 15). The continued remediation of Upper Hazeltine Creek (H1) is expected to be completed during 2019.

Other indicators to suggest a recovering functional creek habitat for Rainbow Trout include preliminary spawner survey data showing 4,890 adult spawners using Reaches 1 and 2 in May 2018, and 40,250 YOY were estimated to be recruited to Polley Lake from Upper Hazeltine Creek (H1) in August 2018 (Minnow unpublished). Abundance (CPUA) for juvenile Rainbow Trout is similar pre-event (i.e., 258 to 612 CPUA in August 2007) and post-event (i.e., 310 to 640 CPUA in August 2018; Table 15). This data appears to indicate a level of recruitment that should support a stable Rainbow Trout population in Polley Lake.

A HEA was undertaken for Upper Hazeltine Creek (H1; Appendix D). The HEA calculation results in a negative balance of 53,314 m^2 units that require offsetting (Table 23). The current offsetting deficit will be adjusted as continued remediation in Upper Hazeltine Creek (H1) occurs and the remediated habitat is monitored and determined to be functioning. If there are residual productivity losses following remediation (i.e., due to time lags or changes in habitat area), additional offsetting options for Upper Hazeltine Creek (H1) are discussed in Section 5.4.1.

Determination**: Offsetting Required**

Table 15: Upper Hazeltine Creek (H1)

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	Spawning; Rearing; Overwintering; Migration	44,650 m^2 of total instream habitat was lost through scour and deposition of material (Reaches 1 to 5).	15,266 m^2 of total instream habitat was remediated. Reaches 1 to 3 have been remediated (approximately 3 km) - designed, constructed and monitored. The design has been approved for the remainder of Upper Hazeltine Creek (approximately 3 km).	Balance of -29,384 m^2 total instream habitat. Fish access to the remediated sections was restored in spring 2018. Overall spatial balance **= Negative**	(-) >4.5 years Overall temporal balance **= Negative**
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	Spawning; Migration	Rainbow Trout CPUE (# fish per minute) in Upper Hazeltine Creek in 2007 (21 to 28 August) in UHC-1 was **3.90**; in UHC-2 was **7.04**; and in UHC-3 was **3.64** (Minnow 2007).	There is no officially published post-event CPUE monitoring data available for Rainbow Trout in Upper Hazeltine Creek. Initial surveys of Upper Hazeltine Creek recorded 4,890 adult spawners using Reaches 1 and 2 of Upper Hazeltine Creek between 10 and 25 May 2018. Electrofishing stations in August 2018 suggest recruitment of 40,250 YOY to Polley Lake from Upper Hazeltine Reaches 1 and 2 combined (Minnow unpublished).	The different in Rainbow Trout CPUE in Upper Hazeltine Creek post-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years (spawning and migration) Overall temporal balance **= Negative**
Rainbow Trout Abundance (Catch Per Unit Area [CPUA])	Spawning; Migration	Rainbow Trout CPUA (# fish per 100 m^2) in Upper Hazeltine Creek in 1991 ranged from **188** to **554** (Bruce and Slaney 1991). Rainbow Trout CPUA (# fish per 100 m^2) in 2007 (21 to 28 August) in UHC-1 was **258**; in UHC-2 was **612**; and in UHC-3 was **467** (Minnow 2007).	Rainbow Trout CPUA (# fish per 100 m^2) in Upper Hazeltine Creek in August 2018 ranged from **310** to **640** (Minnow unpublished).	Rainbow Trout CPUA in Upper Hazeltine Creek is lower post-event (2018) compared to pre-event (1991 and 2007). Overall spatial balance **= Neutral**	(-) >4.5 years (spawning and migration) Overall temporal balance **= Negative**
Rainbow Trout Age Class Structure	Spawning; Migration	Rainbow Trout age class structure in Upper Hazeltine Creek in 1990 ranged from **YOY to Age 2** fish and in 2007 ranged from **YOY to Age 1** fish (Minnow 2007; SNC 2015a). In 1990, 99.4% of Rainbow Trout caught were YOY (Bruce and Slaney 1991). In 2007, 97% of Rainbow Trout caught were YOY (Minnow 2007; SNC 2015a).	There is no officially published post-event age class structure monitoring data available for Rainbow Trout in Upper Hazeltine Creek.	The different in Rainbow Trout age class structure in Upper Hazeltine Creek pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years (spawning and migration) Overall temporal balance **= Negative**

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Habitat Function Metric*	Spawning; Rearing (Mesohabitat Type by Area) Overwintering (Mesohabitat Type by Area and Quality) (Microhabitat Features)	The habitat for Upper Hazeltine Creek was described in 1991 by Bruce and Slaney (Reaches 3-5) and in 2006 by Minnow (Reaches 1-5). Habitat Parameters for Reach 1 of Upper Hazeltine Creek was described as a low gradient run habitat with gravel-sand substrate. Percent wood cover achieved a quality rating of good. Reach 1 habitat parameters with ratings of fair were: bankfull width-to-depth ratio, channel complexity, percent pool, and spawning substrate (Minnow 2007). Reach 2 of Upper Hazeltine Creek was described as a large ponded area associated with beaver activity. The area was roughly 210 m by 45 m and greater than 100 cm deep (Minnow 2007). Reach 2 habitat parameters that achieved quality ratings of good were: percent pool, holding pools, percent wood cover in pools. Reach 2 habitat parameters with ratings of fair were: channel complexity and spawning substrate. A comparison of composite probability-of-use values suggests that Hazeltine Creek contained a fair quantity of suitable rearing habitat for Rainbow Trout fry, but very little for yearling or older fish. Stream depth appears to be the main factor limiting habitat capability for older fish and may in part explain the exodus of yearling and older fish from the system (Bruce and Slaney 1991). Upper Hazeltine Creek provided important spawning habitat for Rainbow Trout from Polley Lake with adults migrating to spawn in the creek between early May and early June (SNC 2015a). Overall, Hazeltine Creek was dominated by shallow riffle/run mesohabitat with some limited pool habitat. Functional aquatic cover was provided mainly by LWD, overhanging vegetation, and pool depth. The proportion of functional aquatic cover, particularly deep pool habitat, was relatively low in Hazeltine Creek. As such, suitable overwintering habitat for sub-adult/adult salmonids was limited (SNC 2015a).	Habitat functionality of Reaches 1 and 2 of Upper Hazeltine Creek were assessed in 2016 (Golder 2017c). Habitat parameters that achieved quality ratings of good were: bankfull width-to-depth ratio, entrenchment ratio, channel complexity, percent pool (by area), pool frequency (mean pool spacing), LWD pieces per channel length, percent wood cover in pools, and spawning substrate size, quality and area (in Reach 2). Holding pools (adult migration) achieved a fair quality rating. Reach I was designed to emphasize juvenile rearing habitat and as such spawning substrate size, quality and area had a lower rating (Golder 2017c). However initial surveys indicate that spawning habitat structures are being used as designed (e.g., redds were observed in 2018; Connors 2018).	Habitat function metrics in Upper Hazeltine Creek pre-event in reaches 1, 2 and 3 were rated as poor, fair, and good respectively. Habitat function metrics in Upper Hazeltine Creek post-event in reaches 1, 2, and 3 were rated as good, good, and not remediated respectively. Overall temporal balance **Reach 1 = Positive** **Reach 2 = Positive** **Reach 3 = Negative**	(-) >4.5 years (spawning, rearing and overwintering) Overall temporal balance **= Negative**

Source: Bruce and Slaney 1991; Golder 2017c; Minnow 2007; Minnow unpublished; SNC 2015a.

* Metric criteria for diagnostics of habitat function are outlined in reference Table 1, adapted from Johnston and Slaney 1996 Technical Circular.

5.3.1.5 Lower Hazeltine Creek (H2)

In Lower Hazeltine Creek (H2), approximately 17,966 m^2 of high-quality spawning, rearing, overwintering, and migratory habitat was destroyed. Lower Hazeltine Creek is currently inaccessible to fish and has been temporarily converted into settling ponds, resulting in an ongoing spatial and temporal loss to fish productivity. Instream habitat remediation has not yet occurred (Table 16).

A HEA was undertaken for Lower Hazeltine Creek (H2; Appendix D). The HEA calculation results in a negative balance of 26,046 m^2 that require remediation and offsetting (Table 23). Once habitat remediation in Lower Hazeltine Creek (H2) is completed and the habitat has been monitored and determined to be functional the residual habitat offset deficit will be recalculated. Offsetting options for Lower Hazeltine Creek (H2) are discussed in Section 5.4.1.

Determination: **Offsetting Required**

Table 16: Lower Hazeltine Creek (H2)

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	S; R; O; M	17,966 m^2 of total instream habitat was destroyed.	0 m^2 of total instream habitat was remediated. Remediation of H2 is currently in the design process. H2 is currently two settling ponds.	Balance of -17,966 m^2 total instream habitat. Overall spatial balance **= Negative**	(-) >4.5 years Overall spatial balance **= Negative**
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	S	Rainbow Trout CPUE (# fish per minute) in Lower Hazeltine Creek in 2007 (21 to 28 August) in LHC-1 was **0.83**; in LHC-2 was **0.55**; and in LHC-3 was **0.56** (Minnow 2007; SNC 2015a).	No remediation has occurred post-event. There is no post-event CPUE monitoring data available for Rainbow Trout in Lower Hazeltine Creek.	The different in Rainbow Trout CPUE in Lower Hazeltine Creek pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years Overall temporal balance **= Negative**
Rainbow Trout Age Class Structure	S	There is no available pre-event Rainbow Trout age class structure data for Lower Hazeltine Creek.	No remediation has occurred post-event. There is no post-event age class structure data for Rainbow Trout in Lower Hazeltine Creek.	The different in Rainbow Trout age class structure in Lower Hazeltine Creek pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years Overall temporal balance **= Negative**
Habitat Function Metric*	R; O (Mesohabitat Type by Area and Quality) (Microhabitat Features)	A comparison of composite probability-of-use values suggests that Hazeltine Creek contains a fair quantity of suitable rearing habitat for Rainbow Trout fry, but very little for yearling or older fish. Stream depth appears to be the main factor limiting habitat capability for older fish and may in part explain the exodus of yearling and older fish from the system (Bruce and Slaney 1991). Pederson (1998) described Lower Hazeltine Creek as meandering through a small floodplain characterized by riffle pool habitat containing some debris and cobble. The riparian areas experienced harvesting from forestry into the riparian areas. Overall fish habitat value was rated as high.	No remediation has occurred post-event. There is no post-event mesohabitat or microhabitat data for Lower Hazeltine Creek.	Habitat function metrics in Lower Hazeltine Creek was rated as high-quality pre-event. Lower Hazeltine Creek temporarily unavailable as habitat for Rainbow Trout. Overall temporal balance = **Negative**	(-) >4.5 years Overall temporal balance **= Negative**

Sources: Bruce and Slaney 1991; Minnow 2007; SNC 2015a.

5.3.1.6 Polley Lake

Other than lakeshore habitat (Riparian) alteration, no permanent physical habitat loss occurred in Polley Lake during the event. A habitat disruption occurred; however, the overall area of Polley Lake remained the same during the event. Habitat alterations to Polley Lake caused by the event included depth changes where shallower shoals were created and the deposition of woody debris occurred. These alterations may serve to increase spring and fall fish habitat (i.e., by providing cover and other beneficial attributes for fish), while reducing available summer habitat (i.e., deeper water). The benthic invertebrate community was smothered in part of the lake through smothering with sediment; however, the benthic invertebrate community is naturally regenerating (Golder 2017c). Elevated copper levels in Polley Lake water were recorded post-event; however, the levels were chemically similar to natural conditions (Minnow 2015). The event caused a spatial and temporal loss to Rainbow Trout productivity due to the blockage of adults from Polley Lake unable to spawn in Upper Hazeltine Creek (H1; Table 17). This resulted in the disruption of the age class structure of Rainbow Trout as juveniles from Hazeltine Creek did not enter Polley Lake for over 4 years (Table 17). Polley Lake was stocked in the fall of 2018 to help address the age class structure of Rainbow Trout and to account for potential mortality of adults entering the Upper Hazeltine Creek (H1). Considering the high abundance, re-stabilizing age class structure and good condition factor of Rainbow Trout and the recovering benthic invertebrate community the productivity of Polley Lake may not require additional offsetting.

Additional monitoring will be necessary to verify that effects on productivity of Rainbow Trout have been addressed, in particular age class structure is identified as productivity indicator by the HRWG (Table 10). Data on measures to address age class structure will be collected and these data will inform the need for offsets. Offsets are therefore to be determined for Polley Lake.

Determination**: To be determined (TBD)**

Table 17: Polley Lake

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Rainbow Trout Abundance (Catch Per Unit Effort [CPUE])	S; R; O; M	Rainbow Trout CPUE (# fish per square foot per hour) in 1973 was **0.0008**, in 1995 was **0.0006**, and in 2012 was **0.0006** (Lirette 2017; Minnow 2018b; SNC 2015a). Survey method was seine netting for the 1973, 1995 and 2012 surveys.	Rainbow Trout CPUE (# fish per square foot per hour) was very similar in September 2014 (**0.0028**) and September 2016 (**0.0036**), and higher than previously documented in 1973, 1995, and 2012 (Lirette 2017; Minnow 2018b). Survey method was overnight gillnet sets.	Rainbow Trout CPUE was higher post-event (**0.0028** and **0.0036** in September 2014 and 2016 respectively), compared to pre-event data (1973, 1995, and 2012; Lirette 2017; Minnow 2018b; SNC 2015a). However, the survey methods used were different pre- and post-event, so it cannot be conclusively determined that the increase in CPUE is related to an actual increase in Rainbow Trout abundance. Overall spatial balance **= Neutral**	(-) >4.5 years (spawning and migration) (-) <1 year (rearing and overwintering) Overall temporal balance **= Negative**
Rainbow Trout Abundance (Population Estimate)	S; R; O; M	Bruce and Slaney (1991) estimated in August 1991 that approximately **54,500** Rainbow Trout fry and parr migrate to Polley Lake from Hazeltine Creek after hatching (SNC 2015a).	In 2016, the Rainbow Trout population was estimated as **42,388** in the **spring** and **21,635** in the **fall**. It is likely that the fall estimate is lower than the actual Rainbow Trout population size (Minnow 2017a).	There is a decrease in Rainbow Trout population in Polley Lake post-event. Overall spatial balance **= Negative**	(-) >4.5 years (spawning and migration) (-) <1 year (rearing and overwintering) Overall temporal balance **= Negative**
Rainbow Trout Age Class Structure	S	Rainbow Trout age class structure have been collected before and after the event (1990 to 2014). Age range of Rainbow Trout in 1990 was **Ages 2 to 6** fish; in 1995 was **Ages 3 to 4** fish; in 2009 was **Ages 3 to 6** fish; and in 2014 was **Ages 1 to 6** fish (SNC 2015a).	There was 3 years of blockage of the Upper Hazeltine Creek for adult passage to spawn; therefore, it was 3 years when no new juveniles were entering Polley Lake. Overall juvenile numbers in the lake declined in this timeframe. This affected age class structure in the lake. Fewer **Ages 1 and 2** fish were captured in 2016 than in 2014 (Minnow 2017a). In 2017, **Ages 1 to 3+** fish were absent from Polley Lake, confirming the limited recruitment associated with no access to Hazeltine Creek for spawning and rearing (Minnow 2018b).	A brood stock of Rainbow Trout was collected and put into a hatchery established on the Mount Polley site in 2014. Approximately 15,000 juveniles from the hatchery were released into Polley Lake in fall 2018 to help readdress the age class structure. Age class structure of the Rainbow Trout population in Polley Lake was less diverse post-event (i.e., 2016 and 2017). Overall spatial balance **= Negative**	(-) >4.5 years (spawning and migration) (-) <1 year (rearing and overwintering) Overall temporal balance **= Negative**
Rainbow Trout Condition Factor	R	Rainbow Trout condition factor (weight/length) was collected between 1973 and 2014. Mean condition of Rainbow Trout in 1973 was **1.341**; in 1995 was **1.253**; in 2012 was **0.993**; in 2007 was **1.06**; and in 2014 was **1.103** (Minnow 2007; SNC 2015a).	Examination of 2016 data relative to 2014 indicated that females were lighter at length, males were not significantly different, and immatures were heavier and longer than those measured in 2014 (Minnow 2017a). In 2017, there appeared to be a general shift towards longer and heavier fish, particularly for female Rainbow Trout, indicative of a demographic shift to older, larger fish (Minnow 2018b).	The condition factor of Rainbow Trout population in Polley Lake is increasing. This is most likely reflective of a shift in the age-class structure instead of being reflective of a positive change in the health of the population. Because of this uncertainty, the positive change in condition factor indicator is not applicable. Overall spatial balance **= Neutral**	(-) <1 year Overall temporal balance **= N/A**

Sources: Lirette 2017; Minnow 2007, 2016b, 2017a, 2017b, 2018b; SNC 2015a.

5.3.1.7 Quesnel Lake – Limnetic Zone

No permanent physical alteration occurred in the limnetic zone of Quesnel Lake during the event. The event likely caused an unquantifiable temporary disturbance to fish communities during the event, resulting in a temporal loss of fish productivity (Table 18).

Other indicators on habitat function include limnetic fish relative abundance and condition factor (Table 18). The event introduced a large volume of fines into the water column. Monitoring data suggests a benefit to fish in the limnetic zone as measured both by abundance and condition factor. The fines released into Quesnel Lake contained nutrients and may have acted as fertilizer in the West Arm. With the addition of these nutrients, zooplankton bloomed, providing more forage for fish communities. Abundance (CPUE) was higher in exposed areas (the West Arm) of Quesnel Lake compared to reference areas. Juvenile Sockeye collected in the West Arm were larger than those caught in reference areas of the lake (DFO, unpublished data).

Laboratory testing of water suggested that the changes in water quality from the event is unlikely to present hazards to aquatic life.

There are no quantifiable negative effects to Quesnel Lake - Limnetic Zone, and there appears to have been a temporary increase in fish abundance and condition. No further offsetting is proposed.

Determination**: No Offsetting**

Table 18: Quesnel Lake - Limnetic Zone

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Limnetic Zone Fish Relative Abundance (CPUE)	R	There is no pre-event data available on relative abundance of limnetic zone fish.	Hoop-net monitoring was conducted in 2015 to 2017. Similar fish communities were observed at the West Arm and in other parts of the lake east of Cariboo Island. Eight fish species were captured from both exposed and reference areas in Quesnel Lake (Minnow 2016b). CPUE (# fish per hour) was higher at exposed areas (calculated by Golder based on Minnow 2016b data).	The difference in limnetic zone Rainbow Trout abundance pre-event and post-event cannot be determined. Comparing post-event relative abundance of limnetic zone Rainbow Trout from reference areas to the West Arm shows CPUE was higher in the West Arm in 2016 (calculated by Golder based on Minnow 2016b data). Overall spatial balance = **Neutral**	(-) < 1 year Overall temporal balance **= Neutral**
Limnetic Zone Fish Condition Factor	R	There is no pre-event data available on condition factor of limnetic zone fish.	Juvenile Sockeye collected from the West Arm west of Cariboo Island in 2014 were notably larger than those collected from reference areas in other parts of the lake east of Cariboo Island (Golder 2015c). Acute lethality (96 h) and 7-d survival and growth testing indicated that water collected from Quesnel Lake, during September and November 2014, was not acutely lethal for Rainbow Trout and survival and growth of Fathead Minnow was not affected (Golder 2017c)	The difference in limnetic zone fish condition factor pre-event and post-event cannot be determined. Comparing post-event condition factors of limnetic zone fish from reference areas to the West Arm shows condition factor for juvenile Sockeye Salmon was higher in the West Arm in 2014. In 2015, condition factor was similar across all regions of the lake (Golder 2017c). Overall spatial balance **= Neutral**	(-) <1 year Overall temporal balance **= Negative**
Turbidity	R	Between May 1995 and July 2014, the mean, minimal, and maximum turbidity (NTU) were 1.3, 0.35 and 4.8 respectively (MPMC 2014b).	By mid-November 2014, measurements of temperature, turbidity and specific conductivity were uniform throughout most of the water column. Turbidity at depth decreased to less than 10 NTU, which corresponded with an increase in turbidity in surface waters. This relatively small change in turbidity at the surface compared to deeper waters resulted in a cloudy appearance within the West Basin of the lake throughout the late fall and winter. By early spring (March and April 2015), turbidity at surface and depth decreased and was below 24-h (9 NTU) and 30-d (3 NTU) BC aquatic life WQGs. (Golder 2015a). In 2014, Juvenile Sockeye did not appear to move out of the West Arm to avoid turbidity. Effects to limnetic fish foraging efficiency did not appear to have occurred (Golder 2015c).	Water chemistry shows that turbidity and total metals concentrations in the limnetic zone of the West Arm are unlikely to present hazards to aquatic life (Golder 2017c). Overall spatial balance = **Neutral**	(-) <1 year Overall temporal balance **= Negative**
Phytoplankton and Zooplankton Biomass	R	There is pre-event zooplankton abundance and biomass data presented in Hume et al. (2005) and MacLellan et al. (1993); however, due differences in resolution of taxonomic identification and units, these data cannot be compared to post-event data (Golder 2015c).	Chlorophyll *a* assessments were undertaken annually between 2014 and 2017, and results indicate that there is no discernable difference in biomass (chlorophyll *a*) in the West Arm relative to the east of Cariboo Island (i.e., the reference site; Golder 2017c), and chlorophyll *a* concentrations were within the range of historical values (Golder 2017c). There is no discernable difference in total zooplankton biomass or abundance, or in the relative biomass or abundance of dominant taxa, relative to the reference (Golder 2017c). Water from Quesnel Lake was not acutely lethal for *Daphnia* and survival of *Ceriodaphnia* was not impaired lab tests from post-event water samples (Golder 2017c).	The differences in phytoplankton and zooplankton biomass in the limnetic zone pre-event and post-event cannot be determined. Comparing post-event data from the West Arm to reference areas shows that no changes in phytoplankton and zooplankton biomass were observed in the limnetic zone (Golder 2017c). Overall spatial balance = **Neutral**	(-) <1 year Overall temporal balance **= Neutral**

Sources: Golder 2015a, 2015c, 2017c; Minnow 2016b; MPMC 2014b; SNC 2015a.

5.3.1.8 Quesnel Lake – Littoral Zone

In the littoral zone of Quesnel Lake, approximately 94,394 m^2 of rearing, spawning, and migratory habitat was permanently altered through the smothering of sediment from the event. Approximately 6,350 m^2 has been remediated, so there is currently a spatial loss of shoreline habitat. The event also caused a temporal loss to fish productivity as previous habitat was altered for approximately 4.5 years (Table-19). Additional monitoring information is required to evaluate the functionality of the remediated littoral habitat.

Determination**: TBD**

Table-19: Quesnel Lake - Littoral Zone

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	R; S; M	94,394 m^2 of littoral area was affected (SNC 2015a).	6,350 m^2 of total shoreline habitat was remediated. This includes the areas of remediated habitat at the mouth of Edney Creek and the gravel shoals created along the shoreline.	Balance of -88,044 m^2 total instream habitat. Overall spatial balance **= Negative**	(-) >4.5 years Overall temporal balance **= Negative**
Littoral Zone Fish Relative Abundance	R	There is no pre-event data available on littoral fish abundance.	The actual contribution of the affected area of littoral zone to fish productivity is not known; however, the available data suggest that the decrease in benthic invertebrate prey items have not resulted in a decrease in condition factor of forage fish, Lake Trout, or Burbot captured in the littoral zone (Golder 2018c). Similar fish communities observed at effluent-exposed and reference areas. Eight different fish species were captured from both exposed and reference areas in Quesnel Lake (Minnow 2016b). CPUE was higher in exposed areas (calculated by Golder based on Minnow 2016b data).	The different in littoral zone fish abundance pre-event and post-event cannot be determined. Comparing post-event fish abundance of littoral zone fish from reference areas to the West Arm shows similar fish communities with higher CPUE were observed Overall spatial balance **= Neutral**	(-) >4.5 years Overall temporal balance **= Negative**
Littoral Zone Fish Condition Factor	R	There is no pre-event data available on littoral zone fish condition factor.	Mean condition factors were similar both across years and regions for sentinel fish and the data do not suggest a difference in body condition for sentinel fish residing in the West Basin compared to those in the reference areas (Golder 2017c).	The different in littoral zone fish condition factor pre-event and post-event cannot be determined. Comparing post-event fish condition factors of littoral zone fish from reference areas to the West Arm shows similar fish conditions were observed Overall spatial balance **= Neutral**	(-) >4.5 years Overall temporal balance **= Negative**
Littoral Habitat Quality	R	In 2012, 51% of littoral habitat of Quesnel Lake was ranked as “Very High” and “High”; 48% was ranked “moderate; and 2% was ranked “Low” and “Very Low” (SNC 2015a). The shoreline next to Hazeltine Creek Mouth was ranked “Very High” (SNC 2015a). 15% of “Very High” ranked juvenile fish habitat at the mouth of Hazeltine Creek was permanently altered (SNC 2015a).	Natural recovery is in progress.	The different in littoral habitat area pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years Overall temporal balance **= Negative**
Potential Shoreline Spawning Habitat Area	S	2 km of shoreline was affected by the event. Approximately 1.2 km of shoreline near the mouth of Hazeltine Creek was rated “Very High”, and the remainder was rated “High” (SNC 2015a).	The shoreline design at the mouth of Edney Creek incorporates shallow gravel shoal habitat that is accessible to fish under a wide range of lake levels (Golder 2018c).	Most of the potential shoreline spawning habitat area has not been remediated. Overall spatial balance **= Negative**	(-) >4.5 years Overall temporal balance **= Negative**
Habitat Features by Area	R	In 2012, the littoral habitat of Quesnel Lake comprised: gravel beach (49%); rocky shore (35%), and 36% had aquatic vegetation (SNC 2015a).	There is no post-event habitat features data available for the littoral zone of Quesnel Lake.	The different in habitat features pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years Overall temporal balance **= Negative**
Submergent and Emergent Vegetation by Area	R	In 2012, 36% of the shoreline area of Quesnel Lake had aquatic vegetation, predominantly emergent vegetation (SNC 2015a).	There is no official monitoring data available.	The different in submerged and emergent vegetation pre-event and post-event cannot be determined. Overall spatial balance = **Unable to determine due to the absence of post-event data; this indicator has not been used in determination of residual effects.**	(-) >4.5 years Overall temporal balance **= Negative**
Benthic Invertebrate Relative Abundance and Diversity	R	In 2007, the depositional benthic invertebrate community at the mouth of Hazeltine Creek at Quesnel Lake had a density of 21,000 organisms per m^2 and a richness of 30 taxa, comprised of chironomids (midges; 26.5%), ostracods (seed shrimp; 14.5%), and oligochaetes (aquatic worms; 10.4% (Minnow 2007).	The 2014, 2015, and 2016 data indicated that far-field littoral areas did not show reductions in density or diversity. However, the near-field littoral areas exhibited statistically significant reductions in mean density and diversity, and recovery was not yet evident in 2016 (Minnow 2015, 2016a, 2018b). The 2017 data are not directly comparable to the data collected earlier because the methods used were changed (Minnow 2018c).	Benthic invertebrate abundance and diversity is still recovering to pre-event levels. Overall spatial balance **= Negative**	(-) >4.5 years Overall temporal balance **= Negative**

Sources: Golder 2017c, 2018c; Minnow 2015, 2016b, 2018c; SNC 2015a.

5.3.1.9 Quesnel Lake – Benthic Zone

In the benthic zone of Quesnel Lake, about 1.8 km^2 of benthic habitat was altered with the smothering of tailings. No anthropogenic remediation work has been conducted in the Quesnel Lake benthic zone, resulting in a spatial and temporal loss (Table 20). Natural recolonization has been occurring over the last 4.5 years.

There is limited data to compare benthic fish abundance or condition factor pre and post-event. Preliminary benthic invertebrate monitoring suggests the recovery process is starting, but density and diversity are still significantly lower post-event compared to pre-event (Table 20).

A HEA has not been undertaken for Quesnel Lake – Benthic Zone. However, impacts did occur, and the approach will be to provide out-of-kind offsets. Offsetting options for Quesnel Lake - Benthic Zone are discussed in Section 5.4.2.

Determination**: Offsetting Required**

Table 20: Quesnel Lake - Benthic Zone

Indicator	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Area	R	The area of breach-related infill within the estimated depositional zone is approximately 1.8 km^2 (Tetra Tech 2015b).	0 m^2 of total benthic habitat was remediated. Potential remediation options are discussed in Section 4.11.3; MNR was selected as the preferred option.	Overall spatial balance **= TBD**	(-) >1 year Overall temporal balance **= TBD**
Total Benthic Area Smothered	R	The deposition of material initially caused a reduction in the benthic invertebrate community (e.g., a reduction in food organisms for fish) which, based on more current data appears to be recovering (Figure 22; Minnow 2015, 2016b, 2017c).	Preliminary data suggests natural recovery of the benthic community is in progress (Figure 22; Minnow 2015, 2016b, 2017c).	The density of benthic invertebrates in the Quesnel Lake – Benthic Zone is lower than pre-event. Overall spatial balance **= Negative**	(-) >1 year Overall temporal balance **= Negative**
Benthic Zone Fish Relative Abundance	R	Based on the available information, relatively little is known about the specific distribution of fish species within Quesnel Lake, particularly benthic and pelagic, non-salmonid species (SNC 2015a).	Fish have been observed in the profundal zone of the West Basin during a remote operated vehicle (ROV) inspection of the outfall in 2018.	The different in benthic fish relative abundance pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of both pre-event and post-event data; this indicator has not been used in determination of residual effects.**	(-) >1 year Overall temporal balance **= Negative**
Benthic Zone Fish Condition Factor	R	There is no pre-event benthic zone fish condition factor data available.	There is no post-event benthic zone fish condition factor data available.	The different in benthic fish condition factor pre-event and post-event cannot be determined. Overall spatial balance **= Unable to determine due to the absence of pre-event data; this indicator has not been used in determination of residual effects.**	(-) >1 year Overall temporal balance **= Negative**
Benthic Invertebrate Relative Abundance and Diversity	R	There is limited data on the abundance and diversity of the benthic invertebrate community pre-event. In 2007, the mean density (organisms per m^2) was approximately 31,000, the number of taxa was approximately 30 (Minnow 2007).	Early sampling indicates some recovery, but additional benthic sampling will be necessary to determine the current status of the benthic community and its current trajectory to recover.	Benthic invertebrate relative abundance and diversity post-event is lower compared to pre-event conditions. Overall spatial balance **= Negative**	TBD Overall temporal balance **= Negative**

Sources: Golder 2017c; Minnow 2015, 2016a, 2016b, 2017b; Tetra Tech 2015b.

5.3.1.10 Quesnel River

No permanent physical alteration of habitat occurred in Quesnel River and benthic invertebrate abundance and diversity were similar in Quesnel River and reference stations. As there was no significant physical alteration of habitat in Quesnel River and no measurable residual effects, no offsetting is proposed.

Determination: **No Offsetting**

Table 21: Quesnel River

Metric	Habitat Function	Pre-Event Data	Post Event Data	Spatial Balance	Temporal Balance
Turbidity	S; R; O; M	No permanent physical alteration of habitat has occurred in the Quesnel River (SNC 2015a). The available evidence indicates a low magnitude of risk comparable to reference conditions: ■ Plankton - No significant reductions in chronic water algal growth tests or vascular plant growth toxicity tests on field-collected water samples. No chronic toxicity to cladocerans in representative non-turbid waters. ■ Benthic Invertebrates - Benthic invertebrate samples collected from Quesnel River and the corresponding reference area in Cariboo River had concentrations of COPCs similar to reference conditions. ■ Fish – Significant effects were not observed for fish toxicity tests including 7-d Rainbow Trout survival and growth, 30-d Rainbow Trout survival and development, and 7-d Fathead Minnow survival and growth toxicity tests on field collected water samples.	Monitoring results of Quesnel River conducted in 2014, 2015, 2016, and 2017 show no indications of further effects post-event (Golder 2017c).	Turbidity of Quesnel River pre-event and post-event are comparable (Golder 2017c). Overall spatial balance **= Neutral**	(-) <1 year Overall temporal balance **= Negative**

Sources: Golder 2015d, 2017c; SNC 2015a.

5.3.1.11 Riparian Habitat

Riparian areas are important fish habitat because they link terrestrial and aquatic ecosystems and provide ecological functions such as improving water quality, providing bank stability, contributing organic matter (e.g., leaf litter and large woody debris) to waterbodies, and providing habitat complexity.

For the purposes of quantifying riparian area losses, we have defined the riparian zone as the Riparian Management Zone as described in Part 4 of the Forest Planning and Practices Regulation under the *Forest and Range Practices Act*.

SNC (2015a) estimated that the event altered 737,464 m^2 of riparian habitat along Hazeltine and Edney Creek. Altered riparian habitat for Polley Lake and Quesnel Lake - Riparian Zone were estimated using the application of a 10 m Riparian Reserve Zone to the affected area. In total, 765,574 m^2 of riparian habitat are estimated to be altered by the event. A breakdown of the riparian habitat altered by EU, and riparian habitat replanted to-date by EU, is provided in Table 23. The estimated area of replanted riparian habitat (i.e., 285,689 m^2) was calculated based on the assumptions in Section 5.3.12.1. An estimated 479,885 m^2 of riparian habitat still requires replanting.

To-date, riparian planting consists of staking live wattles of willow and planting black cottonwood, prickly rose, black twinberry, red osier dogwood, sitka alder, and coniferous trees species. In addition, riparian areas have been seeded using a locally sources multispecies seed blend.

Table 22: Riparian Habitat

Ecological Unit	Altered Riparian Habitat (m^2)	Remediated Riparian Habitat (m^2)	Spatial Balance (m^2)
Edney Creek	20,215	26,771	+6,556 Overall spatial balance **= Gain**
Upper Hazeltine Creek (H1)	530,094[2]	265,047	-265,047 Overall spatial balance **= Negative**
Lower Hazeltine Creek (H2)	187,155[2]	0	-187,155 Overall spatial balance **= Negative**
Polley Lake	7,300[3]	7,300	0 Overall spatial balance **= Neutral**
Quesnel Lake - Littoral Zone	20,810[4]	0	-20,810 Overall spatial balance **= Negative**
Total	**765,574**	**285,689**	**-479,885**

[1]Based on Edney Creek being in Riparian Class S3, with a Riparian Management Area width of 40 m (Section 47 (1) of the Forest Planning and Practices Regulation, SNC 2015a). Altered riparian habitat estimate based on SNC (2015a).

[2]Based on Hazeltine Creek being in Riparian Classes S2, S3 and L1-B (reach-dependent), with a Riparian Management Area width of 40 m (S2), 50 m (S3), and 70 m (L1-B) (Section 47 (1) of the Forest Planning and Practices Regulation; SNC 2015a). Altered riparian habitat estimate based on SNC (2015a).

[3]Based on Polley Lake being in Riparian Class L1-B, with a Riparian Reserve Zone width of 10 m (Section 49 (1) of the Forest Planning and Practices Regulation).

[4]Quesnel Lake is in Riparian Class L1-A (i.e., lakes greater than 1,000 ha). Lakes of Riparian Class L1-A have a Riparian Reserve Zone of 0 m; however, to be conservative, a 10 m width was applied to Quesnel Lake (Section 49 (1) of the Forest Planning and Practices Regulation).

A HEA was undertaken for riparian habitat and results in a current negative balance of 774,069 m^2 that require offsetting Table 23. The current riparian habitat offset balance will need to be adjusted as ongoing habitat remediation continues to restore areas of riparian habitat. Riparian remediation will be ongoing through remediation of the remaining sections of the aquatic EUs.

Offsetting is required to compensate for the temporal loss of functional riparian fish habitat between the date of the event, and the time it will take for riparian habitat to reach a state similar to pre-event conditions, which Mallik et al. (2011) estimates to be approximately 18 years. Offsetting options for riparian habitat are discussed in Section 5.4.3.

Determination**: Offsetting Required**

5.3.1.12 Offsetting for Aquatic and Riparian Habitat - Habitat Equivalency Analysis

HEA is a means to determine the amount of compensatory restoration required to provide services that are equivalent to the interim loss of natural resource services following an “injury” (Kohler and Dodge 2006). Further background on HEA is provided in Section 4.2.4 and for convenience a brief summary is provided here.

HEA is used to determine the nature and degree to which a restoration project might provide adequate replacement for an injured resource. HEA uses a discounting algorithm to value a natural resource asset which is equal to all future services of that asset after degradation due to injury. The formula to calculate the level of ecological services gained and lost is a percent increase from a baseline level for each year of assessed losses and potential gains are added for the duration of years loss over the compensatory action period. A discount rate is applied each year to actualize the losses or gains as a percentage rate and per time services provided sooner are more highly valued that those provided later. These calculations were made using the software Visual_HEA (Kohler and Dodge 2006, Pioch et al. 2017).

A formal HEA assessment was conducted on EUs: Middle Edney Creek, Upper Hazeltine Creek, Lower Hazeltine Creek. HEA was conducted on these EUs due to insufficient data for pre- and / or post-event fish abundance (CPUE) and / or fish age class structure data for the injured sites. HEA was not conducted on Polley Lake, Quesnel Lake - Benthic Zone, and Quesnel Lake - Littoral Zone yet, due to the nature of the EUs as described in Sections 5.3.1.6, 5.3.1.8 and 5.3.1.9, respectively. The results of the HEA for each EU are presented in Table 23. EU-specific assumptions used to determine the input parameters are described in Table 24.

Table 23: Summary of Habitat Equivalency Analysis Results

Ecological Unit (EU)	Area (m^2)			
	Impacted	Calculated HEA Units Required for Offsetting	Remediated (to date)	Remaining for Remediation or Offsetting (to date)
Polley Lake	TBD	TBD	TBD	TBD See Section 5.3.1.6
Upper Hazeltine Creek	44,650	53,314	15,266	38,048
Lower Hazeltine Creek	17,966	26,046	0	26,046
Middle Edney Creek	1,350	1,499	1,553	0
Quesnel Lake – Littoral Zone	94,394	TBD	6,350	TBD See Section 5.3.1.8
Quesnel Lake – Benthic Zone	1,800,000	TBD	TBD	TBD See Section 5.3.1.9
Riparian Areas	765,372	1,059,767	285,698	774,069

Note: Habitat remediation remains underway in a number of EU. Additional habitat credits are expected to result when that habitat has been constructed (e.g., Reach 3 of Hazeltine Creek).

5.3.1.13 HEA Calculation (Long Term Commitments)

This Remediation Plan sets out the proposed components to be used in the calculation of habitat offsets. The time loss functions are based on estimates obtained from the literature which will have uncertainty associated with those estimates. Attainment of the offsets "owing" will be verified as part of habitat verification monitoring (see Figure 8) and it is expected that parameters used in the HEA calculations may be adjusted based on the findings of that monitoring. This could also result in adjustments to the amount of offsets. The HRWG provides a suitable forum for oversight of the delivery of sufficient habitat offset amounts and while the group is intended as a collaborative group, representatives of the HRWG include those with regulatory authority for such oversight. The RP sets out the initial amounts of habitat owing and provides a mechanism whereby accounting for offsets remains part of MPMC's long term commitments.

The continuum of monitoring, assessment and recalculation of offsets "owing" provides a direct measurement and accounting for uncertainty in the success of habitat offset projects.

Table 24: Habitat Equivalency Assessment (HEA) Per Site Using Assumptions for Natural Recovery Detailing the Parameters Used and Assumptions

Site	Injured Area (m^2)	Pre-Injury (Base-line) Service Level (%)	Pre-Restoration Service Level (%)	Time for 100% Natural Baseline Recovery	Natural Recovery Level (%)	Time for Baseline to Return from Restorations (years)	Size of Compensatory Replacement Habitat (m^2)	Area Remediated (m^2)	Remaining Area for Remediation or Offsetting (m^2)	Assumptions
Polley Lake	TBD	100	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD See Section 5.3.1.6
Upper Hazeltine Creek	44,650	100	0	Infinite (will never reach natural baseline services without restoration Service)	0	7	53,314	15,266	38,048	Restoration of physical construction was completed in 2017. For Reaches 1 and 2, remediation construction restored access and in-stream habitat function in 2017. Fish utilization occurred starting in 2018: four years post-event. For Reaches 1 and 2, after remediation activities, in-channel habitat features achieved a quality rating of "good" based on Table 1 habitat function metrics. This is as good, if not better, than the habitat was pre-event. Full recovery of Reaches 1 and 2 is anticipated six years post-event due to benthic invertebrate community recovery and unknown variables. This accounts for four years of blocked access and two years for recovery. Density of juvenile Rainbow Trout and YOY production is roughly equal pre- and post-event suggesting food supply is available and the benthic invertebrate community is recovering. For Reach 3, it is anticipated that remediation construction will restore access and in-stream habitat function in 2019. Fish utilization is expected to occur starting in 2020: six years post-event. For Reach 3, after remediation activities, it is anticipated that in-channel habitat features will achieve a quality rating of "good" based on Table 1 habitat function metrics. Full recovery of Reach 3 is anticipated eight years post-event due to benthic invertebrate community recovery and unknown variables. This comes from six years of blocked access and two years for recovery. Times for recovery for Reaches 1 and 2 and Reach 3 are averaged together. This results in a value of seven years used.
Lower Hazeltine Creek	17,966	100	0	Infinite	0	10	26,046	0	26,046	Post-event service levels provided by the habitat were rated at 0%. For Lower Hazeltine Creek, it is anticipated that remediation construction will restore access and in-stream habitat function in 2020. Fish utilization is anticipated to occur in 2021: seven years post-event. Full recovery of Lower Hazeltine Creek is anticipated 10 years post-event due to benthic invertebrate community recovery and unknown variables. This account for six years of blocked access and 4 years for recovery.
Middle Edney Creek	1,350	100	50	Infinite	0	3	1,499	1,5532	0	Productivity of Middle Edney Creek post-event is assumed to be 50%, as the channel was altered (i.e., not destroyed). The physical construction was completed in less than one year. Access to Middle Edney Creek was restored in less than one year, assuming no spawning productivity was lost. After two years of remediation activities, in-channel habitat features achieved a quality rating of "good" based on Table 1 habitat function metrics. A full recovery of in-stream habitat function will take three years. Abundance (CPUE) numbers pre-event and post-event is roughly equal, suggesting food supply is available for Rainbow Trout and the benthic invertebrate community is recovering. and some habitat features remained.
Quesnel Lake – Littoral Zone	94,394	100	0	Infinite	NA	5	TBD	6,350	TBD	TBD See Section 5.3.1.8

Site	Injured Area (m^2)	Pre-Injury (Base-line) Service Level (%)	Pre-Restoration Service Level (%)	Time for 100% Natural Baseline Recovery	Natural Recovery Level (%)	Time for Baseline to Return from Restorations (years)	Size of Compensatory Replacement Habitat (m^2)	Area Remediated (m^2)	Remaining Area for Remediation or Offsetting (m^2)	Assumptions
Quesnel Lake – Benthic Zone	1,800,000	100	0	Infinite	0	5	TBD	1,800,000	TBD	TBD See Section 5.3.1.9
Riparian	765,372	100	0	Infinite	0	18	1,059,767	285,698	774,069	For riparian areas, some remediation activities began in 2015 with planting and some are ongoing. An assumed average value of remediation occurring three years post-event is used for the HEA calculation. For riparian areas, it is anticipated that natural recovery would restore habitat function in 20 years. The riparian area for Hazeltine and Edney Creeks estimated by SNC (2015a) and the riparian area estimated by the HHWG for Polley Lake and Quesnel Lake littoral zone do not overlap. Riparian habitat in Upper Edney Creek (E1) and Quesnel River were not affected by the event (HRWG 2015). Riparian habitat was altered in the following EUs: Middle Edney Creek (E2); Lower Edney Creek (E3); Upper Hazeltine Creek (H1); Lower Hazeltine Creek (H2); Polley Lake; and Quesnel Lake - Littoral Zone (SNC 2015a; HRWG 2015). There is no riparian habitat in the following EUs: Quesnel Lake – Benthic Zone; and Quesnel Lake – Limnetic Zone. Riparian habitat in Middle Edney Creek (E2) and Quesnel Lake - Littoral Zone has not been replanted (Table 6). Riparian habitat in Lower Edney Creek (E3) has been replanted (Table 6). 50% of Upper Hazeltine Creek (H1) riparian habitat has been replanted (approximately 3 km); leaving 50% (approximately 3 km) yet to be replanted. Riparian habitat in Reach 5 of Lower Hazeltine Creek (H2) has been partially planted and seeded (Table 6); however, the majority of H2 has not been replanted; therefore, this area is considered 0% revegetated. The revegetated riparian habitat completed at Polly Flats includes all the affected riparian at Polly Lake (Table 6).

Note: Reach 4 (Hazeltine Canyon) was not included in the HEA calculations because that section is not accessible to fish, and was not accessible pre-breach.

5.3.2 Upland Terrestrial Habitat

Areas of upland terrestrial habitat affected by the event occur in the Interior Cedar Hemlock (ICH) BEC zone. Site series within affected areas include the Quesnel Wet Cool (ICH wk2) and Horsefly Moist Cool (ICH mk3).

SNC estimated the event altered 2,374,700 m^2 of total terrestrial habitat, which includes 737,464 m^2 riparian habitat (Section 5.3.1.11; SNC 2015a, b). An additional 28,110 m^2 of riparian habitat was estimated by the HRWG for Polley Lake and Quesnel Lake - Littoral Zone leaving an estimated 1,609,328 m^2 of affected upland terrestrial habitat.

The remediation plan for the altered upland terrestrial habitat includes:

- **Site preparation and soil amendments**. Site preparation methods are described in Section 4.2.3 and include mixing natural soil with the tailings soil and creating microsites across the upland terrestrial area. Soil inoculation and using topsoil borrowed from donor natural sites may be added to some areas with large volumes of deposited material to bolster soil microbial communities, soil nutrient levels, soil structural properties, and to provide a local seed bank (Ohsowski et al. 2012).
- **Revegetation program**. The revegetation program aims to re-establish a natural trajectory of succession within the upland terrestrial area, using natural pioneer species that are tolerant of difficult growing conditions and early-mid successional species (Section 4.2.3). To-date, 90% (approximately 1,448,395 m^2) of upland terrestrial habitat has been replanted based on advice from University of British Columbia (UBC) Forest Ecology, First Nations wishes, and generally based on standard BC silviculture stocking standards (Province of British Columbia 2019), leaving approximately 10% (approximately 160,933 m^2) of upland terrestrial habitat to be replanted. Based on the *Reference Guide for Forest Development Stocking Standards* (Province of British Columbia 2019), the delay to establish regeneration ranges from four- to seven- years dependent on the site series for the ICH wk2 and mk3. Where short regeneration delay periods are indicated (i.e., four years), planting is the preferred reforestation method (MOF 2002). The regeneration date is defined as the date at which the minimum number of healthy well-spaced trees of the preferred and acceptable species are established and the minimum number of preferred trees are established, which must be maintained until the sites is determined to be free growing (MOF 2002).

Possible offsetting options for upland terrestrial habitat are described in Section 5.4.4.

Determination**: TBD monitoring required**

5.3.2.1 Assumptions

- The total upland terrestrial habitat affected is equivalent to the estimated affected terrestrial habitat reported by SNC (2015b) minus the riparian habitat area estimated by SNC (2015a) and the riparian habitat area estimated by the HRWG.
- Planting of the upland terrestrial area completed to-date follows the BC silviculture stocking standards for the appropriate BEC subzone and site series (Province of British Columbia 2019).
- Soil amendments completed to-date will be conducive to the growth of vegetation that has been planted in the upland terrestrial area.

5.3.3 Uncertainties in Residual Effects, Offset, and Compensation Determination

There are uncertainties associated with the determination of residual effects, offsets and compensation for the EUs, riparian habitat and upland terrestrial habitat. This section describes the key uncertainties accounted for in the determination of residual effects and offset / compensation determination for each area. Accounting for uncertainties allows for adaptive management of habitat offsets and better satisfies the “no-net-loss” outcome of fish productivity.

Upper Edney Creek (E1)

- Uncertainties from the limited pre-event data, including the lack of salmon spawner escapement data, and limited juvenile salmon abundance data.
- Uncertainties from inconsistencies between pre- and post-event survey methodologies. In 2007, the survey methodology used for calculating abundance (CPUE) of Rainbow Trout was electrofishing, while in 2016 and 2017 it was minnow trapping.
- Timing of surveys was also inconsistent in Upper Edney Creek (E1). Pre-event surveys were conducted in late August of 2007, while 2016 and 2017 surveys were conducted from April to October and May to November respectively.

Middle Edney Creek (E3)

- Uncertainties from the limited pre-event data, including the lack of pre-event Rainbow Trout abundance (CPUE) and salmon spawner escapement data, and limited juvenile salmon abundance data.
- Uncertainties from possible inconsistencies in the collection of fish for determining Rainbow Trout age class structure pre- and post-event, and possible different month of fish collection.

Lower Edney Creek (E2)

- Uncertainties from the limited pre-event data, including the lack of pre-event Rainbow Trout abundance (CPUE) and salmon spawner escapement data, and limited juvenile salmon abundance data.
- Uncertainties from possible inconsistencies in the collection of fish for determining Rainbow Trout age class structure pre- and post-event, and possible different month of fish collection.

Upper Hazeltine Creek

- Uncertainties due to the lack of post-event Rainbow Trout abundance (CPUE) and age class structure data.

Lower Hazeltine Creek

- Uncertainties due to the lack of post-event Rainbow Trout abundance age class structure data.

Polley Lake

- Uncertainties from inconsistencies between pre- and post-event survey methodologies. In 1973, 1995, and 2012, the survey methodology used for calculating abundance (CPUE) of Rainbow Trout was seine netting, while in 2014 and 2016 it was gillnet sets.
- Uncertainties from possible inconsistencies in the collection of fish for determining Rainbow Trout age class structure and condition factor pre- and post-event, and possible different month of fish collection.

Quesnel Lake – Benthic Zone

- Uncertainties from the lack of pre-event data, including the lack of pre-event benthic zone fish relative abundance (CPUE), pre-event benthic zone fish condition factor and consistent pre- and post-event benthic invertebrate community data.

Quesnel Lake – Limnetic Zone

- Uncertainties from the lack of pre- and post- event data, including the lack of pre-event limnetic zone fish relative abundance (CPUE), pre-event limnetic zone fish condition factor and official submergent and emergent vegetation monitoring data.

Quesnel Lake – Littoral Zone

- Uncertainties from the lack of pre-event data, including the lack of pre-event littoral zone fish relative abundance (CPUE), littoral zone fish condition factor and zooplankton abundance and biomass data.

Riparian Habitat

- Uncertainties associated with natural vegetation species growing and establishing on affected sites (so far monitoring has shown that replanted areas are growing).
- Uncertainties associated with natural infilling by propagules from the surrounding area leading to a natural trajectory for succession.
- Uncertainty in the loss of wetland areas adjacent with Edney and Hazeltine Creeks.

Upland Terrestrial Habitat

- Uncertainties associated with site preparation techniques making soils conducive to native plant establishment and growth.
- Uncertainties associated with the success of planting of pioneering species and natural infilled by propagules from the surrounding area leading to a natural trajectory for succession.

- Loss of wetlands in the upland terrestrial habitat will have effects on availability of amphibian breeding habitat. The compensation is not encompassed by only following the silviculture stocking guidelines as this does not replace loss wetland habitat.
- Uncertainties associated with the effect the event had, and continues to have, on amphibians. Further monitoring in the CEMP or a focused amphibian study may be required.

5.4 Proposed Offsets and Compensation

There are no proposed offsets for six EUs: Upper Edney Creek (E1), Middle Edney Creek (E2), Lower Edney Creek (E3), Polley Lake, Quesnel Lake – Limnetic Zone, and Quesnel River. The rationale for no proposed offset for these EUs is provided in Sections 5.3.1.1, 5.3.1.2, 5.3.1.3, 5.3.1.6, 5.3.1.7 and 5.3.1.9 respectively.

Offsets are proposed for riparian habitat and four EUs: Upper Hazeltine Creek (H1), Lower Hazeltine Creek (H2), Quesnel Lake – Benthic Zone, and Quesnel Lake – Littoral Zone. The rationale for proposing offsets for riparian habitat and these EUs is provided in Sections 5.3.1.11, 5.3.1.4, 5.3.1.5, 5.3.1.9 and 5.3.1.8 respectively. Proposed offset options for H1, H2 and Quesnel Lake – Littoral Zone are described in Section 5.4.1, for Quesnel Lake – Benthic Zone is described in Section 5.4.2, and for riparian habitat is described in Section 5.4.3. Proposed offsets are common approaches known to have the potential to increase fish productivity (Loughlin and Clarke 2014).

Compensation is proposed for upland terrestrial habitat. The rationale for proposing compensation for upland terrestrial habitat is provided in Section 5.3.2, and proposed compensation is described in Section 5.4.4.

The HRWG will provide input into a decision for the most appropriate offset to meet productivity effects/shortfalls for each EU, the riparian habitat and the upland terrestrial habitat.

5.4.1 Potential Offset Options for Hazeltine Creek (H1 and H2) and Quesnel Lake – Littoral Zone

5.4.1.1 On-Site Off-Channel Habitat Creation

Habitat creation is considered offset to serious harm to fish under the federal *Fisheries Act* (Loughlin and Clarke 2014) and has been common practice since the 1980s. Hazeltine Creek (H1 and H2) was destroyed and Quesnel Lake – Littoral Zone was altered as a result of the event. Pre-event, Upper Hazeltine Creek (H1) provided spawning and rearing habitat for a single species (i.e., Rainbow Trout), while Lower Hazeltine Creek (H2) provided spawning and rearing habitat for multiple species (e.g., Rainbow Trout and other salmonid species such as sockeye salmon). A potential offset option for H1, H2 and Quesnel Lake – Littoral Zone is the construction of small off-channel streams to provide additional spawning and rearing habitat, or to improve access to H1 from Polley Lake, and from Quesnel Lake to H2.

Habitat creation should be undertaken using a watershed approach to identify and remove potential stressors that will affect the created habitat prior to undertaking habitat enhancement and creation (Loughlin and Clarke 2014). Off-channel habitat can be created using different techniques such as groundwater fed off-channels, overflow channels that become wetted during flood events, and surface-fed channels (Lister and Finnigan 1997). Selection of the type of off-channel habitat created will depend on the characteristics of the site and the spawning and rearing requirements of the species the off-channel habitat is designed for (Lister and Finnigan 1997). Design of off-channel habitat for spawning and rearing must consider riparian vegetation, substrate type suitable for spawning for target species, the macroinvertebrate community, physical design of the habitat (e.g., channel width, channel depth, riffle / pool structure), and cover features available such as large woody debris (Loughlin and Clarke 2014). Monitoring and follow-up programs are necessary to determine the productivity provided by created off-channel habitat (Loughlin and Clarke 2014). For offsetting programs this will require data on the productivity prior to the disturbance event, productivity after the disturbance event, and productivity after habitat creation and enhancement projects are constructed.

5.4.1.2 Off-Site Off-Channel Habitat Creation

DFO (2013) prefer offsets that occur within the vicinity of the Project, or within the same watershed; therefore, a potential offset option for H1, H2 and / or Quesnel Lake – Littoral Zone is the construction of off-site off-channel habitat within the Quesnel Lake watershed. Off-channel habitat creation can provide spawning, rearing, and overwintering habitat for target fish species to increase fish productivity. Off-channel habitat can be created using different techniques such as groundwater fed off-channel habitat, overflow channels that become wetted during flood events, and surface-fed channels (Lister and Finnigan 1997). Selection of the type of off-channel habitat created will depend on the characteristics of the site and the spawning and rearing requirements of the fish species for which off-channel creation is being designed (Lister and Finnigan 1997). The design of off-channel habitat for spawning and rearing needs to consider riparian vegetation, substrate type suitable for spawning for target species, the macroinvertebrate community, physical design of the habitat (e.g., channel width, channel depth, riffle / pool structure), and cover features available such as large woody debris (Loughlin and Clarke 2014). The input of First Nations, local biologists and streamkeeper volunteers can provide considerable benefit to accelerating such concepts with locally informed ideas.

5.4.1.3 Removal of Barriers and Reconnection of Fish Habitat

Damaged and incorrectly installed culverts, fords and bridges can prevent the passage of fish. Perched culverts can reduce the chance a fish can access the culvert. Culverts can affect the flow of water which can affect fish passage. If there is not enough flow, the water can be too shallow for fish to pass. Alternatively, too much flow can make it too difficult for a fish to swim up the culvert. The chances of debris getting trapped and blocking the culvert is increased when the upstream opening is too narrow. The lack of proper habitat features, such as resting pools below the outfall of a culvert, can also create a barrier to fish passage (MOTI 2013; Votapka 1991).

There are 1,123 culverts (i.e., round culverts, oval culvert, wood box culverts, or pipe arch), fords, and bridges in the Quesnel River watershed identified as barriers to fish passage (Government of BC 2019; Pedersen 1998 Appendix C). The location of each fish barrier and the associated stream / tributary is provided in Appendix C. Where the length and channel width of the fish barrier is known, the potential offset area (m^2) is provided in Appendix C. A potential offset option for H1, H2 and / or Quesnel Lake – Littoral Zone is to maintain, remove or replace fish barriers to regain passage for fish to access spawning and rearing areas.

Numerous examples exist of the success of removing fish barriers and promoting habitat connectivity (DFO 2016). Culvert restoration and upgrades have shown, when completed properly, to increase passage success, fish biomass and species richness (Favaro et al. 2014; Goerig et al. 2015).

5.4.1.4 Streambank Stabilization and Riparian Planting

A potential offset option for H1, H2 and / or Quesnel Lake – Littoral Zone is to stabilize banks and revegetated riparian areas within the Quesnel Lake to Edney Creek watershed. Anthropogenic activities such as forest harvesting and infrastructure construction has increased exposure to streams, resulting in increased water temperature, sediment, and channelization (Pedersen 1998). Restoration activities such as bank stabilization and revegetation of riparian areas, both of which are needed on a variety of watercourses throughout the watershed (Pedersen 1998), can contribute to the overall health of a stream, increasing the quality of salmonid habitat.

5.4.1.5 Invasive Fish Eradication

DFO (2013) consider offsets that are undertaken outside of the Project site, or for fish species other than those affected, provided the offsets are supported by clear fisheries management objectives or regional restoration priorities. Therefore, a potential offset option for H1, H2 and / or Quesnel Lake – Littoral Zone is to provide funds to support the eradication of invasive smallmouth bass (*Micropterus dolomieu*) in the Beaver Creek watershed.

Smallmouth bass is an invasive fish species, occurring in reservoirs, ponds, rivers, and streams. It is an efficient predator, feeding on invertebrates as juveniles and then fish after the age of two (Bobrowski 2017). This has a negative effect on native fish species by reducing prey availability and through direct predation. Predation may have an impact on salmonid species in particular; juvenile salmonids can make up over 50% of smallmouth bass diet where they overlap (Tabor et al. 1993; 2007). Smallmouth bass is also able to reproduce faster and more often than most native fish, adding additional competition onto native fish populations (Bobrowski 2017). This species occurs in watersheds throughout southern BC as well as Vancouver Island (Government of BC 2019). A population was also illegally introduced into Beaver Creek, which drains into the Quesnel River, in 2003 (Bobrowski 2017). By 2007, smallmouth bass had moved downstream as far as the confluence of Beaver Creek and Quesnel River and upstream of Beaver Lake. It is expected to continue to spread throughout central BC (Bobrowski 2017).

Population control efforts can be focused through eradication and containment. Eradication focuses on removing populations of smallmouth bass through a variety of methods. Containment seeks to stop the spread of smallmouth bass through the installation of artificial barriers.

Eradication and control programs for smallmouth bass has shown some success in both reducing smallmouth bass population numbers and increasing native fish abundance; however, a multi-year approach is needed to avoid bass populations rebounding (Biron et al. 2014; Weidel et al. 2007).

5.4.2 Proposed Offset Option for Quesnel Lake - Benthic Zone

5.4.2.1 Lake Fertilization

The offset of Quesnel Lake benthic habitat with new deep lake habitat (like for like offset) is not a practical offsetting option because an ecologically viable lake with a depth of approximately 100 m would require construction of a water dam and would alienate considerable land. Given that desired outcomes for offsetting are to increase productivity, we have considered lake fertilization to be an appropriate means of directly increasing productivity of Quesnel Lake.

Nutrient addition can be used to enhance fish food production in lakes where food may be a limiting factor (Gerwing and Plate 2018; Basset et al. 2016; Envirowest 1990). It is well established that nutrient addition can compensate for the loss in productivity resulting from dam construction and operation (Ashley and Slaney 1997; Stockner and Shortreed 1985) by increasing productivity of edible phytoplankton and, in turn, increasing zooplankton biomass, such as *Daphnia spp*. which is a key forage item for planktivorous fish (Perrin and Stables 2001; Perrin and Stables 2000; Thompson 1999). The stimulation of the lower trophic levels, when done right can play a key role in increasing the productivity of fish populations (Hebert et al. 2013). Inorganic nutrients are added to the lake to enhance primary trophic levels (e.g., plants and phytoplankton), which in turn increases secondary trophic levels (e.g., zooplankton and benthic invertebrates) that are important food sources for juvenile Salmon (Envirowest 1990). Nutrient additions are particularly viable for oligotrophic lakes (Loughlin and Clarke 2014).

During habitat assessment in the late 1980s and early 1990s, Quesnel Lake was assessed to have excellent physical characteristics (e.g., temperature, thermocline and euphotic zone depth) for rearing habitat for juvenile Sockeye Salmon. However, nutrient concentrations and phytoplankton productivity was low relative to other interior Fraser lakes (Shortreed et al. 2001). *Daphnia* was abundant during years of lower fry density but during years of high fry density its abundance declined to levels where sockeye diet shifted to less efficient prey items (Shortreed et al. 2001). Quesnel Lake is a potentially suitable candidate for fertilization during dominant and subdominant brood years. Fertilization of Quesnel Lake was estimated to have the potential to produce several million additional adult Sockeye returns in each dominant and subdominant brood year (Stockner and Shortreed 1994).

Nutrient enrichment programs have been undertaken with measurable success. In 1999 The BC Ministry of Environment undertook a 5-year program, and nutrient addition to a limnetic area of 1,400 ha^2 in the Alouette Reservoir starting (Harris et al. 2010). Monitoring from the initial research phase from 1999 to 2002 indicated lake fertilization was meeting the established goals (Harris et al. 2010). Monitoring results from this program indicate increase in the density of phytoplankton, increase in zooplankton biomass and density, and increase in fish abundance during the nutrient addition program in comparison to pre-fertilization baseline conditions (Harris et al. 2010). Recently, BC Hydro undertook a 10-year program nutrient enrichment program to a 4.1 km^2 reservoir area in Wahleach Reservoir, BC (Hebert et al. 2013; BC Hydro 2005). Results from the monitoring program report increased phytoplankton and zooplankton abundance and biomass as a result of nutrient addition (Hebert et al. 2013). Increased phytoplankton and zooplankton productivity have translated into increased fish abundance and biomass since the program's inception. Assessments of Wahleach Reservoirs' fish populations indicate a significant increase in abundance and overall biomass since the start of nutrient enhancement (Hebert et. al. 2013).

Gerwing and Plate (2018) provide a contemporary review of the effectiveness of nutrient enhancement as a remediation or compensation strategy for salmonid fisheries from several such efforts. Their review provides important considerations in use of this offsetting method so that increased primary producer and invertebrate populations will transfer into increases in fishery productivity. A fertilization program needs to be coupled with appropriate monitoring. Anecdotally, following the year of the breach, DFO observed that sockeye salmon juveniles in the West Arm were more abundant and larger in size than sockeye juveniles in other parts of Quesnel Lake and water quality measurements in Quesnel Lake found that nutrient levels were increased as a result of forest nutrients being washed into the lake from the debris flow. This and experience elsewhere (Gerwing and Plate 2018) suggests that there is merit in considering this as a practical offset measure.

When done correctly, increased fishery productivity of Quesnel Lake does appear to be a likely outcome to such an offsetting measure. The estimate of 5 years of productivity impacts from the breach to Quesnel Lake benthos provides a suitable period over which the offset would involve MPMC funding a lake fertilization program for the Quesnel Lake west arm as an offset to the impacts of the breach on the West Arm of Quesnel Lake. Consultation with DFO would also be needed for conclusion of lake fertilization as the productivity increase from fertilization is largely transient, occurring for the duration of fertilization (Gerwing and Plate 2018; Envirowest 1990).

Through consultation for this RP (and more broadly), MPMC are aware that lake fertilization may be a controversial proposal for certain area residents and lake users. Consultation would be a required part of implementing lake fertilization. Based on expectations from what was heard through consultation to date and some of the concerns identified, it was felt that a contingent offset option was appropriate.

5.4.2.2 Contingency Option for Quesnel Lake - Benthic Zone Offset

A suitable contingency option was tabled by FLNR at a November 2018 HRWG meeting. A known negative impact on local fish productivity from invasive species has been identified as a conservation priority for action and it was suggested that contributions towards an invasive species eradication program could be a suitable form of productivity offsets.

The quantification of an appropriate dollar amount for that offset could be based on a costing exercise for 5 years of a lake fertilization program with that amount paid into invasive species control programs over that period of 5 years. The technical and managerial leadership of the invasive species program are already in place so MPMC would be a funding contributor towards a program seen by fishery managers as an important regional program. Additional information on such a program is provided in Section 5.4.1.5 above.

5.4.3 Proposed Offset Options for Riparian Habitat

Riparian habitat offsetting will be used to account for the time lag required for riparian plantings to become ecologically functional. To achieve riparian habitat offsetting a combination of options can be employed and are discussed below. Riparian enhancement and restoration within the watershed.

- **Riparian habitat creation:** through the creation of off-channel fish habitat (Sections 5.4.1.1 and 5.4.1.2) additional riparian areas will also be created.
- **Removal of barriers to fish passage:** removing fish barriers will enable fish to access areas that may contain suitable habitat for spawning and rearing including areas with intact functional riparian areas (Section 5.4.1.3).

- **Riparian enhancement or restoration:** identifying important areas for fish spawning, rearing, or overwintering in the Quesnel Lake and Edney Creek Watershed and the surrounding area may identify locations that would benefit from riparian enhancement or restoration due to degradation from natural (e.g., wildfire) or anthropogenic (e.g., road creation) events.

5.4.4 Proposed Offsets for Upland Terrestrial Habitat

For the purposes of this RP upland terrestrial habitat means those areas damaged that are not within the streamside riparian zone as defined by the province of BC. Those riparian zone areas are being handled as they would with other aquatic habitat disturbances in the riparian zone.

The remedial objectives for terrestrial habitat are to reforest those areas such that the terrestrial area provides forest on a successional trajectory and associated wildlife habitat. Offsets for the interim losses are based BC forestry model wherein reforestation of clear-cut areas is required. Additionally, for the “use” of the timber values, stumpage fees would be paid to BC. It is proposed that offsets therefore be based on the stumpage fee formula used by BC.

6.0 IMPLEMENTATION AND SCHEDULE

The RP is an integrated plan (Figure 8) that is developed to address both physical damages through direct remediation work and through risk management measures for the introduction of tailings constituents. The implementation of risk management requires ongoing monitoring (e.g., in the case of MNR) to confirm risk expectations and to verify identified areas of scientific uncertainty. In those instances where risks are uncertain (e.g., where conditions at the time of the ERA did not allow such a determination to be reached), MPMC are carrying out specific studies that are adjunct studies to the CEMP. The regulatory oversight for these studies is carried out through the CEMP process. The implementation of habitat remediation work will continue through the HRWG. This group is the logical group for confirmation of habitat credits as verified through monitoring, re-evaluation of offsets owing as monitoring data confirm habitats are functioning as intended. The HRWG will also have the role of evaluating and prioritizing offsetting options to be constructed. MPMC recognize that while the HRWG provides these inputs, the presentation of information and data to that working group remains part of MPMC's long term commitments. It is anticipated that the HRWG may wish to review their TOR for the implementation of the RP.

The implementation of the RP and the scheduling of resources is carried out by MPMC who direct either their own crews or the crews of locally contracted construction firms. Schedules and other matters are determined with greater clarity as the work plans become finalized with the HRWG. A conceptual schedule is provided below in Table 25. It will be subject to change as finalized work plans are concluded, monitoring is carried out and habitat offset balances are recalculated based on survey findings.

The schedule below was developed by MPMC.

Table 25: Conceptual Schedule for Implementation of Remediation

Item	Anticipated Schedule
Remediation Plan	29 March submission
Hazeltine Creek Reach 3	Plans submitted agreed 2018, construction to +3100, remainder summer 2019
Hazeltine Creek Reach 5	2020
Hazeltine Creek/Edney Mouth Re-alignment	2020-2021
Sediment Control Ponds decommissioning designs	2021
Polley Lake Shoreline	2020
Comprehensive Environmental Monitoring Plan (CEMP)	Conditionally Approved 2018, and as updated every 3 years
HRWG Terms of Reference Review (to identify if changes needed for implementation of RP)	2019

We note that the implementation of a remediation plan will normally require monitoring of the outcome of remedial works and adjustments to provide attainment of remedial objectives. A monitoring plan has not been included in this RP because monitoring will be carried out in accordance with the CEMP. The CEMP is currently designed as a tool for permit monitoring and risk management components of the RP. It is proposed that the HRWG develop a habitat-specific monitoring plan because risk management monitoring and habitat function monitoring are typically different technical areas that persons with appropriate technical backgrounds would provide feedback on. This will also fit with the main regulatory oversight for habitat remediation being within the *Fisheries Act* and the *Water Sustainability Act* and regulatory oversight over permit and risk management monitoring being overseen under the *Environmental Management Act*. There are logical linkages that exist within these two technical areas such as construction of habitat and water quality in that habitat. However, those linkages functioned well in making habitat decisions as water quality considerations were a substantial part of decisions on, for example, fish re-introduction into upper Hazeltine Creek (see for instance scope of information provided in Golder 2018b).

7.0 CLOSURE

We trust that this report provides sufficient information for your present needs. If you have any questions, please do not hesitate to contact the undersigned at 604-296-4200.

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https://golderassociates.sharepoint.com/sites/10023g/documents_1894924/2. issued/076-r-23197-finalremediationplan/rev0/1894924-076-r-rev0-23197-mount polley remediation plan 29mar_19.docx

REFERENCES

Ashley KI, Slaney PA. 1997. Chapter 13 - Accelerating Recovery of Stream, River and Pond by low-level nutrient replacement. Pp. 13-1 – 13-24. In: Slaney PA, Zaldokas D (ed.). 1997. Fish Habitat Rehabilitation Procedures. Watershed Restoration Technical Circular No. 9. Ministry of Environment, Lands and Parks and Ministry of Forests.

Basset M, Schindler EU, Johner D, Weir T, Sebastian D, Vidmanic L, Ashley KI. 2016. Kootenay Lake Nutrient Restoration Program Year 22 (North Arm) and Year 10 (South Arm) (2013) Report. Prepared for the Resource Management, Ministry of Forests, Lands and Natural Resource Operations. 132 p.

BC Hydro. 2005. Wahleach Water Use Plan. Physical Works Terms of Reference. WAHWORKS-2 – Wahleach Reservoir Fertilization Program. A BC Hydro Water Use Plan Terms of Reference.

Biron M, Clément M, Moore D, Chaput G. 2014. Results of a Multi-year Control and Eradication Program for Smallmouth Bass (*Micropterus dolomiue*) in Miramichi Lake, New Brunswick, 2011-2012. Fisheries and Oceans Canada, Science Branch, Aquatic Resources Division. V + 58 p.

Bobrowski R. 2017. Invasive Fish in the Cariboo Region. Ministry of Forests, Lands and Natural Resource Operations. [https://bcinvasives.ca/documents/2017_Invasive_Fish.pdf]. Accessed 8 March 2019.

Bolam SG, Rees HL. 2003. Minimizing impacts of maintenance dredged material disposal in the coastal environment: a habitat approach. Environmental Management 32(2):171-188.

Bradford MJ, Smokorowski KE, Clarke KD, Keatley BE, Wong MC. 2016. Equivalency metrics for the determination of offset requirements for the Fisheries Protection Program. May 2016. Department of Fisheries and Oceans Canada.

Bronsro A, Ogilvie J, Nikl L, Adams MA. 2016. River rehabilitation following a tailings dam embankment breach and debris flow. In: Proceedings Tailings and Mine Waste. 2016. Keystone, Colorado, 2-5 October 2016.

Bruce JA, Slaney TL. 1991. Polley Lake Tributary Assessment. Prepared by Aquatic Resources Ltd for BC Ministry of Environment, Williams Lake, B.C. Regional Fisheries Report No. CA915. 51 p.

Burd BJ. 2002. Evaluation of mine tailings effects on a benthic marine infaunal community over 29 years. Marine Environment Research 53:481-519.

Cañedo-Argüelles M, Rieradevall M. 2011. Early succession of the macroinvertebrate community in a shallow lake: response to changes in the habitat condition. Limnologica 41:363-370.

CCHMC (Consolidated Cariboo Hydraulic Mining Co., Ltd.). Undated (ca. 1900). In: Gold Mines and Mining – BC; British Columbia Historical Photograph Albums. University of British Columbia Rare Books and Special Collections.

Connors K, Anderson P, Hughes C. 2018. Monitoring of a remediated stream impacted by the 2014 Mount Polley tailing storage facility breach. Poster presented at Canadian Conference for Fisheries Research. December 2018.

Cruz-Motta JJ, Collins J. 2004. Impacts of dredged material disposal on a tropical soft-bottom benthic assemblage. Marine Pollution Bulletin 48(3):270-280.

DFO (Department of Fisheries and Oceans). 2012. Pathways of Effects: National Guidelines. Illustrating the links between human activity and its potential impact on aquatic ecosystems. Fisheries and Oceans Canada. 32pp.

DFO. 2013. Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting. November 2013. Published by Ecosystem Programs Policy, DFO, Ottawa, Ontario.

DFO. 2014. Proposed Approach to Remediation of Hazeltine Creek. Letter of response from Alain Magnan (DFO) to Dale Reimer (Mount Polley Mining Corporation). December 18, 2014.

DFO. 2016. Success Stories. [http://www.dfo-mpo.gc.ca/pnw-ppe/rfcpp-ppcpr/success-succes-eng.html]. Accessed 8 March 2019.

Efroymson RA, Nicolette JP, Suter II GW. 2003. A framework for net environmental benefit analysis for remediation or restoration of petroleum-contaminated sites. Oak Ridge National Laboratory. ORNL/TM-2003/17.

Ellis DV, Hoover PM. 1990. Benthos on tailings beds from an abandoned coastal mine. Marine Pollution Bulletin 21(10):477-480.

Envirowest (Envirowest Consultants Inc.). 1990. Fish Habitat Enhancement – A manual for freshwater, estuarine, and marine habitats. Prepared by Envirowest for Fisheries and Oceans Canada, Government of Canada. 324 p.

Favaro C, Moore JW, Reynolds JD, Beakes MP. 2014. Potential loss and rehabilitation of stream longitudinal connectivity: fish populations in urban streams with culverts. Canadian Journal of Fisheries and Aquatic Sciences 71:1-12.

Frouz J, Prach K, Pižl V, Háněl L, Starý J, Tajovský K, Materna J, Balík V, Kalcík J, Řehounková K. 2008. Interactions between soil development, vegetation and soil fauna during spontaneous succession in post mining sites. European Journal of Soil Biology 44:109–121.

Gerwing TG, Plate E. 2018. Effectiveness of nutrient enhancement as a remediation or compensation strategy of salmonid fisheries in culturally oligotrophic lakes and streams in temperate climates. Restoration Ecology 27:279-288.

Goerig E, Castro-Santos T, Bergeron NE. 2015. Brook Trout passage performance through culverts. Canadian Journal of Fisheries and Aquatic Sciences 73(1):94-104.

Golder (Golder Associates Ltd.). 2015a. Forest conditions and dieback in areas of thicker tailings deposition. Submitted to Mount Polley Mining Corporation. Document No. 1411734-047-TM-Rev2-1100. 4 p.

Golder. 2015b. Design Criteria for Hazeltine Creek Rehabilitation. Submitted to Mount Polley Mining Corporation. Document No. 1411734-006-TM-Rev0-7000. 20 p.

Golder. 2015c. Quesnel and Polley Lakes Aquatic Productivity Impact Assessment. Submitted to Mount Polley Mining Corporation. Reference No. 1411737-038-R-Rev0. 80 p.

Golder. 2015d. Mount Polley Tailings Dam Failure – Surface Water Quality Impact Assessment. Submitted to Mount Polley Mining Corporation. Document No. 1411734-036-R-RevA-10000. 101 p.

Golder. 2016a. Mount Polley Mine Tailings Storage Facility, Perimeter Embankment Breach Update Report; Post-Event Environmental Impact Assessment. Prepared for Mount Polley Mining Corporation. Document No. 1411734-124-R-Rev0-10000. 1942 p.

Golder. 2016b. Mount Polley Mine – Development of a Treatment Target for Copper in Hazeltine Creek Using the Biotic Ligand Model. Submitted to Mount Polley Mining Corporation. Document No. 1411734-175-TM-Rev0-16000. 16 p.

Golder. 2017a. Mount Polley Rehabilitation and Remediation Strategy: Detailed Site Investigation Update, Mount Polley Mine, BC. Submitted to Mount Polley Mining Corporation. Document No. 1662612-107-R-Rev0-22291. 1061 p.

Golder. 2017b. Mount Polley Rehabilitation and Remediation Strategy: Human Health Risk Assessment. Submitted to Mount Polley Mining Corporation. Document No. 1662612-086-R-Rev0-22392. 2270 p.

Golder. 2017c. Mount Polley Rehabilitation and Remediation Strategy: Ecological Risk Assessment. Submitted to Mount Polley Mining Corporation. Document No. 1662612-162-R-Rev0-22396. 8228 p.

Golder. 2017d. Hazeltine Creek Fish Passage Assessment – Mount Polley Mine. Technical Memorandum prepared for Mount Polley Mining Corporation. Submitted to Mount Polley Mining Corporation. December 15, 2017. 25pp.

Golder. 2017e. Edney Creek Habitat Assessment – Mount Polley Mine. Prepared for Mount Polley Mining Corporation. April 2017.

Golder. 2018a. Study Design Concept: Terrestrial Component for the Mount Polley Mine Comprehensive Environmental Monitoring Plan -– Mount Polley Mine. Submitted to Mount Polley Mining Corporation. Ref. No. 1894924-025-TM-Rev0-23182. 21 p.

Golder. 2018b. Implementation Plan: Upper Hazeltine Creek Fish Re-Introduction. Document No. 1894924-003-R-Rev0-21245. 45 p.

Golder. 2018c. Conceptual Remediation Plan - Perimeter Embankment Breach – Mount Polley Mine. Prepared for Mount Polley Mining Corporation. January 2018. 96 p.

Golder. 2019. Geotechnical investigation and trafficability assessment: Edney Flats, Quesnel Lake, Mount Polley Mine BC. Technical Memorandum 1894924-060-TM-Rev0-23100. 3 January 2019.

Government of BC. 2019. Habitat Wizard. [http://maps.gov.bc.ca/ess/hm/habwiz/]. Accessed 8 March 2019.

Gregory SV, Swanson FJ, McKee WA, Cummins KW. 1991. An ecosystem perspective of riparian zones. BioScience 41(8):540-551.

Harris SL, Andrusak H, Andrusak G, Sebastian D, Scholten G, Weir T, Vidmanic L, Johnson EJ, Down NE. 2010. The Alouette Reservoir Nutrient Restoration Program, 2003-2008. Fisheries Project Report No. RD129. Province of British Columbia, Ministry of Environment, Aquatic Ecosystem Protection Branch. [http://a100.gov.bc.ca/appsdata/acat/documents/r41091/Projectreport129_1389823912600_9823285216.pdf]. Accessed 11 March 2019.

Hebert AS, Harris SL, Weir H, Vidmanic L, Down NE. 2013. Wahleach Reservoir Nutrient Restoration Project, 2011-2012. Province of British Columbia, Ministry of Environment, Ecosystems Protection & Sustainability Branch, Conservation Science Section.

Hickman T, Raleigh RF. 1982. Habitat Suitability Index Models: Cutthroat Trout. Fish and Wildlife Services, Biological Services Program. FWS/OBS-82/10.5.

HKP (Hallam Knight Piésold Ltd.). 1997. Mount Polley Mining Corporation - Mount Polley Mine - 1997 Fisheries Monitoring Program. October 1997.

Holte B, Oug E. 1996. Soft-bottom macrofauna and responses to organic enrichment in the subarctic waters of Tromsø, Northern Norway. Journal of Sea Research 36(3/4):227-237.

Hughes DJ, Shimmield TM, Black KD, Howe JA. 2015. Ecological impacts of large-scale disposal of mining waste in the deep sea. Scientific Reports 5. Article No: 9985.

Johnston NT and Slaney PA. [ed.] 1996. Fish habitat rehabilitation procedures. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests, Watershed Restoration Program, Technical Circular No. 9.

Johnston NT, Slaney PA. 1996. Fish Habitat Assessment Procedures. Watershed Restoration Technical Circular No. 8, revised April 1996.

Kathman RD, Brinkhurst RO, Woods RE, Cross SF. 1984. Benthic studies in Alice Arm, B.C., following cessation of mine tailings disposal. Canadian Technical Report of Hydrogeological Ocean Science No. 37.

Kennedy CB, Day SJ, Anglin CD. 2016. Geochemistry of tailings from the Mount Polley Mine, British Columbia. In: Proceedings Tailings and Mine Waste 2016, Keystone, Colorado, USA. 2-5 October 2016.

Kohler KE, Dodge RE. 2006. Visual_HEA: Habitat Equivalency Analysis software to calculate compensatory restoration following natural resource injury. Proceedings of the 10th International Coral Reef Symposium. Okinawa, Japan. pp. 1611-1616.

Kvassnes AJS, Sweetman AK, Skei J, Iversen E. 2009. Sustainable use and future of submarine tailings placements in the Norwegian extractive industry. 8th ICARD (International Conference on Acid Rock Drainage), Skellefteå, Sweden. 22-26 June 2009.

Laval BE, Morrison J, Potts DJ, Carmack EC, Vagle S, James C, McLaughlin FA, Foreman, M. 2008. Wind-driven Summertime Upwelling in a Fjord-type Lake and its Impact on Downstream River Conditions: Quesnel Lake and River, British Columbia, Canada. Journal of Great Lakes Research 34:189-203.

Levy DA, Johnson RL, Hume JM. 1991. Shifts in fish vertical distribution in response to an internal seiche in a stratified lake. Limnology and Oceanography 36:187-92.

Lirette MG. 2015. Polley Lake Fish Assessment, September 2014. Prepared for Mount Polley Mining Corporation. Likely, B.C. 25 p.

Lirette MG. 2017. Polley Lake Fish Assessment. September, 2016. Prepared for Mount Polley Mining Corporation. Likely, B.C.

Lister DB, Finnigan RJ. 1997. Chapter 7 Rehabilitating Off-channel Habitat. In: Slaney PA, Zaldokas D (ed.). 1997. Fish Habitat Rehabilitation Procedures. Watershed Restoration Technical Circular No. 9. Ministry of Environment, Lands and Parks, Vancouver, BC.

Loughlin KG, Clarke KD. 2014. A review of methods used to offset residual impacts of development project on Fisheries Productivity. Canadian Science Advisory Secretariat Research Document 2013/097. DFO, St. John’s NL. 72 p.

Mallik AU, Newaz S, Mackereth RW, Shahi C. 2011. Geomorphic changes of headwater systems 2-23 years after forest harvesting by clearcutting. Ecosphere 2(4): Article 43. [https://esajournals.onlinelibrary.wiley.com/doi/epdf/10.1890/ES10-00144.1]. Accessed 8 March 2019.

McPhail JD. 2007. The freshwater fishes of British Columbia. Edmonton, Alberta, Canada: The University of Alberta Press. 620 pp.

Meidinger DV, Pojar J. 1991. Ecosystems of British Columbia. Special Report Series No. 6. Research Branch, Ministry of Forests. 330 pp.

MEMPR (Ministry of Energy, Mines and Petroleum Resources, CANMET and Rescan Environmental Services Ltd.). 1991. A preliminary biological and geological assessment subaqueous tailings disposal in Benson Lake, British Columbia. MEND Report 2.11.1c-a.

Merritt RW, Cummins KW (eds). 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Company.

Minnow (Minnow Environmental Inc.). 2007. Hazeltine Creek Habitat Characterization. Submitted to Mount Polley Mining Corporation. 28 p.

Minnow. 2009. Mount Polley Mine - Aquatic Environmental Characterization of Hazeltine Creek - 2007. Submitted to Mount Polley Mining Corporation. October 2009.

Minnow. 2014. Aquatic Environmental Description Report: Mount Polley Mine Discharge of Treated Water to Polley Lake. Submitted to Mount Polley Mining Corporation, Likely, BC.

Minnow. 2015. Mount Polley Tailings Dam Failure Sediment Quality Impact Characterization. Submitted to Mount Polley Mining Corporation. May 2015.

Minnow. 2016a. Memorandum: Benthic Invertebrate Community Metrics in the Vicinity of the Mount Polley Mine, 2015. Submitted to Mount Polley Mining Corporation. November 2016.

Minnow. 2016b. License # XHAB 28 2016 fish data submission. Memo submitted to Fisheries and Oceans Canada on behalf of MPMC. November 2016.

Minnow. 2017a. Polley Lake Fish Monitoring. 2016. Submitted to Mount Polley Mining Corporation. Report 167202.0055. March 2017.

Minnow. 2017b. Benthic Invertebrate Community Monitoring in the Vicinity of the Mount Polley Mine, 2016. Submitted in Draft for Mount Polley Mining Corporation. June 2017.

Minnow. 2018a. Edney Creek Fish Usage and Fish Habitat Characterization, 2016 and 2017. Submitted to Mount Polley Mining Corporation. March 2018.

Minnow. 2018b. Polley Lake and Frypan Creek 2017 Fish Monitoring. Submitted to Mount Polley Mining Corporation. March 2018.

Minnow. 2018c. Benthic Invertebrate Community and Productivity Monitoring in the Vicinity of the Mount Polley Mine, 2017. Memorandum submitted March 27, 2108 by Minnow Environmental Inc. to Mount Polley Mining Corporation. 318 pp.

Minns CK. 1997. Quantifying “no net loss” of productivity of fish habitats. Can. J. Fish. Aquat. Sci. 54: 2463-2473.

MOE (Ministry of Environment). 2014. Technical Guidance 22: Using monitored natural attenuation and enhanced attenuation for groundwater remediation. [https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/technical-guidance/tg22.pdf]. Accessed 8 March 2019.

MOE. 2015. Definitions and Acronyms for Contaminated Sites. Environmental Management Act and Contaminated Sites Regulation. Environmental Protection Division. Issued by: Environmental Emergencies and Land Remediation Branch. [https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/docs/procedures/procedure08.pdf]. Accessed 5 November 2017.

MOE. 2016. Technical Guidance 8: A Framework for the Development and Use of Freshwater Science-Based Environmental Benchmarks for Aquatic Life in Environmental Management Act Permitting for Mines. Issued by Environmental Protection Division Regional Operations Branch [https://www2.gov.bc.ca/assets/gov/environment/waste-management/industrial-waste/industrial-waste/mining-smelt-energy/guidance-documents/tg8_framework_for_sbebs.pdf]. Accessed 22 January 2018.

MOF (Ministry of Forests). 2002. Establishment to free growing guidebook. Cariboo Forest Region. Rev. Ed., Version 2.3 Victoria, BC, Forest Practices Code of British Columbia Guidebook. [https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/stocking-standards/efgg/efg-car-print.pdf]. Accessed 11 March 2019.

Morton KF, Williams I. 1990. Sockeye salmon (*Oncorhynchus nerka*) utilization of Quesnel Lake, British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1756.

MOTI (Ministry of Transportation). 2013. Culverts and Fish Passage. MOTI. Environmental Management. [https://www2.gov.bc.ca/assets/gov/driving-and-transportation/transportation-infrastructure/engineering-standards-and-guidelines/environment/references/3824_culvertfishpassage_infosheet.pdf]. Accessed 8 March 2019.

MPMC (Mount Polley Mining Corporation). 2009. Mount Polley Mine Technical Assessment Report for a Proposed Discharge of Mine Effluent. In Support of an Application for the Discharge of Mine Effluent Under the Waste Discharge Regulation of the British Columbia *Environmental Management Act*. [https://www.mountpolleyreviewpanel.ca/sites/default/files/background-documents/MOE00001_2009-07_MPMC_Mount%20Polley%20Mine%20Technical%20Assessment%20Report%20for%20a%20Proposed%20Discharge%20of%20Mine%20Effluent.pdf]. Accessed 10 Dec 2017.

MPMC. 2014a. Quesnel Lake Cloudiness at Lake Overturn. Public information bulletin distributed by post. 14 November 2014. 4 p.

MPMC. 2014b. Baseline/Background Water Chemistry Data Search for the MPMC PEEIAR. Memorandum from McMahen K, MPMC to van Geest J, Golder Associates Ltd. 26 March 2014. 10 p.

MPMC. 2015a. Post-Event Environmental Impact Assessment Report – Key Findings Report. 5 June 2015. Submitted to Ministry of Environment.

MPMC. 2015b. Quesnel Lake Water Clarity at Lake Overturn – Fall 2015. MPMC Information Bulletin. [https://www.imperialmetals.com/assets/docs/mt-polley/2015-11-10_QLWCALO.pdf] Accessed 22 March 2019.

Mudroch A, Hall GEM, Azcue J, Jackson TA, Reynoldson T, Rosa F. 1993. Preliminary report on the effects of abandoned mine tailings at Wells, BC, on the aquatic ecosystem of Jack of Clubs Lake. Part I: reconnaissance study. Fraser River Action Plan DOE FRAP 1993-07.

Newbury, RW and Gabourey MN. 1993. Stream Analysis and Fish Habitat Design: A Field Manual. Newbury Hydraulics Ltd. Gibsons, BC.

Nidle B, Shortreed KS, Masuda K. 1994. Limnological data from the 1985-1990 study of Quesnel Lake. Can Dat Rep Fish Aquat Sci 940. pp. 82.

Nikl L, Wernick B, Van Geest J, Hughes C, McMahen K, Anglin CD. 2016. Mount Polley Mine Embankment Breach: Overview of Aquatic Impacts and Rehabilitation. In: Proceedings Tailings and Mine Waste. 2016. Keystone, Colorado, USA. 2-5 October 2016.

Nilsson HC, Rosenberg R. 2000. Succession in marine benthic habitats and fauna in response to oxygen deficiency: analysed by sediment profile-imaging and by grab samples. Marine Ecological Progress Series 197:139-149.

NOAA (National Oceanic and Atmospheric Administration). 1995. Habitat equivalency analysis: an overview. NOAA Damage Assessment and Restoration Program, Policy and Technical Paper Series, No. 95-1 (revised 2006).

Norkko A, Bonsdorff E. 1996. Rapid zoobenthic community responses to accumulations of drifting algae. Marine Ecological Progress Series 131:143-157.

Ogilvie J, Topps H, Nikl L. 2018. An innovative approach to monitoring the physical stability of constructed fish habitat using drones. Proceedings of the British Columbia Mine Reclamation Symposium; 17-20 September 2018; Williams Lake BC: Technical and Research Committee on Reclamation.

Ohsowski BM, Klironomos JN, Dunfield KE, Hart MM. 2012. The potential of soil amendments for restoring severely disturbed grasslands. Applied Soil Ecology 60:77-83.

Oliver JS, Slattery PN, Hulberg LW, Nybakken JW. 1977. Patterns of succession in benthic infaunal communities following dredging and dredged material disposal in Monterey Bay. Environmental Effects Laboratory: United States Army Engineer Waterways Experiment Station, 1-192.

Olsgard F, Hasle JR. 1993. Impact of waste from titanium mining on benthic fauna. Journal Experimental Marine Biology and Ecology 172:185-213.

Parkinson EA, Hume JM, Dolighan R. 1989. Size selective predation by Rainbow Trout on two lacustrine Oncorhynchus nerka populations. Fisheries Management Report No. 94.

Pedersen R. 1998. Overview Report. Quesnel River Study Area. Fish Habitat Assessment Procedure. Prepared for Weldwood of Canada Ltd., Cariboo Division, Williams Lake Operations. Submitted March 1998. [http://www.env.gov.bc.ca/cariboo/env_stewardship/wrp/reports/fhap/quesnel/quesnel.html#_Toc414700241]. Accessed 8 March 2019.

Pennak, RW. 1978. Fresh-water invertebrates of the United States. 2nd Ed. John Wiley & Sons.

Perrin CJ, Stables TB. 2000. Restoration of fish populations in Wahleach Reservoir, 1997 – 1999. Report prepared by Limnotek Research and Development Inc. for B.C. Hydro. 175p.

Perrin CJ, Stables TB. 2001. Restoration of fish populations in Wahleach Reservoir: Fish and zooplankton in 2000. Report prepared by Limnotek Research and Development Inc. for B.C. Ministry of Water Land and Air Protection. 67p.

Pioch S, Johnston MW, Vaissièrec AC, Bergerd F, Jacoba C, Dodge R. 2017. An update of the Visual_HEA software to improve the implementation of the Habitat Equivalency Analysis method. Ecological Engineering 105:276-283.

Pojar J, Klinka K, Meidinger DV. 1987. Biogeoclimatic Ecosystem Classification in British Columbia. Forest Ecology and Management 22:119-154.

Province of British Columbia. 2019. Reference Guide for Forest Development Stocking Standards. XLSX document updated March 2019. [https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/stocking-standards]. Accessed 11 March 2019.

Samuelsson GS, Raymon C, Agrenius S, Schaanning M, Corneliessen G, Bunnarsson JS. 2017. Response of marine benthic fauna to thin-layer capping with activated carbon in a large-scale field experiment in the Grenland fjords, Norway. Environ Sci Pollu Res 24:14218 – 14233.

Scott W, Crossman E. 1973. Freshwater Fishes of Canada. Oakville, ON. Galt House Publications Ltd. 966 pp.

Shortreed KS, Morton KF, Malange K, Hume JMB. 2001. Factors limiting juvenile sockeye production and enhancement potential for selected B.C. nursery lakes. Canadian Science Advisory Secretariat Research Document 2001/098. 69 p.

Slaney PA and Zaldokas D. 1997. Fish Habitat Rehabilitation Procedures. Watershed Technical Circular No. 9.

Smith DG, Croker GF, McFarlane K. 1995. Human Perception of Water Appearance. New Zealand Journal of Marine and Freshwater Research 29:45-50.

SNC (SNC-Lavalin). 2015a. Mount Polley Tailings Storage Facility Failure – Fish and Fish Habitat Impact Assessment. Prepared for Mount Polley Mining Corporation. June 3, 2015. 66 p + Appendices.

SNC. 2015b. Mount Polley Hydrotechnical and Geomorphological Impact Assessment. Prepared for Mount Polley Mining Corporation. June 4, 2015. 108 p + Appendices.

Stockner JG, Shortreed KS. 1985. Whole-Lake Fertilization Experiments in Coastal British Columbia Lakes: Empirical Relationships Between Nutrient Inputs and Phytoplankton Biomass and Production. Canadian Journal of Fisheries and Aquatic Sciences 42(4):649-658.

Stockner JG, Shortreed KS. 1994. Autotrophic picoplankton community dynamics in a pre-alpine lake in British Columbia, Canada. In: Fott J (ed.). Limnology of Mountain Lakes. Dordrecht: Springer. p. 133-142.

Tabor RA, Footen BA, Fresh KL, Celedonia MT, Mejia F, Low DL, Park L. 2007. Smallmouth bass and largemouth bass predation on juvenile Chinook salmon and other salmonids in the Lake Washington basin. North American Journal of Fisheries Management 27(4):1174-1188.

Tabor RA, Shively RS, Poe TP. 1993. Predation of juvenile salmonids by smallmouth bass and northern squawfish in the Columbia River near Richland, Washington. North American Journal of Fisheries Management 13(4):831-838.

Tetra Tech (Tetra Tech EBA Inc.). 2015a. Quesnel Lake Water Column Observations and Modelling. Prepared for MPMC. May 2015.

Tetra Tech. 2015b. Bathymetry Analysis and Volume Balance. Prepared for Mount Polley Mining Corporation. May 2015.

Tetra Tech. 2017. Evaluation of the Potential for Sediment Resuspension in Quesnel Lake during Overturn: An Integration of Available Information. Technical Memorandum prepared for MPMC. 5 April 2017.

Thompson LC. 1999. Abundance and production of zooplankton and kokanee salmon (Oncorhynchus nerka) in Kootenay Lake, British Columbia during artificial fertilization. Ph. D Thesis. Vancouver: University of British Columbia, Department of Zoology. 252p.

Van Dolah RF, Calder DR, Knott DM. 1984. Effects of dredging and open-water disposal on benthic macroinvertebrates in a South Carolina estuary. Estuaries 7(1):28-37.

Votapka FE. 1991. Considerations for fish passage through culverts. Transportation Research Record, 1291:347-353.

Walker LR, del Moral R. 2003. Primary Succession and Ecosystem Rehabilitation. Cambridge University Press, New York, USA.

Wallace JB, Anderson NH. 1995. Habitat, life history, and behavioral adaptations of aquatic insects. In: Merritt RW, Cummins KW (eds.). An introduction to the aquatic insects of North America, 3rd ed. Kendall/Hunt Publishing Company.

Weidel BC, Josephson DC, Kraft CE. 2007. Littoral fish community response to smallmouth bass removal from an Adirondack lake. American Fisheries Society, 136:778-789.

APPENDIX A

List of Design and Record Drawings Issued for Hazeltine Creek Habitat Remediation

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
001	General Cover Sheet and Drawing List	1	15 June 2017	ISSUED FOR CONSTRUCTION	Golder
010	General General Notes	1	15 June 2017	ISSUED FOR CONSTRUCTION	Golder
050	General Hazeltine Creek Access Roads	1	15 June 2017	ISSUED FOR CONSTRUCTION	Golder
100	Channel Work Alignment and Profile Full Alignment	0	19 November 2015	ISSUED FOR RECORD	Golder
101	Channel Work Alignment and Profile Chainage 0+000 to 1+200	0	19 November 2015	ISSUED FOR RECORD	Golder
102	Channel Work Alignment and Profile Chainage 1+200 to 2+400	0	19 November 2015	ISSUED FOR RECORD	Golder
103	Channel Work Alignment and Profile Chainage 2+400 to 3+600	0	19 November 2015	ISSUED FOR RECORD	Golder
104	Channel Work Alignment and Profile Chainage 3+600 to 4+800	0	19 November 2015	ISSUED FOR RECORD	Golder
105	Channel Work Alignment and Profile Chainage 4+800 to 6+000	0	19 November 2015	ISSUED FOR RECORD	Golder
106	Channel Work Alignment and Profile Chainage 6+000 to 6+600	0	19 November 2015	ISSUED FOR RECORD	Golder
106A	Channel Work Alignment and Profile Chainage 7+775 to 9+068	0	19 November 2015	ISSUED FOR RECORD	Golder
107	Channel Work Typical Meander Pattern Geometry Plan	0	19 November 2015	ISSUED FOR RECORD	Golder

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
108	Channel Work Reach 1 Typical Civil Section	0	19 November 2015	ISSUED FOR RECORD	Golder
109	Channel Work Reach 2 Typical Civil Section	0	19 November 2015	ISSUED FOR RECORD	Golder
110	Channel Work Reach 3 Typical Civil Section	0	19 November 2015	ISSUED FOR RECORD	Golder
111	Channel Work Reach 5 Typical Civil Section	0	19 November 2015	ISSUED FOR RECORD	Golder
112	Channel Work Reach 6 (Edney Creek) Typical Civil Section	0	19 November 2015	ISSUED FOR RECORD	Golder
120	Channel Work Hazeltine Creek Temporary Overflow Plan and Profile	0	19 November 2015	ISSUED FOR RECORD	Golder
121	Channel Work Hazeltine Creek Temporary Overflow Sections and Details	0	19 November 2015	ISSUED FOR RECORD	Golder
130	Channel Work Reach 6 (Edney Creek) Shoreline Restoration Plan	0	19 November 2015	ISSUED FOR RECORD	Golder
131	Channel Work Reach 6 (Edney Creek) Shoreline Restoration Sections and Details	0	19 November 2015	ISSUED FOR RECORD	Golder
140	Channel Work Reach 1 Habitat Construction Full Alignment and Profile	1	09 February 2017	ISSUED FOR RECORD	Golder
141	Channel Work Reach 1 Habitat Construction Alignment and Profile (0+200 to 0+600)	1	09 February 2017	ISSUED FOR RECORD	Golder
142	Channel Work Reach 1 Habitat Construction Alignment and Profile (0+600 to 1+000)	1	09 February 2017	ISSUED FOR RECORD	Golder

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
143	Channel Work Reach 1 Habitat Construction Alignment and Profile (1+000 to 1+400)	1	09 February 2017	ISSUED FOR RECORD	Golder
150	Channel Work Reach 2 Habitat Construction Full Alignment and Profile	3	15 December 2017	ISSUED FOR RECORD	Golder
151	Channel Work Reach 2 Habitat Construction Alignment and Profile 1+100 to 1+500	3	15 December 2017	ISSUED FOR RECORD	Golder
152	Channel Work Reach 2 Habitat Construction Alignment and Profile 1+500 to 1+900	3	15 December 2017	ISSUED FOR RECORD	Golder
153	Channel Work Reach 2 Habitat Construction Alignment and Profile 1+900 to 2+300	3	15 December 2017	ISSUED FOR RECORD	Golder
154	Channel Work Reach 2 Habitat Construction Alignment and Profile 2+300 to 2+700	3	15 December 2017	ISSUED FOR RECORD	Golder
155	Channel Work Reach 2 Habitat Construction Detailed Survey, Typical Construction	3	15 December 2017	ISSUED FOR RECORD	Golder
160	Channel Work Reach 3 Habitat Construction Full Alignment and Profile	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
161	Channel Work Reach 3 Habitat Construction Alignment and Profile 2+600 to 3+000	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
162	Channel Work Reach 3 Habitat Construction Alignment and Profile 3+000 to 3+400	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
163	Channel Work Reach 3 Habitat Construction Alignment and Profile 3+400 to 3+800	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
164	Channel Work Reach 3 Habitat Construction Alignment and Profile 3+800 to 4+200	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
165	Channel Work Reach 3 Habitat Construction Alignment and Profile 4+200 to 4+600	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
166	Channel Work Reach 3 Habitat Construction Alignment and Profile 4+600 to 5+000	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
167	Channel Work Reach 3 Habitat Construction Alignment and Profile 5+000 to 5+400	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
168	Channel Work Reach 3 Habitat Construction Alignment and Profile 5+400 to 5+800	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
169	Channel Work Reach 3 Habitat Construction Alignment and Profile 5+800 to 6+200	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
170	Channel Work Reach 3 Habitat Construction Alignment and Profile 6+200 to 6+450	0	31 May 2018	ISSUED FOR CONSTRUCTION	Golder
180	Channel Work Reach 5 Habitat Construction Full Alignment and Profile	A		ISSUED FOR DISCUSSION	Golder
181	Channel Work Reach 5 Habitat Construction Alignment and Profile 7+700 to 8+100	A		ISSUED FOR DISCUSSION	Golder
182	Channel Work Reach 5 Habitat Construction Alignment and Profile 8+100 to 8+500	A		ISSUED FOR DISCUSSION	Golder
201	Channel Work Conceptual Section 5 Years After Planting	0	19 November 2015	ISSUED FOR USE	Envirowest
210	Channel Work Reach 1 Typical Plan Habitat Detail Without Woody Debris	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
211	Channel Work Reach 1 Typical Profile Habitat Detail Weir and Bedload Stabilizer	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
211A	Channel Work Reach 1 Typical Profile Habitat Detail Weir and Bedload Stabilizer	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
212	Channel Work Reach 1 Typical Profile Habitat Detail	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
213	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 1	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
214	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 2	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
215	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 3	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
216	Channel Work Reach 1 Typical Plan Habitat Detail With Woody Debris	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
217	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 1	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
218	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 2	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
219	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 3	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
219A	Channel Work Reach 1 Typical Sections Habitat Detail Sheet 4	0	08 October 2016	ISSUED FOR CONSTRUCTION	Envirowest
220	Channel Work Reach 2 Typical Plan Habitat Detail Without Woody Debris	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
221	Channel Work Reach 2 Typical Plan Habitat Detail Without Woody Debris	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
222	Channel Work Reach 2 Typical Profile Habitat Detail Weir	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
222A	Channel Work Reach 2 Typical Profile Habitat Detail Weir	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
223	Channel Work Reach 2 Typical Profile Habitat Detail Weir	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
223A	Channel Work Reach 2 Typical Profile Habitat Detail Weir and Bedload Stabilizer	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
224	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 1	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
225	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 2	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
226	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 3	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
227	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 4	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
228	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 5	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
229	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 6	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
230	Channel Work Reach 2 Typical Plan Habitat Detail With Woody Debris	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
231	Channel Work Reach 2 Typical Plan Habitat Detail With Woody Debris	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
232	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 1	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
233	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 2	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
234	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 3	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
235	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 4	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
236	Channel Work Reach 2 Typical Sections Habitat Detail Sheet 5	2	15 June 2017	ISSUED FOR CONSTRUCTION	Envirowest
240	Channel Work Reach 3 Typical Plan Habitat Detail Off-Line Pool Weir Without Woody Debris	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
241	Channel Work Reach 3 Typical Profile Habitat Detail Off-Line Pool Weir	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
242	Channel Work Reach 3 Typical Profile Habitat Detail Off-Line Pool Weir	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
243	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 1	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
244	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 2	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
245	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 3	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
246	Channel Work Reach 3	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
	Typical Plan Habitat Detail Off-Line Pool Weir With Woody Debris				
247	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 1	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
248	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 2	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
249	Channel Work Reach 3 Typical Sections Habitat Detail Off-Line Pool Weir Sheet 3	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
250	Channel Work Reach 3 Typical Plan Habitat Detail In-Line Pool Weir Without Woody Debris	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
251	Channel Work Reach 3 Typical Plan Habitat Detail Glide Without Woody Debris	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
252	Channel Work Reach 3 Typical Profile Habitat Detail In-Line Pool Weir	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
253	Channel Work Reach 3 Typical Profile Habitat Detail In-Line Pool Weir and Bedload Stabilizer	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
254	Channel Work Reach 3 Typical Sections Habitat Detail In-Line Pool	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
	Weir Sheet 1				
255	Channel Work Reach 3 Typical Sections Habitat Detail In-Line Pool Weir and Glide Sheet 2	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
256	Channel Work Reach 3 Typical Sections Habitat Detail Glide Sheet 3	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
257	Channel Work Reach 3 Typical Plan Habitat Detail In-Line Pool Weir With Woody Debris	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
258	Channel Work Reach 3 Typical Plan Habitat Detail Glide With Woody Debris	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
259	Channel Work Reach 3 Typical Sections Habitat Detail In-Line Pool Weir Sheet 1	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
260	Channel Work Reach 3 Typical Sections Habitat Detail	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
261	Channel Work Reach 3 Typical Wetland Plan, Profile And Section	1	31 May 2018	ISSUED FOR CONSTRUCTION	Envirowest
262	Channel Work Reach 6 Typical Profile Habitat Detail	0	19 November 2015	ISSUED FOR USE	Envirowest
263	Channel Work Reach 6	0	19 November 2015	ISSUED FOR USE	Envirowest

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
	Typical Sections Habitat Detail Sheet 1				
264	Channel Work Reach 6 Typical Sections Habitat Detail Sheet 2	0	19 November 2015	ISSUED FOR USE	Envirowest
280	Polley Lake Outlet Structure Fish Exclusion at Polley Lake Plan	0	19 November 2015	ISSUED FOR RECORD	Golder
281	Polley Lake Outlet Structure Fish Exclusion at Polley Lake Details (1 of 2)	0	19 November 2015	ISSUED FOR RECORD	Golder
282	Polley Lake Outlet Structure Fish Exclusion at Polley Lake Details (2 of 2)	0	29 September 2015	ISSUED FOR CONSTRUCTION	Golder
283	Fish Exclusion at Reach 2 Reach 2 Plan Sheet 1	1	09 May 2018	ISSUED FOR RECORD	Golder
284	Fish Exclusion at Reach 2 Reach 2 Details (1 of 2) Sheet 2	1	09 May 2018	ISSUED FOR RECORD	Golder
285	Fish Exclusion at Reach 2 Reach 2 Details (2 of 2) Sheet 3	1	09 May 2018	ISSUED FOR RECORD	Golder
290	Polley Lake Outlet Structure Overall General Arrangement Plan	1	08 April 2015	ISSUED FOR RECORD	Golder
300	Polley Lake Outlet Structure Existing Geotechnical Conditions Plan, Elevation, Section	2	08 April 2015	ISSUED FOR RECORD	Golder
301	Polley Lake Outlet Structure General Arrangement and Notes Plan, Elevation, Section	3	08 April 2015	ISSUED FOR RECORD	GEA

No.	Drawing Title	Rev	Issue Date	Issue Purpose	Lead
302	Polley Lake Outlet Structure Weir Structure Plan, Elevation, Section	1	08 April 2015	ISSUED FOR RECORD	GEA
303	Polley Lake Outlet Structure Weir Structure Details	1	08 April 2015	ISSUED FOR RECORD	GEA
304	Polley Lake Outlet Structure Access Walkway Plan, Elevation, Section	2	08 April 2015	ISSUED FOR RECORD	GEA
305	Polley Lake Outlet Structure Access Walkway Details	1	08 April 2015	ISSUED FOR RECORD	GEA
306	Polley Lake Outlet Structure Flashboards Detail	1	08 April 2015	ISSUED FOR RECORD	GEA
310	Polley Lake Outlet Structure Pool-Weir Fishway General Arrangement Plan	0	04 May 2018	ISSUED FOR CONSTRUCTION	Golder
311	Polley Lake Outlet Structure Pool-Weir Fishway Plan and Section	0	04 May 2018	ISSUED FOR CONSTRUCTION	Golder
312	Polley Lake Outlet Structure Pool-Weir Fishway Sections and Detail	0	04 May 2018	ISSUED FOR CONSTRUCTION	Golder

APPENDIX B

Offsetting Ideas Discussion

Appendix C: Offsetting Ideas Tabulated by Rank, Source, Location and Project Description (assembled by MPMC)

Rank	Source	Location	Project Description
1	Richard Holmes	Horsefly River	Various creeks through out the Horsefly watershed can be addressed. Detailed info is available in the FRBC data bank (this is paper copy only). See Appendix D.
2	Richard Holmes	Quesnel River	DFO rearing channels downstream of the Likely Bridge in Likely, BC.
3	Judy Hillaby	Horsefly River	Erosion near Mitchell Bay has high potential to under cut the access road. Would also effect fish passage.
4	Steve Hoxquard	Moffat Creek	Improve bank and channel stability. Preliminary Assessments have been done.
5	Colleen Hughes	Horsefly Spawning Channel	https://www.wltribune.com/community/horsefly-salmon-festival-creates-hopeful-future-for-run/ https://www.wltribune.com/community/horsefly-river-celebrates-sockeye-salmon-run-with-festival-sept-15-to-16/
6	Colleen Hughes	Future	River watcher Camera system (Lee Williston agreed this has potential offset value).

APPENDIX C

Offsetting Activities - Barrier Removal

Table 1: Potential Habitat Offsetting Activities

UTM V10 Easting	UTM V10 Northing	Stream Name	Potential OffsetArea m²	Habitat Value	Barrier Type	Potential Actions
629036	5790127	Tributary to Tisdal Creek	0.4	Low habitat value	Round Culvert	Remove / Deactivate Crossing
608521	5789299	Tributary to Deerhorn Creek	0.7072	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667223	5788229	Tributary to McKusky	1.8	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
644448	5782473	Tributary to Gifford Creek	1.845	Low habitat value	Round Culvert	Remove / Deactivate Crossing
619736	5804825	Tributary to Horsefly Lake	2.32	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
644343	5782524	Gifford Creek	2.337	Low habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
647524	5802450	Tributary to Horsefly River	2.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667778	5812480	Tributary to Horsefly River	2.45	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619627	5804861	Tributary to Horsefly Lake	2.646	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
623777	5804692	Tributary to Horsefly Lake	2.72	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655477	5791032	Tributary to Crooked Lake	2.775	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
652165	5804957	Tributary to Horsefly River	2.79	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616578	5789961	Tributary to Deerhorn Creek	2.79	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
613736	5804540	Tributary to Little Horsefly Lake	2.79	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604944	5803419	Tributary to Horsefly River	2.85	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
649298	5811275	Tributary to Archie Creek	2.88	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
632935	5787249	Tributary to Tisdall Lake	2.945	Low habitat value	Round Culvert	Remove / Deactivate Crossing
651668	5793449	Tributary to McKee Lake	3.2	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
635892	5786487	Tributary to Tisdall Lake	3.33	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653381	5796283	Tributary to McKusky	3.3425	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
609874	5804163	Tributary to Horsefly River	3.35	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614755	5780375	Tributary to Moffat Creek	3.36	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
613146	5787564	Tributary to Deerhorn Creek	3.395	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607607	5781786	Tributary to Moffat Creek	3.4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607954	5781983	Tributary to Moffat Creek	3.42	Low habitat value	Round Culvert	
612506	5802698	Tributary to Gruhs Lake	3.422	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653814	5816150	Tributary to Horsefly Lake	3.45	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659676	5789476	Tributary to Crooked Lake	3.471	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604727	5791045	Tributary to Moffatt Creek	3.48	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
610978	5797871	Tributary to Horesfly River	3.485	Low habitat value	Round Culvert	Remove / Deactivate Crossing
620355	5794680	Tributary to Horsefly River	3.5	Low habitat value	Round Culvert	Replace with new open bottom structure
601709	5782629	Tributary to Moffat Creek	3.6	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
666828	5813435	Tributary to Horsefly River	3.608	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667377	5796996	Tributary to MacKay River	3.63	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633971	5810567	Tributary to Horsefly Lake	3.65	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
634461	5811949	Tributary to Melissa Lake	3.65	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611137	5797750	Tributary to Horesfly River	3.66	Low habitat value	Round Culvert	Remove / Deactivate Crossing
606438	5794411	Trib to Moffat Creek	3.76	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
605426	5807405	Tributary to Horsefly River	3.76	Low habitat value	Round Culvert	
636152	5787883	Tributary to Tisdall Lake	3.78	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604027	5803249	Tributary to Horsefly River	3.78	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
645561	5787717	Tributary to McKinley Creek	3.8	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
666759	5813368	Tributary to Horsefly River	3.8425	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
620241	5778962	Tributary to Moffat Creek	3.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
642960	5791191	Tributary to McKinley Creek	3.96	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
604682	5791178	Tributary to Moffatt Creek	3.965	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667412	5796996	Tribuatry to Mackay River	3.995	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
666649	5797782	Tributary to MacKay River	3.995	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655839	5790234	Tributary to McKusky	4	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS

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651270	5789930	Tributary to McKee Lake	4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616791	5781243	Tributary to Moffat Creek	4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655965	5794049	Tributary to Crooked Lake	4.03	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617102	5778452	Tributary to Moffat Creek	4.04	Medium habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
613455	5781273	Tributary to Moffat Creek	4.05	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614339	5788920	Tributary to Deerhorn Creek	4.068	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
627041	5785630	Trib to Moffat Creek	4.095	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
633877	5786741	Tributary to Tisdall Lake	4.14	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
621804	5803734	Tributary to Horsefly Lake	4.2	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
643441	5814754	Tributary to Viewland Creek	4.24	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611271	5810434	Tributary to Horsefly River	4.24	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
657110	5808270	Tributary to Horsefly River	4.275	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633922	5811033	Tributary to Horsefly Lake	4.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617343	5794652	Tributary to Horsefly River	4.32	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
615557	5812875	Tributary to Niquidet Lake	4.32	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
624689	5792394	Trib to Horsefly River	4.32	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608775	5773518	Tributary to McIntosh Lake	4.35	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
657223	5808382	Tributary to Horsefly River	4.35	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614221	5804599	Tributary to Little Horsefly Lake	4.4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
634950	5787953	Tributary to Tisdall Lake	4.41	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
632849	5780375	Tributary to Moffat Lakes	4.455	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607984	5798591	Tributary to Horsefly River	4.48	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
666477	5813261	Tributary to Horsefly River	4.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622806	5803932	Tributary to Horsefly Lake	4.512	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616229	5802922	Tributary to Horsefly Lake	4.556	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628474	5810503	Tributary to Viewland Creek	4.56	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618340	5777578	Tributary to Moffat Creek	4.56	Medium habitat value	Round Culvert	
651556	5787456	Tributary to Bassett Creek	4.6	Low habitat value	Round Culvert	Remove / Deactivate Crossing
642227	5796891	Tributary to Doreen Creek	4.6	High habitat value	Round Culvert	Remove / Deactivate Crossing
605776	5799058	Tributary to Horsefly River	4.62	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633093	5788858	Tributary to Tisdall Lake	4.68	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
610721	5797864	Tributary to Horesfly River	4.68	Low habitat value	Round Culvert	Remove / Deactivate Crossing
621680	5798179	Tributary to Sucker Creek	4.698	Low habitat value	Round Culvert	Remove / Deactivate Crossing
645095	5790160	Triburtary to McKinley	4.77	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
621190	5795749	Sucker Creek	4.77	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
615651	5808419	Tributary to Niquidet Creek	4.77	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619927	5793997	Trib to Horsefly River	4.774	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
636747	5806200	Prairie Creek	4.8	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
652140	5809944	Tributary to Archie Creek	4.8	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
634582	5781549	Tributary to Moffat Creek	4.838	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
636052	5788298	Tributary to Tisdall Lake	4.845	Low habitat value	Round Culvert	Remove / Deactivate Crossing
612801	5782409	Tributary to Moffat Creek	4.876	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604076	5772518	Tributary to McIntosh Lake	4.902	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607593	5798249	Tributary to Horsefly River	4.928	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
632939	5784170	Tributary to Tisdall Lake	4.95	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
650873	5810243	Tributary to Archie Creek	4.95	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619943	5793571	Trib to Horsefly River	4.95	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
652458	5784933	Tributary to Cruiser Lake	5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
649689	5781316	Tributary to Bosk Lake	5	High habitat value	Round Culvert	Remove / Deactivate Crossing
617598	5792454	Tributary to Woodjam Creek	5	High habitat value	Round Culvert	Replace with new open bottom structure
633086	5787063	Tributary to Tisdall Lake	5.04	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608753	5790556	Tributary to Deerhorn Creek	5.043	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
605513	5788128	Tributary to Mussel Creek	5.044	Low habitat value	Round Culvert	Remove / Deactivate Crossing

616127	5789789	Tributary to Deerhorn Creek	5.096	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
632054	5791857	Tributary to Tisdall Lake	5.1	Low habitat value	Round Culvert	
660144	5802387	Tributary to Mackay River	5.13	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
622291	5792697	Tributary to Horsefly River	5.13	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611747	5784072	Tributary to Mussel Creek	5.15	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628044	5783929	Tributary to Moffat Creek	5.15	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656833	5787257	Tributary to Bassett Creek	5.16	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
601963	5772656	Tributary to McIntosh Lake	5.208	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
649348	5805647	Tributary to Horsefly River	5.225	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630078	5790182	Tributary to Tisdal Creek	5.225	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
637528	5790388	Tributary to Tisdall Creek	5.25	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604467	5793007	Tributary to Moffatt Creek	5.25	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648284	5799690	Tributary to McKusky	5.28	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656180	5809194	Archie Creek	5.28	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611362	5806270	Tributary to Alah Creek	5.3	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
657132	5806304	Tributary to Horsefly River	5.301	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
601577	5782301	Tributary to Moffat Creek	5.31	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611793	5809141	Tributary to Horsefly River	5.36	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
614120	5788477	Tributary to Deerhorn Creek	5.365	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
612676	5781839	Tributary to Moffat Creek	5.4	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
625299	5800295	Tributary to Sucker Creek	5.4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
635478	5780368	Tributary to Moffat Lakes	5.4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651585	5792399	Tributary to McKee Lake	5.46	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
653395	5786311	Tributary to McKinley	5.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630271	5783381	Tributary to Moffat Creek	5.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
613272	5781899	Tributary to Moffat Creek	5.52	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
635354	5780326	Tributary to Moffat Lakes	5.52	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625401	5800274	Tributary to Sucker Creek	5.6	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647577	5799314	Tributary to McKusky	5.67	High habitat value	Round Culvert	Remove / Deactivate Crossing
609384	5802469	Tributary to Little Horsefly River	5.67	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611452	5809767	Tributary to Horsefly River	5.67	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
626132	5790354	Trib to Horsefly River	5.67	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
615201	5808459	Tributary to Douglas Lake	5.67	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659373	5803746	Tributary to Mckay	5.7	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619772	5793798	Trib to Horsefly River	5.723	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
644896	5790646	Triburtary to McKinley	5.796	Low habitat value	Round Culvert	Remove / Deactivate Crossing
609722	5806663	Tributary to Horsefly River	5.82	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630761	5799325	Tributary to Black Creek	5.8275	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607938	5800954	Tributary to Horsefly River	5.83	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
643497	5815129	Tributary to Viewland Creek	5.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
640779	5816295	Tributary to Horsefly Lake	5.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607599	5805267	Tributary to Horselfy River	5.85	Medium habitat value	Round Culvert	
615684	5781465	Tributary to Moffat Creek	5.91	Low habitat value	Round Culvert	Remove / Deactivate Crossing
651115	5781072	Tributary to Bosk Lake	5.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
649587	5805478	Tributary to Horsefly River	5.94	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628876	5790063	Tributary to Tisdal Creek	5.945	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
652707	5788790	Tributary to McKee Lake	6	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
608499	5801347	Tributary to Horsefly River	6	Low habitat value	Oval Culvert	Replace structure with streambed simulation CBS
615487	5811229	Tributary to Niquidet Creek	6.03	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
614506	5789132	Tributary to Deerhorn Creek	6.032	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
650584	5805642	Tributary to Horsefly River	6.11	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
627964	5776525	Tributary to Moffat Creek	6.144	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
621821	5793787	Trib to Horsefly River	6.15	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS

626601	5792471	Trib to Horsefly River	6.18	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651553	5802229	Tributary to Horsefly River	6.24	Low habitat value	Round Culvert	Remove / Deactivate Crossing
617586	5811080	Tributary to Dillabough Lake	6.3	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
614691	5790286	Trib to Deerhorn Creek	6.3	Medium habitat value	Round Culvert	Replace with new open bottom structure
615397	5784794	Tributary to Woodjam Creek	6.3945	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
631035	5789455	Tributary to Tisdal Lake	6.45	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
627329	5786241	Tributary to Moffat Creek	6.461	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651752	5801411	Tributary to Horsefly River	6.468	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
635691	5792423	Tributary to Horsefly River	6.48	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626543	5801380	Tributary to horsefly Lake	6.5	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
608200	5793772	Tributary to Moffat Creek	6.534	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
666897	5787931	Tributary to McKusky	6.57	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
640893	5815702	Tributary to Horsefly Lake	6.57	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
658559	5803967	Tributary to Horsefly River	6.6	Low habitat value	Round Culvert	Remove / Deactivate Crossing
664343	5798983	Tributary to Eureka Creek	6.6	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
635139	5812792	Tributary to Melissa Lake	6.64	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
643506	5805287	Tributary to Sawley	6.66	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
651693	5810171	Tributary to Archie Creek	6.66	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
638271	5787802	Tributary to Tisdall Lake	6.665	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633249	5782877	Tributary to Moffat Creek	6.6825	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
609905	5804157	Tributary to Horsefly River	6.7	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
609972	5801787	Tributary to Little Horsefly River	6.72	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
624837	5804931	Tributary to Horsefly Lake	6.745	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
632927	5785411	Tributary to Tisdall Lake	6.75	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
656513	5807890	Tributary to Horsefly River	6.75	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
612263	5812747	Tributary to Murdock Lakes	6.79	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
637437	5802701	Tributary to Prarie Creek	6.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617602	5810715	Tributary to Dillabough Lake	6.93	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
621506	5778799	Tributary to Moffat Creek	6.935	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
610905	5797857	Tributary to Horesfly River	6.96	Low habitat value	Round Culvert	Remove / Deactivate Crossing
618001	5807650	Tributary to Horsefly Lake	6.96	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611747	5788176	Unnamed	7	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629213	5790375	Tributary to Tisdal Creek	7	Low habitat value	Round Culvert	Remove / Deactivate Crossing
610409	5809128	Tributary to Horsefly River	7	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
633896	5779180	Tributary to Moffat Lakes	7.0125	Medium habitat value	Round Culvert	Add substrate to further imbed the CBS
638559	5804941	Tributary to Prairie Creek	7.015	High habitat value	Round Culvert	Remove / Deactivate Crossing
634383	5792524	Unnamed	7.084	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
658173	5777617	Tributary to Gotchen Lake	7.1	Low habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
600396	5773939	Tributary to McIntosh Lakes	7.1175	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
625933	5800502	Tributary to Sucker Creek	7.2	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625026	5800412	Tributary to Sucker Creek	7.2	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
628170	5776356	Tributary to Moffat Creek	7.221	Low habitat value	Round Culvert	Remove / Deactivate Crossing
658888	5789803	Tributary to McKusky	7.25	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618207	5777567	Tributary to Moffat Creek	7.259	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
613425	5781675	Tributary to Moffat Creek	7.26	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
644173	5784045	Tributary to McKinley Creek	7.28	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667315	5797115	Tributary to MacKay River	7.304	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
621756	5787932	Trib to Moffat Creek	7.315	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
607560	5806115	Tributary to Horsefly River	7.35	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
627084	5784153	Tributary to Moffat Creek	7.36	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656042	5791348	Tributary to Crooked Lake	7.41	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
643327	5806203	Tributary to Sawley	7.41	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
622805	5776303	Tributary to Moffat Creek	7.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS

632225	5779257	Tributary to Moffat Lakes	7.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653421	5810659	Tributary to Teapot Creek	7.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608496	5783337	Tributary to Moffat Creek	7.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617944	5811678	Tributary to Dillabough Lake	7.47	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629766	5809172	Tributary to Horsefly Lake	7.56	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
612706	5808843	Tributary to Horsefly River	7.56	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
638731	5809353	Tributary to Horsefly Lake	7.6	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
645369	5777884	Tributary to Molybdenite Creek	7.622	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
643343	5804994	Tributary to Sawley	7.65	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
626223	5792750	Trib to Horsefly River	7.65	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
640107	5808952	Tributary to horsefly Lake	7.6725	Low habitat value	Round Culvert	Remove / Deactivate Crossing
641403	5809401	Tributary to horsefly Lake	7.68	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
665341	5813548	Tributary to Horsefly River	7.719	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604811	5803964	Tributary to Horsefly River	7.76	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
642992	5782234	Tributary to Molybdenite Creek	7.79	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629005	5782064	Tributary to Moffat Creek	7.82	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
637684	5809301	Tributary to Horsefly Lake	7.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
639214	5809341	Tributary to Horsefly Lake	7.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641490	5809289	Tributary to horsefly Lake	7.84	Low habitat value	Round Culvert	Remove / Deactivate Crossing
614004	5788239	Tributary to Deerhorn Creek	7.904	Medium habitat value	Round Culvert	
657131	5806598	Tributary to Horsefly River	7.912	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622803	5776314	Tributary to Moffat Creek	7.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647777	5806814	Tributary to Harvie	7.98	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625460	5802424	Tributary to Horsefly Lake	7.99	Low habitat value	Round Culvert	Remove / Deactivate Crossing
620262	5798490	Tributary to Sucker Creek	8.16	Low habitat value	Round Culvert	Remove / Deactivate Crossing
658944	5773648	Tributary to McKinley	8.178	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608337	5790289	Tributary to Deerhorn Creek	8.22	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648041	5804065	Tributary to Horsefly River	8.24	Low habitat value	Round Culvert	Remove / Deactivate Crossing
623163	5792763	Trib to Horsefly River	8.24	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
612383	5808019	Tributary to Horsefly River	8.24	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
653490	5811223	Tributary to Teapot Creek	8.277	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
654343	5794079	Tributary to Crooked Lake	8.28	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604913	5781258	Tributary to Moffat Creek	8.28	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
632699	5785715	Tributary to Tisdall Lake	8.28	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
606509	5777506	Tributary to McIntosh Lake	8.357	High habitat value	Round Culvert	
643758	5780633	Gifford Creek	8.36	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655847	5790190	Tributary to McKusky	8.385	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
652427	5804959	Tributary to Horsefly River	8.4	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608287	5789585	Tributary to Deerhorn Creek	8.466	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
644817	5789933	Tributary to McKinley Creek	8.5	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
657953	5779549	Tributary to Gotchen Lake	8.536	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633324	5782704	Tributary to Moffat Creek	8.55	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641814	5804710	Tributary to Sawley	8.55	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
628528	5810959	Tributary to Viewland Creek	8.56	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
616685	5810002	Tributary to Niquidet Creek	8.58	Medium habitat value	Round Culvert	Replace with new open bottom structure
626256	5790533	Trib to Horsefly River	8.64	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
602494	5774688	Tributary to McIntosh Lks	8.664	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
636422	5787030	Tributary to Tisdall Lake	8.68	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616145	5787092	Tributary to Woodjam Creek	8.73	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608929	5799803	Tributary to Horsefly River	8.76	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
668092	5812063	Tributary to Horsefly River	8.815	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608119	5786280	Tributary to Walters Lake	8.82	Medium habitat value	Round Culvert	
619177	5800460	Tributary to Sucker Creek	8.827	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS

658276	5777332	Tributary to Gotchen Lake	8.874	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
605995	5811984	Tributary to Horsefly River	8.906	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633335	5782647	Tributary to Moffat Creek	8.925	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656806	5807936	Tributary to Horsefly River	8.925	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641583	5808845	Tributary to horsefly Lake	8.97	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
648968	5782114	Tributary to Bosk Lake	9	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616235	5789821	Tributary to Deerhorn Creek	9	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630292	5783430	Tributary to Moffat Creek	9	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626341	5792334	Trib to Horsefly River	9	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608424	5806512	Tributary to Horsefly River	9	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
617435	5806636	Tributary to Horsefly Lake	9.04	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
644153	5790411	Tributary to McKinley Creek	9.12	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
604963	5792297	Tributary to Moffatt Creek	9.13	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
631247	5787266	Tributary to Tisdall Lake	9.145	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622610	5803340	Tributary to Horsefly Lake	9.1575	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656725	5806652	Tributary to Horsefly River	9.174	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
618047	5798831	Tributary to Gibbons Creek	9.18	Medium habitat value	Round Culvert	Add substrate to further imbed the CBS
612328	5802688	Tributary to Gruhs Lake	9.23	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
638422	5790905	Tributary to McKinley	9.24	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618917	5802895	Tributary to Horsefly Lake	9.28	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
667590	5812480	Tributary to Horsefly River	9.28	Low habitat value	Round Culvert	
626118	5784256	Trib to Moffat Creek	9.317	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
666546	5813542	Tributary to Horsefly River	9.36	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
608943	5799801	Tributary to Horsefly River	9.38	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648037	5798134	Tributary to McKusky	9.405	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
611465	5807716	Tributary to Horsefly River	9.42	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
620662	5799955	Tributary to Gibbons Creek	9.4905	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653181	5780783	Tributary to Gotchen Lake	9.5	Low habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
646528	5788581	Tributary to Elbow Lake	9.5	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
608404	5785218	Tributary to Cossack Lake	9.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614738	5786302	Tributary to Woodjam Creek	9.5	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
655516	5805017	Tributary to Mackay River	9.6	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656963	5806646	Tributary to Horsefly River	9.646	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
609132	5791625	Tributary to Deerhorn Creek	9.682	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
643914	5786800	Tributary to Molybdenite	9.69	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
658718	5789865	Tributary to Crooked Lake	9.702	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
615284	5787557	Tributary to Deerhorn Creek	9.72	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
640457	5795733	Tributary to Doreen Creek	9.785	High habitat value	Round Culvert	Remove / Deactivate Crossing
646234	5807795	Tributary to Fritz	9.81	High habitat value	Round Culvert	Remove / Deactivate Crossing
627014	5784209	Tributary to Moffat Creek	9.828	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
601943	5775045	Tributary to McIntosh Lake	9.84	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
653176	5785847		9.8875	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
641151	5791406	Tributary to McKinley Lake	9.96	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
640719	5786312	Tributary to Molybdenite	9.975	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629505	5784153	Tributary to Moffat Creek	9.991	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628797	5777961	Tributary to Moffat Creek	10.074	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
642098	5799338	Tributary to Horsefly	10.08	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
615339	5785119	Tributary to Woodjam Creek	10.1505	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
627355	5779542	Tributary to Moffat Creek	10.16	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617213	5795326	Tributary to Gibbons Creek	10.24	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622158	5786182	Tributary to Moffat Creek	10.248	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
649337	5796686	Tributary to McKusky	10.26	Low habitat value	Round Culvert	Remove / Deactivate Crossing
646807	5806842	Tributary to Horsefly River	10.266	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS

613947	5782455	Tributary to Moffat Creek	10.269	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
634227	5786612	Tributary to Tisdall Lake	10.285	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
610031	5801728	Tributary to Little Horsefly River	10.336	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619053	5799568	Tributary to Gibbons Creek	10.35	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
623988	5805297	Tributary to Horsefly Lake	10.395	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641300	5809182	Tributary to horsefly Lake	10.4	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
650994	5805609	Tributary to Horsefly River	10.44	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
614615	5780840	Tributary to Moffat Creek	10.545	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
659563	5809601	Tributary to Horsefly River	10.56	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656640	5779766	Tributary to Gotchen Lake	10.56	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629395	5795569	Tributary to Horsefly River	10.584	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619520	5779044	Tributary to Moffat Creek	10.584	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630531	5777019	Tributary to Moffat Creek	10.584	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
607312	5789951	Tributary to Mussel Creek	10.653	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647908	5800744	Tributary to McKusky	10.67	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
615246	5779685	Tributary to Moffat Creek	10.68	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641415	5808968	Tributary to horsefly Lake	10.72	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
668502	5811416	Tributary to Horsefly River	10.725	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
637550	5802695	Tributary to Prarie Creek	10.8	Low habitat value	Round Culvert	Remove / Deactivate Crossing
637681	5777019	Tributary to Moffat Creek	10.8	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
644497	5802491	Tributary to Horsefly River	10.8	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
606233	5791344	Mussel Creek	10.807	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
644830	5779666	Tributary to Molybdenite Creek	10.812	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
634959	5786457	Tributary to Tisdall Lake	10.85	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
643927	5786878	Tributary to Molybdenite	10.92	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
632511	5799948	Tributary to Black Creek	10.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629491	5783146	Tributary to Moffat Creek	10.925	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651517	5810189	Tributary to Archie Creek	11.005	High habitat value	Round Culvert	Remove / Deactivate Crossing
647419	5806601	Tributary to Harvie Creek	11.02	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
631931	5779355	Tributary to Moffat Lakes	11.0295	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
660015	5802485	Tributary to Mackay River	11.07	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
648988	5801722	Tributary to McKusky Creek	11.07	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
658255	5808939	Tributary to Horsefly River	11.0825	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
646376	5807665	Tributary to Fritz	11.115	High habitat value	Round Culvert	Remove / Deactivate Crossing
620034	5777444	Tributary to Moffat Creek	11.115	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
627479	5784155	Tributary to Moffat Creek	11.118	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
613963	5779014	Tributary to Moffat Creek	11.2	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
665276	5799149	Tributary to MacKay River	11.234	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
644413	5790971	Triburtary to McKinley	11.27	High habitat value	Round Culvert	Remove / Deactivate Crossing
661189	5803163	Tributary to Hawkley Creek	11.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647082	5804651	Tributary to Horsefly River	11.303	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
637037	5794361	Tributary to McKinley	11.31	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
630182	5776998	Tributary to Moffat Creek	11.31	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619060	5778643	Tributary to Moffat Creek	11.316	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625643	5790895	Trib to Horsefly River	11.34	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
612617	5787662	Trib to Deerhorn Creek	11.376	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626897	5809176	Tributary to Viewland Creek	11.43	Medium habitat value	Round Culvert	Replace with new open bottom structure
652527	5804878	Tributary to Horsefly River	11.475	Low habitat value	Round Culvert	Remove / Deactivate Crossing
654573	5779137	Tributary to Gotchen Lake	11.48	Low habitat value	Round Culvert	Remove / Deactivate Crossing
641165	5809994	Tributary to horsefly Lake	11.52	High habitat value	Round Culvert	Remove / Deactivate Crossing
628801	5804381	Tributary to Horsefly Lake	11.55	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
623796	5802640	Tributary to Horsefly Lake	11.56	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
652711	5777872	Tributary to Bosk Lake	11.57	High habitat value	Round Culvert	Remove / Deactivate Crossing

653082	5780751	Tributary to Gotchen Lake	11.61	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653395	5811136	Tributary to Teapot Creek	11.7	Medium habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
651178	5795339	Tributary to McKusky	11.76	Low habitat value	Round Culvert	Remove / Deactivate Crossing
629751	5784537	Tributary to Moffat Creek	11.78	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
627394	5786212	Tributary to Moffat Creek	11.817	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
603855	5791643	Tributary to Moffatt Creek	11.82	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641772	5804411	Tributary to Sawley	11.875	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
650821	5795260	Tributary to McKusky	11.88	Low habitat value	Round Culvert	Remove / Deactivate Crossing
644258	5780185	Gifford Creek	11.88	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
602493	5784058	Tributary to Moffat Creek	11.88	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
619847	5794484	Tributary to Horsefly River	11.89	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
610128	5788772	Tributary to Deerhorn Creek	11.9	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
613138	5776689	Tributary to McIntosh Lake	11.9	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
657136	5806355	Tributary to Horsefly River	11.904	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
607128	5811971	Tributary to Horsefly River	11.931	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
628381	5785020	Tributary to Moffat Creek	11.979	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
613452	5781283	Tributary to Moffat Creek	12	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651997	5809900	Tributary to Archie Creek	12.04	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614535	5781376	Tributary to Moffat Creek	12.1	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
631805	5787567	Tributary to Tisdal Lake	12.103	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
618021	5801759	Tributary to Lemon Lake	12.12	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651981	5802007	Tributary to Horsefly River	12.155	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
648552	5797518	Tributary to McKusky	12.16	High habitat value	Round Culvert	Remove / Deactivate Crossing
654740	5805841	Tributary to Mackay River	12.21	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
640486	5809412	Tributary to Horsefly Lake	12.24	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
652858	5809184	Tributary to Archie Creek	12.2705	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
625134	5776952	Tributary to Moffat Creek	12.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653885	5780009	Tributary to Gotchen Lake	12.42	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
649828	5805660	Tributary to Horsefly River	12.43	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633502	5782466	Tributary to Moffat Creek	12.445	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
630785	5776880	Tributary to Moffat Creek	12.446	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
606647	5791208	Tributary to Mussel Creek	12.462	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625788	5794645	Tributary to Horsefly River	12.474	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626973	5804385	Tributary to Horsefly Lake	12.495	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
665789	5813999	Tributary to Horsefly River	12.5125	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
647702	5805969	Tributary to Harvie Creek	12.6	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
635974	5785627	Tributary to Tisdal Lake	12.6175	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
606864	5799306	Tributary to Harpers Lake	12.665	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
664344	5813694	Tributary to Horsefly River	12.76	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647438	5799902	Tributary to McKusky	12.825	High habitat value	Round Culvert	Remove / Deactivate Crossing
647282	5781573	Tributary to Bosk Lake	12.825	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
654261	5786606	Tributary to Bassett Creek	12.84	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
611182	5793974	Tributary to Deerhorn Creek	12.84	Low habitat value	Round Culvert	Replace with new open bottom structure
632104	5776282	Tributary to Moffat Creek	12.87	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
621154	5787478	Trib to Moffat Creek	12.87	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
647781	5798373	Tributary to McKusky	12.92	High habitat value	Round Culvert	Remove / Deactivate Crossing
667893	5812347	Tributary to Horsefly River	12.972	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622293	5778943	Tributary to Moffat Creek	12.993	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
625576	5788954	Tributary to Horsefly River	13.038	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
603381	5791291	Tributary to Moffatt Creek	13.05	Medium habitat value	Round Culvert	
668276	5811836	Tributary to Horsefly River	13.064	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
622967	5776329	Tributary to Moffat Creek	13.08	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
602392	5783381	Tributary to Moffat Creek	13.108	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS

639842	5787235	Tributary to Molybdenite	13.14	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
605603	5789463	Mussel Creek	13.14	Medium habitat value	Round Culvert	Replace with new open bottom structure
648175	5803944	Tributary to Harvie Creek	13.16	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
652852	5806140	Tributary to Horsefly River	13.2	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
637467	5776965	Tributary to Moffat Creek	13.2	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
642642	5804164	Tributary to Sawley	13.2	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
637924	5800374	Tributary to Prarie Creek	13.23	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648613	5787969	Tributary to Elbow Lake	13.248	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
604547	5805159	Tributary to Horsefly River	13.36	High habitat value	Round Culvert	Replace with new open bottom structure
647599	5798667	Tributary to McKusky	13.39	High habitat value	Round Culvert	Remove / Deactivate Crossing
631419	5789290	Tributary to Tisdal Lake	13.39	High habitat value	Round Culvert	Add substrate to further imbed the CBS
659798	5802876	Tributary to Mckay	13.42	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
621951	5786007	Tributary to Moffat Creek	13.5	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
653941	5811337	Tributary to Teapot Creek	13.53	Low habitat value	Round Culvert	Remove / Deactivate Crossing
623447	5780605	Tributary to Moffat Creek	13.68	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
616978	5778442	Tributary to Moffat Creek	13.68	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
608339	5794926	Tributary to Moffat Creek	13.72	Low habitat value	Round Culvert	Replace with new open bottom structure
615945	5778592	Tributary to Moffat Creek	13.802	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
608128	5800143	Tributary to Horsefly River	13.804	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618040	5798813	Tributary to Gibbons Creek	13.855	Medium habitat value	Round Culvert	Add substrate to further imbed the CBS
625131	5801761	Tributary to Horsefly Lake	13.855	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
661025	5801286	Tributary to Mackay River	13.86	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
643479	5773806	Tributary to Molybdenite Cr	13.865	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
634598	5786480	Tributary to Tisdall Lake	13.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
611178	5806280	Alah Creek	14	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626452	5794687	Tributary to Horsefly River	14.04	Low habitat value	Round Culvert	Add substrate to further imbed the CBS
636944	5803720	Tributary to Prarie Creek	14.08	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
630892	5776926	Tributary of Moffat Lake	14.2	Low habitat value	Round Culvert	Replace with new open bottom structure
649318	5789318	Tributary to Elbow Lake	14.268	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
655466	5786956	Tributary to Bassett Creek	14.3	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
598272	5780372	Trib to Moffat Creek	14.3	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
628315	5777931	Tributary to Moffat Creek	14.31	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
633620	5782493	Tributary to Moffat Creek	14.35	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
651274	5805582	Tributary to Horsefly River	14.375	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
636562	5791025	Tributary to McKinley	14.7	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
620704	5778932	Tributary to Moffat Creek	14.7	Medium habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
649940	5796340	Tributary to McKusky	14.725	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
626423	5801336	Tributary to horsefly Lake	14.76	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
654849	5802982	Tributary to Horsefly River	14.775	High habitat value	Round Culvert	Remove / Deactivate Crossing
649650	5781829	Tributary to Bosk Lake	14.84	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
622256	5778894	Tributary to Moffat Creek	14.931	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628656	5777950	Tributary to Moffat Creek	15.015	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
652284	5802048	Tributary to Horsefly River	15.045	High habitat value	Round Culvert	Remove / Deactivate Crossing
659859	5811417	Tributary to Horsefly River	15.08	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628221	5784799	Tributary to Moffat Creek	15.096	High habitat value	Round Culvert	
638968	5804841	Tributary to Prairie Creek	15.12	High habitat value	Round Culvert	Remove / Deactivate Crossing
630293	5777040	Tributary to Moffat Creek	15.21	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618550	5779135	Tributary to Moffat Creek	15.228	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
618296	5800980	Tributary to Gibbons Creek	15.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659775	5802786	Tributary to Mackay River	15.3	High habitat value	Round Culvert	Replace with new open bottom structure
639729	5806171	Tributary to Prairie Creek	15.375	High habitat value	Round Culvert	Remove / Deactivate Crossing
649196	5798426	Tributary to McKusky	15.375	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
627299	5779621	Tributary to Moffat Creek	15.45	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS

652292	5809932	Tributary to Archie Creek	15.51	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
623528	5780398	Tributary to Moffat Creek	15.58	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
660461	5802710	Tributary to Mckay	15.6	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
635645	5786545	Tributary to Tisdall Lake	15.6	Medium habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
666168	5813865	Tributary to Horsefly River	15.655	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
611493	5807617	Tributary to Horsefly River	15.76	High habitat value	Round Culvert	Replace with new open bottom structure
656947	5787353	Tributary to Bassett Creek	15.84	Low habitat value	Round Culvert	Remove / Deactivate Crossing
603069	5789462	Tributary to Moffat Creek	15.95	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
652357	5799946	Tributary to McKusky Creek	15.975	High habitat value	Round Culvert	Remove / Deactivate Crossing
614361	5791193	Tributary to Woodjam Creek	16	Medium habitat value	Round Culvert	Replace with new open bottom structure
610828	5792938	Tributary to Deerhorn Creek	16.15	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
640584	5779607	Tributary to Buster Lake	16.15	Medium habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
654281	5810055	Tributary to Archie Creek	16.2345	High habitat value	Round Culvert	Remove / Deactivate Crossing
654761	5802945	Tributary to Horsefly River	16.2525	Low habitat value	Round Culvert	Remove / Deactivate Crossing
653287	5811023	Tributary to Teapot Creek	16.32	Medium habitat value	Round Culvert	Replace with new open bottom structure
652922	5792060	Tributary to Elbow Lake	16.32	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
651775	5805610	Tributary to Horsefly River	16.33	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
649419	5805318	Tributary to Horsefly River	16.43	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
622339	5794751	Tributary to Horsefly River	16.48	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659665	5803565	Tributary to Mckay	16.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
609435	5787922	Trib to Deerhorn Creek	16.544	Medium habitat value	Round Culvert	Replace with new open bottom structure
650094	5796195	Tributary to McKusky	16.56	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
639728	5808887	Tributary to Horsefly Lake	16.64	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
631390	5787079	Tributary to Tisdall Lake	16.66	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
607200	5812578	Tributary to Horsefly River	16.728	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
651813	5810236	Tributary to Archie Creek	16.7825	High habitat value	Round Culvert	Remove / Deactivate Crossing
661661	5813429	Tributary to Horsefly River	16.8	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
625466	5790459	Trib to Horsefly River	16.8	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
641000	5786263	Tributary to Molybdenite	16.8025	High habitat value	Round Culvert	Add substrate to further imbed the CBS
609831	5785813	Tributary to Mussel Creek	16.892	High habitat value	Oval Culvert	Replace structure with streambed simulation CBS
613468	5780731	Tributary to Moffat Creek	16.92	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
629019	5804336	Tributary to Horsefly Lake	17.01	High habitat value	Round Culvert	Remove / Deactivate Crossing
608969	5797126	Tributary to Moffatt Creek	17.1	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648721	5805641	Tributary to Horsefly River	17.145	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655375	5778465	Tributary to Gotchen Lake	17.16	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
641246	5796094	Tributary to Doreen Creek	17.28	High habitat value	Round Culvert	Remove / Deactivate Crossing
645200	5778731	Tributary to Molybdenite Creek	17.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648164	5782761	Tributary to Bosk Lake	17.324	Medium habitat value	Round Culvert	Replace with new open bottom structure
647340	5781736	Tributary to Bosk Lake	17.43	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
643338	5784209	Tributary to Molybdenite Creek	17.5175	High habitat value	Round Culvert	Remove / Deactivate Crossing
607279	5789952	Tributary to Mussel Creek	17.536	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
602804	5776395	Tributary to McIntosh Lakes	17.6175	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
642185	5799929	Tributary to Horsefly	17.64	High habitat value	Round Culvert	Remove / Deactivate Crossing
652774	5782653	Tributary to Bosk Lake	17.68	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
621594	5776459	Tributary to Moffat Creek	17.856	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
613942	5804690	Tributary to Little Horsefly Lake	17.92	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
655630	5807114	Tributary to Horsefly River	17.98	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
655189	5806371	Tributary to Horsefly River	18	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
647333	5781641	Tributary to Bosk Lake	18.1	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
617234	5793109	Tributary to Woodjam Creek	18.18	High habitat value	Round Culvert	Replace with new open bottom structure
643919	5780393	Gifford Creek	18.231	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
620606	5803381	Tributary to Horsefly Lake	18.24	Medium habitat value	Round Culvert	Replace with new open bottom structure
636291	5786993	Tributary to Tisdall Lake	18.46	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS

619670	5781027	Tributary to Woodjam Creek	18.59	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641149	5809596	Tributary to horsefly Lake	18.59	High habitat value	Round Culvert	Remove / Deactivate Crossing
651834	5777534	Tributary to Bosk Lake	18.7	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
654477	5787540	Tributary to Bassett Creek	18.7	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
667293	5812403	Tributary to Horsefly River	18.72	Medium habitat value	Round Culvert	
651889	5792771	Tributary to McKee Lake	18.8	High habitat value	Round Culvert	
647207	5801739	Tributary to McKusky	19.065	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
666792	5797511	Tributary to MacKay River	19.074	High habitat value	Oval Culvert	Replace structure with streambed simulation CBS
647834	5803433	Tributary to Horsefly River	19.2	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
656565	5791046	Tributary to Crooked Lake	19.203	High habitat value	Oval Culvert	Replace with new open bottom structure
655169	5786917	Tributary to Bassett Creek	19.21	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
647183	5806885	Tributary to Harvie Creek	19.44	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
640601	5783358	Tributary to Molybdenite Creek	19.475	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
643365	5801380	Tributary to Horsefly River	19.5	Medium habitat value	Round Culvert	
612010	5811556	Tributary to Niquidet Creek	19.5	Medium habitat value	Round Culvert	Replace with new open bottom structure
641293	5789800	Tributary to McKinley	19.63	High habitat value	Round Culvert	Remove / Deactivate Crossing
649542	5790833	Tributary to Elbow Lake	19.8	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
654957	5791788	Tributary to Crooked Lake	20	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
665435	5813565	Tributary to Horsefly River	20.28	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
645547	5778025	Tributary to Molybdenite Creek	20.44	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
645948	5808112	Tributary to Fritz	20.58	High habitat value	Round Culvert	Replace with new open bottom structure
664324	5799030	Tributary to Eureka Creek	20.7	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
636357	5785019	Tributary to Tisdal Lake	20.875	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
653703	5788766	Tributary to Bassett Creek	21	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
599516	5781563	Trib to Moffat Creek	21.07	High habitat value	Round Culvert	Replace with new open bottom structure
608478	5802353	Vedder Creek	21.122	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
658880	5775882	Tributary to Gotchen Lake	21.42	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
654869	5789630	Tributary to Bassett Creek	21.45	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
645518	5783040	Gifford Creek	21.84	Medium habitat value	Round Culvert	Replace with new open bottom structure
631308	5800923	Tributary to Horsefly Lake	21.8925	High habitat value	Round Culvert	Remove / Deactivate Crossing
631478	5779402	Tributary to Moffat Lakes	21.9375	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
641489	5800227	Tributary to Horsefly River	21.97	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
658562	5779131	Tributary to Gotchen Lake	22.2	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
629550	5795681	Tributary to Black Creek	22.532	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
608198	5789597	Tributary to Deerhorn Creek	22.54	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
647667	5801073	Tributary to McKusky	22.61	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
653820	5811284	Tributary to Teapot Creek	22.61	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
629014	5804701	Tributary to Horsefly Lake	22.655	High habitat value	Round Culvert	Remove / Deactivate Crossing
635607	5776367	Tributary to Moffat Creek	22.839	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
652548	5777874	Tributary to Bosk Lake	23	High habitat value	Round Culvert	Remove / Deactivate Crossing
658375	5779464	Tributary to Gotchen Lake	23.068	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
614618	5811897	Niquidet Creek	23.1	Medium habitat value	Round Culvert	Replace with new open bottom structure
624953	5801570	Tributary to Horsefly Lake	23.2375	High habitat value	Round Culvert	Remove / Deactivate Crossing
602448	5783636	Tributary to Moffat Creek	23.415	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
655130	5791788	Tributary to Crooked Lake	23.76	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
654356	5789113	Tributary to Bassett Creek	24	High habitat value	Round Culvert	Replace with new open bottom structure
628426	5779070	Tributary to Moffat Creek	24.03	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
627079	5804358	Tributary to Horsefly Lake	24.1875	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
650817	5797473	Tributary to McKusky	24.3	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
620227	5803222	Tributary to Horsefly Lake	24.32	Medium habitat value	Round Culvert	Replace with new open bottom structure
653426	5780516	Tributary to Gotchen Lake	24.7	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
628494	5804487	Tributary to Horsefly Lake	24.96	High habitat value	Round Culvert	Remove / Deactivate Crossing
652026	5799353	Tributary to McKusky Creek	24.97	High habitat value	Round Culvert	Remove / Deactivate Crossing

656672	5790969	Tributary to Crooked Lake	24.975	High habitat value	Oval Culvert	Replace with new open bottom structure
641366	5788836	Tributary to McKinley	25	Low habitat value	Round Culvert	Remove / Deactivate Crossing
644494	5782322	Gifford Creek	25.06	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
666644	5813094	Tributary to Horsefly River	25.071	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
636834	5804280	Tributary to Prarie Creek	25.3	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
651672	5799818	Tributary to McKusky Creek	25.65	High habitat value	Round Culvert	Remove / Deactivate Crossing
616873	5794727	Tributary to Horsefly River	25.92	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
619757	5780972	Tributary to Woodjam Creek	26.1775	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
652188	5803660	Tributary to Horsefly River	26.3	High habitat value	Round Culvert	Remove / Deactivate Crossing
608077	5800781	Tributary to Horsefly River	26.46	High habitat value	Round Culvert	Replace with new open bottom structure
648099	5800144	Tributary to McKusky	26.474	High habitat value	Round Culvert	Replace with new open bottom structure
607651	5813531	Tributary to Horsefly River	26.564	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
623210	5775749	Tributary to Moffat Creek	26.586	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
627696	5804086	Tributary to Horsefly Lake	26.825	High habitat value	Round Culvert	Remove / Deactivate Crossing
631948	5786864	Tributary to Tisdall Lake	26.88	High habitat value	Round Culvert	Remove / Deactivate Crossing
642191	5796817	Tributary to Doreen Creek	27.12	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
640017	5779083	Tributary to Buster Lake	27.5625	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
653122	5792097	Tributary to Elbow Lake	27.68	High habitat value	Round Culvert	Replace with new open bottom structure
617864	5785563	Tributary to Woodjam Creek	27.69	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
632761	5798158	Tributary to Black Creek	28.16	Low habitat value	Round Culvert	Remove / Deactivate Crossing
651795	5805651	Tributary to Horsefly River	28.175	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
627680	5779042	Tributary to Moffat Creek	28.56	Low habitat value	Round Culvert	Replace with new open bottom structure
643945	5774311	Tributary to Molybdenite Creek	28.9	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
635417	5797479	Tributary to Horsefly River	28.98	High habitat value	Round Culvert	Replace with new open bottom structure
653042	5809353	Tributary to Archie Creek	29	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
654914	5787559	Tributary to Bassett Creek	29.25	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
641889	5808563	Tributary to horsefly Lake	29.415	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
655552	5790561	Tributary to Crooked Lake	29.575	High habitat value	Round Culvert	Replace with new open bottom structure
651807	5777454	Tributary to Divan Creek	30	Medium habitat value	Round Culvert	Replace with new open bottom structure
658600	5776456	Tributary to Gotchen Lake	30	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
637997	5786455	Tributary to Molybdenite Creek	30.52	High habitat value	Round Culvert	Remove / Deactivate Crossing
655538	5777458	Tributary to McKinley Creek	30.523	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
623886	5786538	Tributary to Moffat Creek	31.2	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
644959	5802661	Unnamed	31.2	Medium habitat value	Round Culvert	
627037	5776826	Tributary to Moffat Creek	31.35	Medium habitat value	Round Culvert	Add substrate to further imbed the CBS
639797	5787982	Tributary to Molybdenite	31.45	High habitat value	Oval Culvert	
641986	5808479	Tributary to horsefly Lake	32.22	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
648254	5798026	Tributary to McKusky	32.24	High habitat value	Round Culvert	Remove / Deactivate Crossing
628788	5779613	Tributary to Moffat Creek	32.34	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
646393	5785277	Tributary to McKinley	32.375	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
640450	5783131	Tributary to Molybdenite Creek	32.4	High habitat value	Round Culvert	Replace with new open bottom structure
620347	5794693	Tributary to Horsefly River	32.5	Low habitat value	Round Culvert	Replace with new open bottom structure
647100	5806662	Tributary to Harvie Creek	32.76	High habitat value	Round Culvert	Replace with new open bottom structure
641828	5786280	Tributary to Molybdenite	32.89	Medium habitat value	Round Culvert	Replace with new open bottom structure
597618	5777423	Blue Moon Creek	33.18	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
647783	5807025	Tributary to Harvie Creek	33.3	High habitat value	Round Culvert	Remove / Deactivate Crossing
655521	5779282	Tributary to Gotchen Lake	33.46	Medium habitat value	Round Culvert	Replace with new open bottom structure
654345	5793723	Tributary to Crooked Lake	33.84	High habitat value	Round Culvert	Replace with new open bottom structure
627844	5804470	Tributary to Horsefly Lake	33.88	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
621475	5776952	Tributary to Moffat Creek	34.344	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
623522	5776516	Tributary to Moffat Creek	34.76	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
648109	5762678	Tributary to Bosk Lake	35.28	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
654361	5809922	Archie Creek	35.62	High habitat value	Round Culvert	Remove / Deactivate Crossing

642745	5788825	Tributary to McKinley	35.815	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
654794	5779227	Tributary to Gotchen Lake	35.84	Medium habitat value	Round Culvert	Replace with new open bottom structure
633423	5775985	Tributary to Moffat Creek	36.3	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
650203	5796033	Tributary to McKusky	37.05	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
652383	5804459	Tributary to Horsefly River	37.2	High habitat value	Round Culvert	Replace with new open bottom structure
621240	5785485	Tributary to Moffat Creek	37.4	High habitat value	Round Culvert	Replace with new open bottom structure
623284	5804264	Tributary to Horsefly Lake	37.8	Low habitat value	Round Culvert	Replace with new open bottom structure
645604	5807444	Tributary to Fritz	37.94	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
636131	5776468	Tributary to Moffat Creek	37.944	High habitat value	Round Culvert	Replace with new open bottom structure
652653	5784070	Cruiser Creek	37.9475	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
648563	5804582	Harvie Creek	38.08	High habitat value	Wood Box Culvert	
652950	5809966	Tributary to Archie Creek	38.2	High habitat value	Round Culvert	Replace with new open bottom structure
617897	5804542	Tributary to Horsefly Lake	39.26	Medium habitat value	Oval Culvert	Replace with new open bottom structure
656593	5779753	Tributary to Gotchen Lake	39.375	High habitat value	Round Culvert	Replace with new open bottom structure
650818	5785556	Tributary to Cruiser Lake	40.08	Medium habitat value	Round Culvert	Replace with new open bottom structure
664138	5799079	Imperial Creek	40.6	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
609915	5804389	Tributary to Horsefly River	40.95	Medium habitat value	Round Culvert	Replace with new open bottom structure
662651	5801197	Tributary to Mackay River	41.21	High habitat value	Round Culvert	Replace with new open bottom structure
623645	5787770	Trib to Moffat Creek	41.4	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
637255	5776941	Tributary to Moffat Creek	42	Medium habitat value	Round Culvert	Replace with new open bottom structure
607754	5799142	Tributary to Horsefly River	42.18	Medium habitat value	Round Culvert	Replace with new open bottom structure
649257	5781263	Tributary to Bosk Lake	42.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
638489	5804969	Tributary to Prairie Creek	42.72	High habitat value	Round Culvert	Remove / Deactivate Crossing
618269	5796653	Sucker Creek	44.52	Medium habitat value	Round Culvert	Replace with new open bottom structure
656414	5779677	Tributary to Gotchen Lake	44.73	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659032	5779400	Tributary to Gotchen Lake	45.346	High habitat value	Round Culvert	Remove / Deactivate Crossing
653349	5806394		45.7405	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
611078	5809212	Tributary to Horsefly River	46	Low habitat value	Round Culvert	Replace with new open bottom structure
656380	5786958	Tributary to Bassett Creek	46.3	High habitat value	Round Culvert	Replace with new open bottom structure
602615	5781929	Blue Moon Creek	46.4	Medium habitat value	Round Culvert	Replace with new open bottom structure
659688	5803516	Tributary to Mckay	47.25	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
612544	5796650	Sucker Creek	47.4	Medium habitat value	Round Culvert	Replace with new open bottom structure
656367	5818523	Tributary to Horsefly Lake	48.9	High habitat value	Round Culvert	Install downstream weir(s) to backwater CBS
629052	5795454	Wilmot Creek	49.2	Medium habitat value	Round Culvert	Replace with new open bottom structure
652884	5788712	Tributary to McKee Lake	50.15	High habitat value	Round Culvert	Replace with new open bottom structure
656744	5787058	Tributary to Bassett Creek	50.895	High habitat value	Round Culvert	Remove / Deactivate Crossing
645843	5808175	Tributary to Fritz	51.909	High habitat value	Round Culvert	Replace with new open bottom structure
652389	5804443	Tributary to Horsefly River	52.08	High habitat value	Round Culvert	Replace with new open bottom structure
640724	5799547	Tributary to Horsefly	54.34	High habitat value	Round Culvert	Remove / Deactivate Crossing
617294	5808677	Tributary to Dillabough Lake	55.44	Medium habitat value	Round Culvert	Replace with new open bottom structure
642815	5773511	Tributary to Molybdenite Cr	56.5	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
659939	5802526	Tributary to Mackay River	56.658	High habitat value	Round Culvert	Replace with new open bottom structure
640360	5784443	Tributary to Molybdenite Creek	57.66	High habitat value	Round Culvert	Replace with new open bottom structure
625983	5804692	Tributary to Horsefly Lake	58.5	High habitat value	Round Culvert	Replace with new open bottom structure
613541	5795762	Tributary to Horsefly River	58.65	Low habitat value	Round Culvert	Replace with new open bottom structure
655721	5791508	Tributary to Crooked Lake	63	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
646000	5774554	Tributary to Molybdenite Creek	63	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
662631	5800267	Tributary to Imperial Creek	63.41	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
648164	5781102	Tributary to Bosk Lake	63.7	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
609766	5801977	Tributary to Little Horsefly River	64	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
660042	5802684	Tributary to Imperial Creek	64	Medium habitat value	Round Culvert	Replace with new open bottom structure
631736	5779321	Tributary to Moffat Lakes	70.08	High habitat value	Round Culvert	Replace with new open bottom structure
611230	5793832	Deerhorn Creek	71.004	High habitat value	Round Culvert	

640502	5783895	Tributary to Molybdenite Creek	71.46	High habitat value	Round Culvert	Replace with new open bottom structure
665442	5787644	Tributary to McKusky	72.756	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
629989	5795673	Tributary to Black Creek	72.8	High habitat value	Round Culvert	Replace with new open bottom structure
624767	5802148	Tributary to Horsefly Lake	76.08	Low habitat value	Round Culvert	Replace with new open bottom structure
649764	5790198	Bassett Creek	79.5	High habitat value	Oval Culvert	Replace with new open bottom structure
661274	5801438	Tributary to Imperial Creek	80.75	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
643841	5806143	Tributary to Sawley	85.785	Low habitat value	Round Culvert	Replace structure with streambed simulation CBS
626175	5802440	Tributary to Horsefly Lake	87.885	Medium habitat value	Round Culvert	Remove / Deactivate Crossing
647936	5783359	Gifford Creek	90	Medium habitat value	Round Culvert	Replace with new open bottom structure
652005	5784148	Tributary to Bosk Lake	90	Medium habitat value	Round Culvert	Replace with new open bottom structure
652667	5810000	Tributary to Archie Creek	100	Low habitat value	Round Culvert	Replace with new open bottom structure
614280	5802574	Tributary to Horsefly Lake	101.616	Medium habitat value	Round Culvert	Replace with new open bottom structure
647571	5799069	Tributary to McKusky	106.2	High habitat value	Round Culvert	Remove / Deactivate Crossing
659655	5801754	Tributary to MacKay River	107.25	High habitat value	Round Culvert	Remove / Deactivate Crossing
653524	5786240	Tributary to Cruiser Lake	108	Low habitat value	Round Culvert	
648599	5780135	Tributary to Bosk Lake	117.75	High habitat value	Round Culvert	Remove / Deactivate Crossing
653892	5816009	Tributary to Horsefly Lake	119.25	High habitat value	Round Culvert	Replace structure with streambed simulation CBS
638231	5800280	Prairie Creek	122.4	High habitat value	Wood Box Culvert	
618902	5796880	Tributary to Sucker Creek	139.2	Medium habitat value	Round Culvert	Replace structure with streambed simulation CBS
		Total	11944.1397			

APPENDIX D

Habitat Equivalency Assessment Calculations

VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

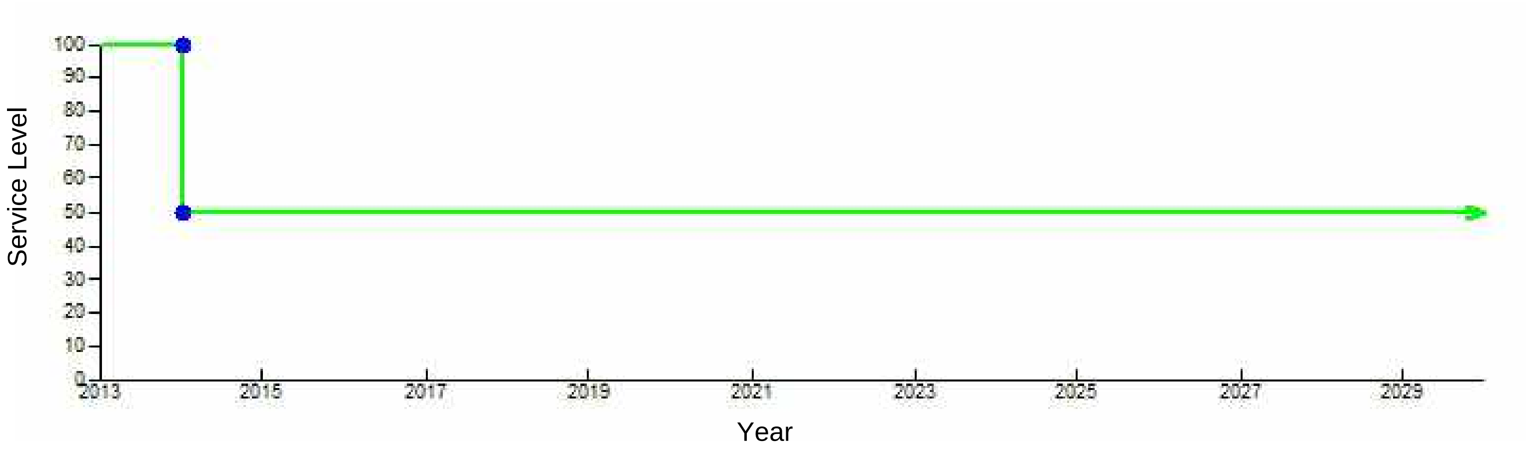
Sitename: Middle Edney

Date: 2019-03-11 10:26:46 AM
Datafile: C:\\Users\\mbenrabah\\Desktop\\HEA\\HEA Lower Hazeltine H2.hea

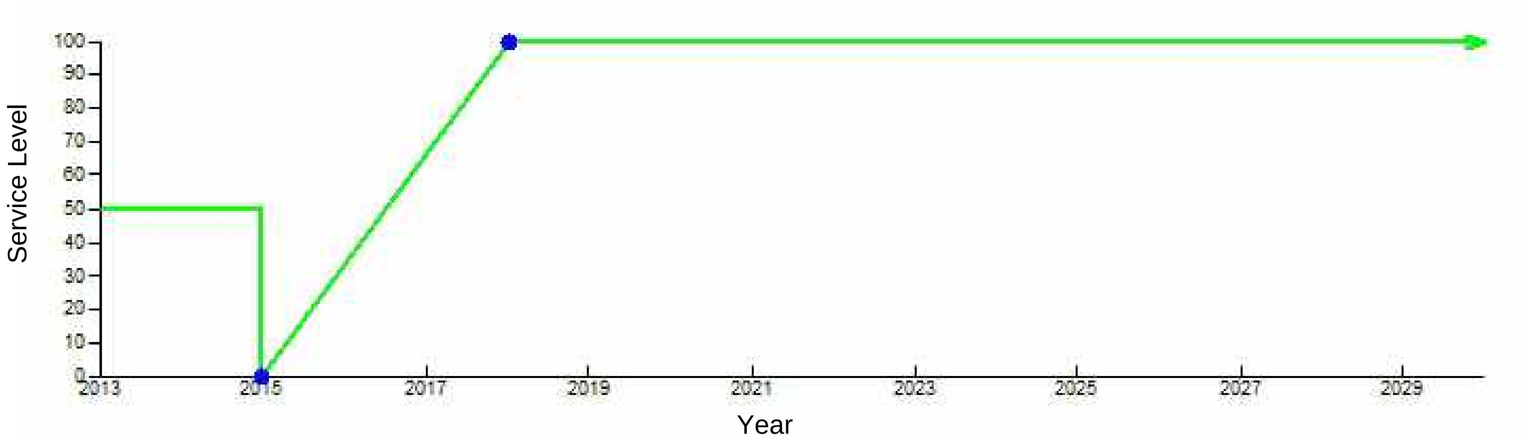
Units: sq. m
Time units: year

Claim year: 2014
Amount of affected units: 1350
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 50.00%
Value ratio injured/restored: 1.00
Discount rate per unit of time(%): 3.000

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs lost
2014	.00%	50.00%	25.00%	337.500	1.000	337.500
2015	50.00%	50.00%	50.00%	675.000	0.971	655.340
2016	50.00%	50.00%	50.00%	675.000	0.943	636.252
2017	50.00%	50.00%	50.00%	675.000	0.915	617.721
2018	50.00%	50.00%	50.00%	675.000	0.888	599.729
2019	50.00%	50.00%	50.00%	675.000	0.863	582.261
2020	50.00%	50.00%	50.00%	675.000	0.837	565.302
2021	50.00%	50.00%	50.00%	675.000	0.813	548.837
2022	50.00%	50.00%	50.00%	675.000	0.789	532.851
2023	50.00%	50.00%	50.00%	675.000	0.766	517.331
2024	50.00%	50.00%	50.00%	675.000	0.744	502.263
2025	50.00%	50.00%	50.00%	675.000	0.722	487.634
2026	50.00%	50.00%	50.00%	675.000	0.701	473.431
2027	50.00%	50.00%	50.00%	675.000	0.681	459.642
2028	50.00%	50.00%	50.00%	675.000	0.661	446.255
2029	50.00%	50.00%	50.00%	675.000	0.642	433.257
2030	50.00%	50.00%	50.00%	675.000	0.623	420.638
Beyond						14021.256

Total Discounted Service Unit Years (DSUYs) lost: 22837.500

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs gained
2015	.00%	33.33%	-33.33%	-450.000	0.971	-436.893
2016	33.33%	66.67%	0.00%	0.000	0.943	0.000
2017	66.67%	100.00%	33.33%	450.000	0.915	411.814
2018	100.00%	100.00%	50.00%	675.000	0.888	599.729
2019	100.00%	100.00%	50.00%	675.000	0.863	582.261
2020	100.00%	100.00%	50.00%	675.000	0.837	565.302
2021	100.00%	100.00%	50.00%	675.000	0.813	548.837
2022	100.00%	100.00%	50.00%	675.000	0.789	532.851
2023	100.00%	100.00%	50.00%	675.000	0.766	517.331
2024	100.00%	100.00%	50.00%	675.000	0.744	502.263
2025	100.00%	100.00%	50.00%	675.000	0.722	487.634
2026	100.00%	100.00%	50.00%	675.000	0.701	473.431
2027	100.00%	100.00%	50.00%	675.000	0.681	459.642
2028	100.00%	100.00%	50.00%	675.000	0.661	446.255
2029	100.00%	100.00%	50.00%	675.000	0.642	433.257
2030	100.00%	100.00%	50.00%	675.000	0.623	420.638
Beyond						14021.256

Total Discounted Service Unit Years (DSUYs) Gained: **20565.608**
Discounted SUYs gained per unit: **15.234**

Replacement habitat size (sq. m): 1.00 * 22837.5/15.234 **1499.135**

VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

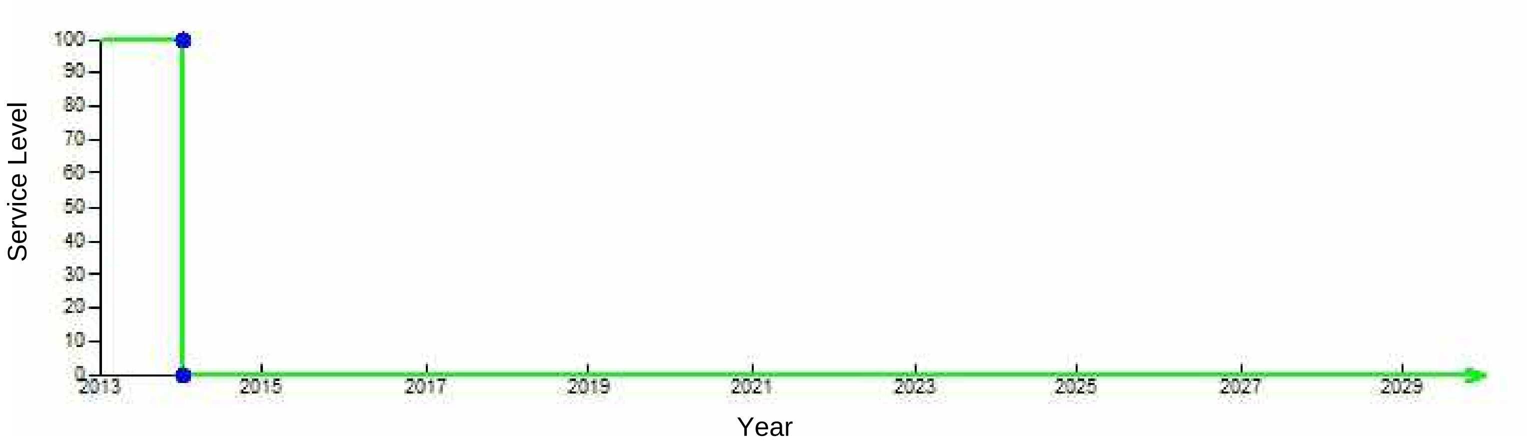
Sitename: Upper Hazeltine (H1)

Date: 2019-03-11 10:29:54 AM
Datafile: C:\\Users\\mbenrabah\\Desktop\\HEA\\HEA Lower Hazeltine H2.hea

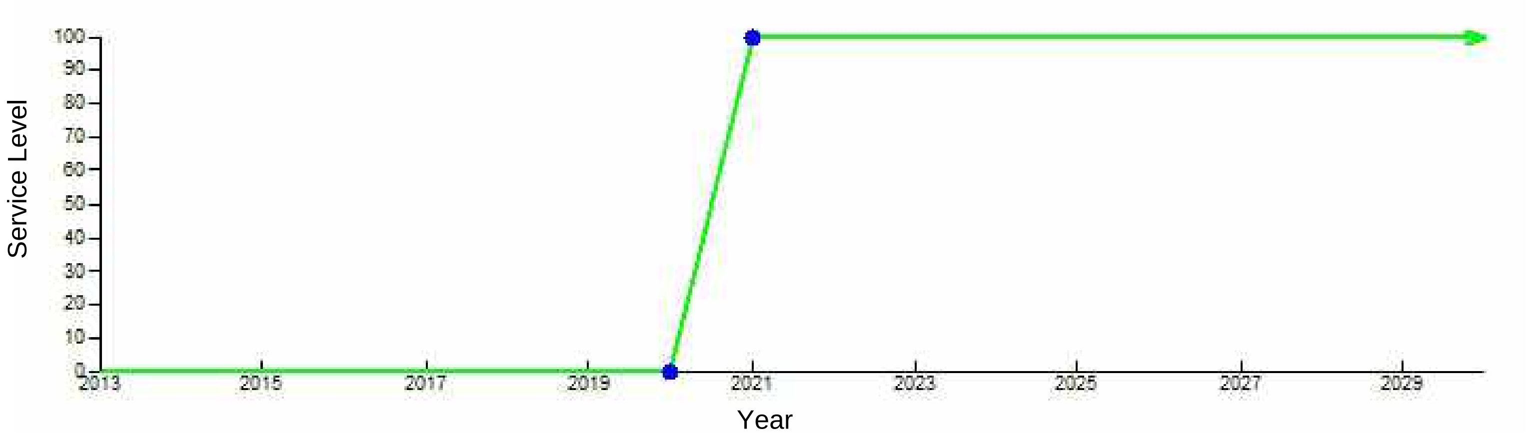
Units: sq. m
Time units: year

Claim year: 2014
Amount of affected units: 44650
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio injured/restored: 1.00
Discount rate per unit of time(%): 3.000

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs lost
2014	.00%	100.00%	50.00%	22325.000	1.000	22325.000
2015	100.00%	100.00%	100.00%	44650.000	0.971	43349.515
2016	100.00%	100.00%	100.00%	44650.000	0.943	42086.907
2017	100.00%	100.00%	100.00%	44650.000	0.915	40861.075
2018	100.00%	100.00%	100.00%	44650.000	0.888	39670.947
2019	100.00%	100.00%	100.00%	44650.000	0.863	38515.482
2020	100.00%	100.00%	100.00%	44650.000	0.837	37393.672
2021	100.00%	100.00%	100.00%	44650.000	0.813	36304.536
2022	100.00%	100.00%	100.00%	44650.000	0.789	35247.122
2023	100.00%	100.00%	100.00%	44650.000	0.766	34220.507
2024	100.00%	100.00%	100.00%	44650.000	0.744	33223.793
2025	100.00%	100.00%	100.00%	44650.000	0.722	32256.110
2026	100.00%	100.00%	100.00%	44650.000	0.701	31316.612
2027	100.00%	100.00%	100.00%	44650.000	0.681	30404.477
2028	100.00%	100.00%	100.00%	44650.000	0.661	29518.910
2029	100.00%	100.00%	100.00%	44650.000	0.642	28659.136
2030	100.00%	100.00%	100.00%	44650.000	0.623	27824.404
Beyond						927480.128

Total Discounted Service Unit Years (DSUYs) lost: 1510658.333

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs gained
2020	.00%	100.00%	50.00%	22325.000	0.837	18696.836
2021	100.00%	100.00%	100.00%	44650.000	0.813	36304.536
2022	100.00%	100.00%	100.00%	44650.000	0.789	35247.122
2023	100.00%	100.00%	100.00%	44650.000	0.766	34220.507
2024	100.00%	100.00%	100.00%	44650.000	0.744	33223.793
2025	100.00%	100.00%	100.00%	44650.000	0.722	32256.110
2026	100.00%	100.00%	100.00%	44650.000	0.701	31316.612
2027	100.00%	100.00%	100.00%	44650.000	0.681	30404.477
2028	100.00%	100.00%	100.00%	44650.000	0.661	29518.910
2029	100.00%	100.00%	100.00%	44650.000	0.642	28659.136
2030	100.00%	100.00%	100.00%	44650.000	0.623	27824.404
Beyond						927480.128

Total Discounted Service Unit Years (DSUYs) Gained: 1265152.571
Discounted SUYs gained per unit: 28.335

Replacement habitat size (sq. m): 1.00 * 1510658.333/28.335 53314.435

VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

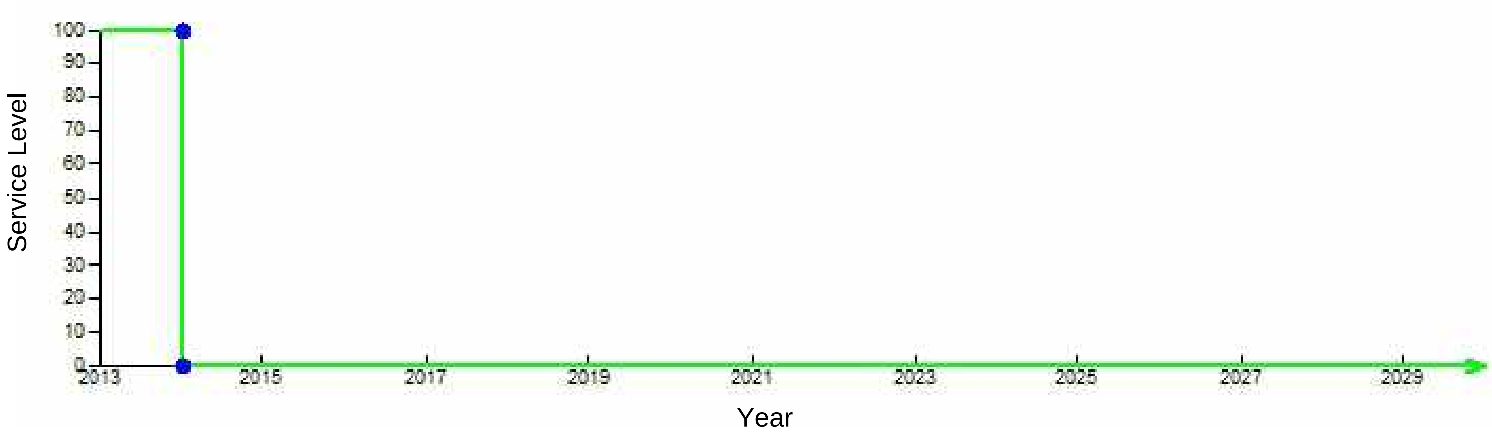
Sitename: Lower Hazeltine (H2)

Date: 2019-03-11 10:18:23 AM
Datafile: C:\\Users\\mbenrabah\\Desktop\\HEA\\HEA Lower Hazeltine H2.hea

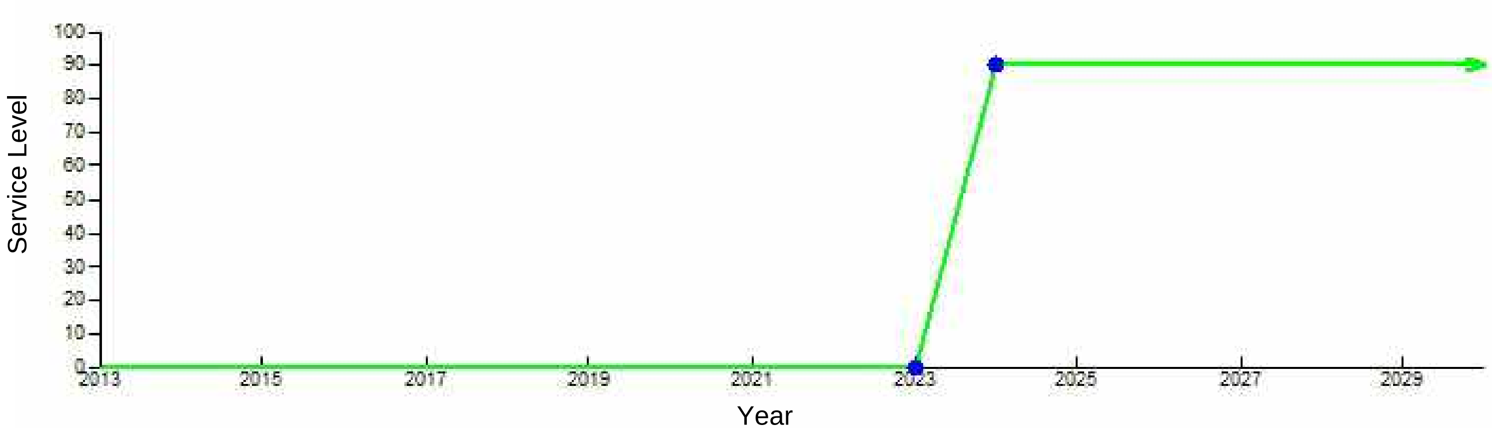
Units: sq. m
Time units: year

Claim year: 2014
Amount of affected units: 17966
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio injured/restored: 1.00
Discount rate per unit of time(%): 3.000

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs lost
2014	.00%	100.00%	50.00%	8983.000	1.000	8983.000
2015	100.00%	100.00%	100.00%	17966.000	0.971	17442.718
2016	100.00%	100.00%	100.00%	17966.000	0.943	16934.678
2017	100.00%	100.00%	100.00%	17966.000	0.915	16441.435
2018	100.00%	100.00%	100.00%	17966.000	0.888	15962.558
2019	100.00%	100.00%	100.00%	17966.000	0.863	15497.629
2020	100.00%	100.00%	100.00%	17966.000	0.837	15046.242
2021	100.00%	100.00%	100.00%	17966.000	0.813	14608.002
2022	100.00%	100.00%	100.00%	17966.000	0.789	14182.526
2023	100.00%	100.00%	100.00%	17966.000	0.766	13769.443
2024	100.00%	100.00%	100.00%	17966.000	0.744	13368.391
2025	100.00%	100.00%	100.00%	17966.000	0.722	12979.021
2026	100.00%	100.00%	100.00%	17966.000	0.701	12600.991
2027	100.00%	100.00%	100.00%	17966.000	0.681	12233.972
2028	100.00%	100.00%	100.00%	17966.000	0.661	11877.642
2029	100.00%	100.00%	100.00%	17966.000	0.642	11531.692
2030	100.00%	100.00%	100.00%	17966.000	0.623	11195.817
Beyond						373193.908

Total Discounted Service Unit Years (DSUYs) lost: 607849.667

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs gained
2023	.00%	90.00%	45.00%	8084.700	0.766	6196.250
2024	90.00%	90.00%	90.00%	16169.401	0.744	12031.553
2025	90.00%	90.00%	90.00%	16169.401	0.722	11681.119
2026	90.00%	90.00%	90.00%	16169.401	0.701	11340.892
2027	90.00%	90.00%	90.00%	16169.401	0.681	11010.575
2028	90.00%	90.00%	90.00%	16169.401	0.661	10689.879
2029	90.00%	90.00%	90.00%	16169.401	0.642	10378.523
2030	90.00%	90.00%	90.00%	16169.401	0.623	10076.236
Beyond						335874.530

Total Discounted Service Unit Years (DSUYs) Gained: 419279.556
Discounted SUYs gained per unit: 23.337

Replacement habitat size (sq. m): 1.00 * 607849.667/23.337 26046.171

VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

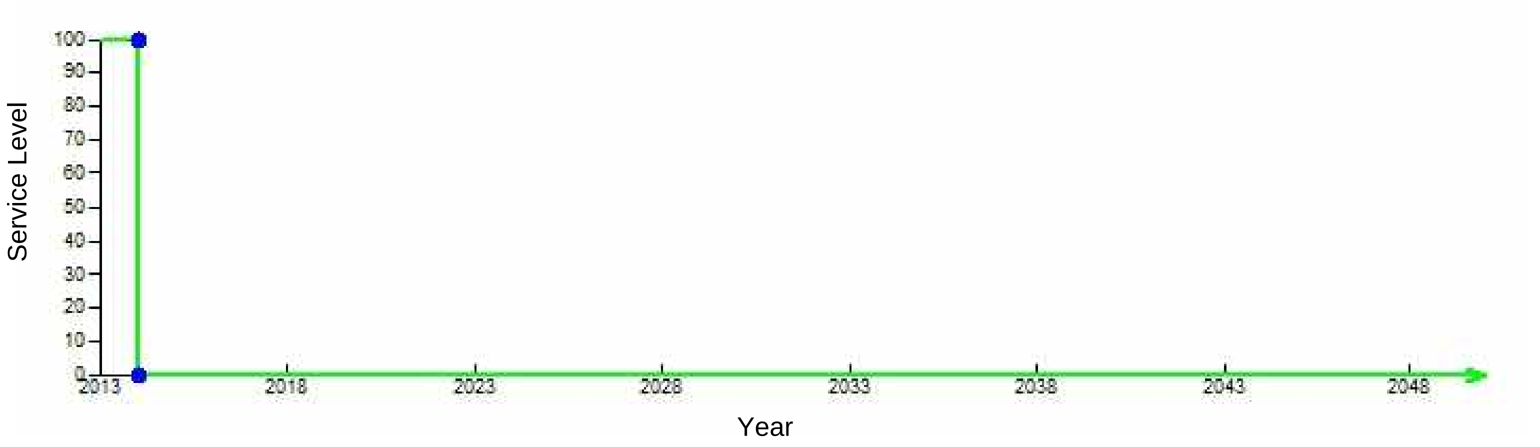
Sitename: Middle Edney

Date: 2019-03-11 10:33:37 AM
Datafile: C:\\Users\\mbenrabah\\Desktop\\HEA\\HEA Riparian 20yr.hea

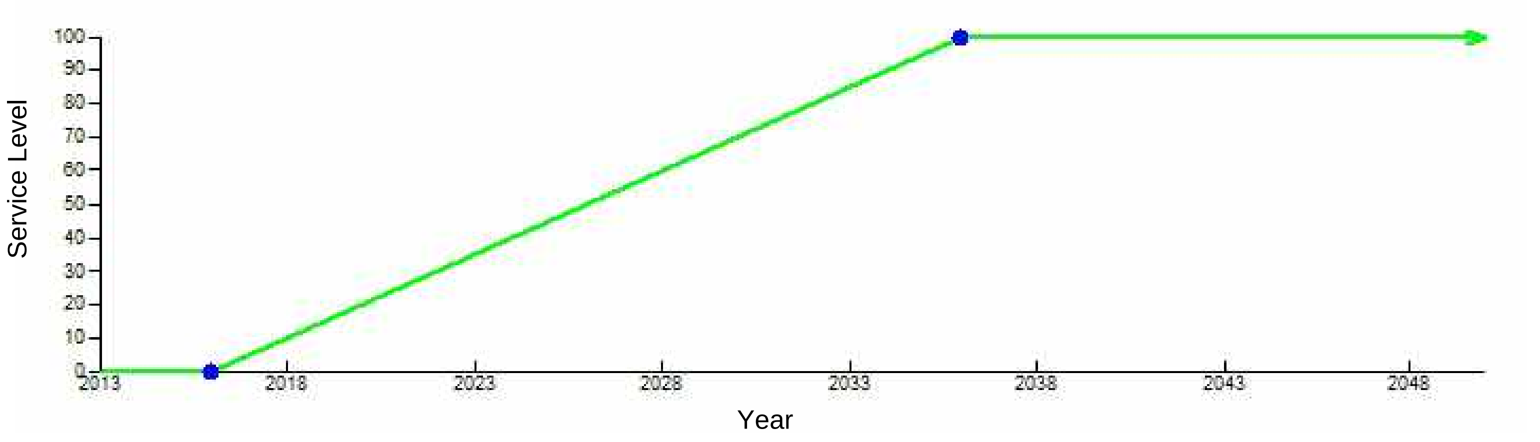
Units: sq. m
Time units: year

Claim year: 2014
Amount of affected units: 765372
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio injured/restored: 1.00
Discount rate per unit of time(%): 3.000

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost					
	Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs lost
2014	.00%	100.00%	50.00%	382686.000	1.000	382686.000
2015	100.00%	100.00%	100.00%	765372.000	0.971	743079.612
2016	100.00%	100.00%	100.00%	765372.000	0.943	721436.516
2017	100.00%	100.00%	100.00%	765372.000	0.915	700423.802
2018	100.00%	100.00%	100.00%	765372.000	0.888	680023.109
2019	100.00%	100.00%	100.00%	765372.000	0.863	660216.611
2020	100.00%	100.00%	100.00%	765372.000	0.837	640987.001
2021	100.00%	100.00%	100.00%	765372.000	0.813	622317.476
2022	100.00%	100.00%	100.00%	765372.000	0.789	604191.724
2023	100.00%	100.00%	100.00%	765372.000	0.766	586593.907
2024	100.00%	100.00%	100.00%	765372.000	0.744	569508.648
2025	100.00%	100.00%	100.00%	765372.000	0.722	552921.017
2026	100.00%	100.00%	100.00%	765372.000	0.701	536816.522
2027	100.00%	100.00%	100.00%	765372.000	0.681	521181.089
2028	100.00%	100.00%	100.00%	765372.000	0.661	506001.057
2029	100.00%	100.00%	100.00%	765372.000	0.642	491263.162
2030	100.00%	100.00%	100.00%	765372.000	0.623	476954.527
2031	100.00%	100.00%	100.00%	765372.000	0.605	463062.647
2032	100.00%	100.00%	100.00%	765372.000	0.587	449575.386
2033	100.00%	100.00%	100.00%	765372.000	0.570	436480.957
2034	100.00%	100.00%	100.00%	765372.000	0.554	423767.919
2035	100.00%	100.00%	100.00%	765372.000	0.538	411425.164
2036	100.00%	100.00%	100.00%	765372.000	0.522	399441.907
2037	100.00%	100.00%	100.00%	765372.000	0.507	387807.677
2038	100.00%	100.00%	100.00%	765372.000	0.492	376512.308
2039	100.00%	100.00%	100.00%	765372.000	0.478	365545.930
2040	100.00%	100.00%	100.00%	765372.000	0.464	354898.961
2041	100.00%	100.00%	100.00%	765372.000	0.450	344562.098
2042	100.00%	100.00%	100.00%	765372.000	0.437	334526.309
2043	100.00%	100.00%	100.00%	765372.000	0.424	324782.824
2044	100.00%	100.00%	100.00%	765372.000	0.412	315323.130
2045	100.00%	100.00%	100.00%	765372.000	0.400	306138.961
2046	100.00%	100.00%	100.00%	765372.000	0.388	297222.292
2047	100.00%	100.00%	100.00%	765372.000	0.377	288565.333
2048	100.00%	100.00%	100.00%	765372.000	0.366	280160.517
2049	100.00%	100.00%	100.00%	765372.000	0.355	272000.502
2050	100.00%	100.00%	100.00%	765372.000	0.345	264078.157
Beyond						8802605.241

Total Discounted Service Unit Years (DSUYs) lost: 25895086.000

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SUYs lost	Discount Factor	Discounted SUYs gained
2016	.00%	5.00%	2.50%	19134.300	0.943	18035.913
2017	5.00%	10.00%	7.50%	57402.900	0.915	52531.785
2018	10.00%	15.00%	12.50%	95671.500	0.888	85002.889
2019	15.00%	20.00%	17.50%	133940.100	0.863	115537.907
2020	20.00%	25.00%	22.50%	172208.700	0.837	144222.075
2021	25.00%	30.00%	27.50%	210477.300	0.813	171137.306
2022	30.00%	35.00%	32.50%	248745.900	0.789	196362.310
2023	35.00%	40.00%	37.50%	287014.500	0.766	219972.715
2024	40.00%	45.00%	42.50%	325283.100	0.744	242041.175
2025	45.00%	50.00%	47.50%	363551.700	0.722	262637.483
2026	50.00%	55.00%	52.50%	401820.300	0.701	281828.674
2027	55.00%	60.00%	57.50%	440088.900	0.681	299679.126
2028	60.00%	65.00%	62.50%	478357.500	0.661	316250.661
2029	65.00%	70.00%	67.50%	516626.100	0.642	331602.635
2030	70.00%	75.00%	72.50%	554894.700	0.623	345792.032
2031	75.00%	80.00%	77.50%	593163.300	0.605	358873.552
2032	80.00%	85.00%	82.50%	631431.900	0.587	370899.693
2033	85.00%	90.00%	87.50%	669700.500	0.570	381920.837
2034	90.00%	95.00%	92.50%	707969.100	0.554	391985.325
2035	95.00%	100.00%	97.50%	746237.700	0.538	401139.535
2036	100.00%	100.00%	100.00%	765372.000	0.522	399441.907
2037	100.00%	100.00%	100.00%	765372.000	0.507	387807.677
2038	100.00%	100.00%	100.00%	765372.000	0.492	376512.308
2039	100.00%	100.00%	100.00%	765372.000	0.478	365545.930
2040	100.00%	100.00%	100.00%	765372.000	0.464	354898.961
2041	100.00%	100.00%	100.00%	765372.000	0.450	344562.098
2042	100.00%	100.00%	100.00%	765372.000	0.437	334526.309
2043	100.00%	100.00%	100.00%	765372.000	0.424	324782.824
2044	100.00%	100.00%	100.00%	765372.000	0.412	315323.130
2045	100.00%	100.00%	100.00%	765372.000	0.400	306138.961
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2047	100.00%	100.00%	100.00%	765372.000	0.377	288565.333
2048	100.00%	100.00%	100.00%	765372.000	0.366	280160.517
2049	100.00%	100.00%	100.00%	765372.000	0.355	272000.502
2050	100.00%	100.00%	100.00%	765372.000	0.345	264078.157
Beyond						8802605.241

Total Discounted Service Unit Years (DSUYs) Gained: **18701625.775**
Discounted SUYs gained per unit: **24.435**

Replacement habitat size (sq. m): 1.00 * 25895086/24.435 **1059767.423**

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