KEMESS UNDERGROUND PROJECT

# Fish and Aquatic Effects Monitoring Plan

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# Fish and Aquatic Effects Monitoring Plan

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## 8.3 FISH AND AQUATIC EFFECTS MONITORING PLAN

### 8.3.1 Purpose and Objectives

This document presents the design for the Fish and Aquatic Effects Monitoring Plan (FAEMP) for the Kemess Underground Project (the Project). With ongoing monitoring occurring in the Project area as part of Kemess South closure, this FAEMP has been designed with the intention of clearly outlining current monitoring efforts in the Project area and integrating future sampling in a cohesive way to support the Project. In addition to providing monitoring to satisfy the British Columbia permit requirements outlined in the Mines Act/Environmental Management Act (MA/EMA), this design document considers federal Metal Mining Effluent Regulations (MMER) Environmental Effects Monitoring (EEM) regulations (Environment Canada 2012a) and where these requirements would integrate with the proposed monitoring program once required.

The purpose of the Fish and Aquatic Effects Monitoring Plan is to provide an outline of the structure and scope of the program, referencing applicable standards, guidelines, and regulations, with a focus on maintaining regulatory compliance. This FAEMP includes only a brief outline of methodologies, with Appendices providing more detailed monitoring approach for each specific component. The scope of the FAEMP includes watercourses immediately adjacent to the Project footprint, as well as their receiving waterbodies. It excludes regular biological monitoring in the north end of the project, which will instead be implemented as required through adaptive management plans. The FAEMP includes the following components:

- Applicable legislation, conditions from the EAC, and permit requirements outlined in the Planning section;
- A Support section, outlining required training and support documentation for the completion of the FAEMP;
- An Implementation section, outlining the general approach of the FAEMP and its relationship to other projects ongoing within the Project area;
- The Monitoring section, including the study design, timeline, and program sampling components;
- A Reporting and Recordkeeping section; and
- Two adaptive management plans (Amazay Lake and Attycelley Creek).

This FAEMP has been designed for the Kemess Underground (KUG) Project to satisfy the requirements of Mines Act /Environmental Management Act permit. The design is intended to provide an integrated approach with other ongoing monitoring programs within the Project area. This includes using the same monitoring techniques as historical data collection approaches to allow comparability between previous and ongoing sampling in the Project Area. The FAEMP was also designed to integrate the requirements of federal Environmental Effects Monitoring program under the Metal Mining Effluent Regulations into the overarching program design to allow overlap of data between the FAEMP and federal EEM programs, when initiated. The overall goals of the FAEMP program include:

- Monitor quality and quantity of mine effluent;
- Monitor changes to quality and quantity of the aquatic receiving environment;
- Provide interpretive results from fish and aquatic resource monitoring (fish, periphyton, and benthic invertebrate communities, and sediment quality); and
- Incorporating monitoring results into management strategies that mitigate potential adverse effects.

### 8.3.2 Planning

#### *8.3.2.1 Roles and Responsibilities*

General Manager

The General Manager will be accountable for the Project's overall environmental performance. The General Manager will be familiar with, and support the FAEMP by helping to evaluate any activities which may cause an adverse effect on fish and aquatic habitats.

Environmental Superintendent

The Environmental Superintendent will be responsible for all environmental management matters for the Project. This includes overseeing the development, implementation, and reporting of the Fish and Aquatic Effects Monitoring Program. The Environmental Superintendent will be aware of legislative and permitting requirements of the FAEMP and ensure permitting and regulatory commitments are satisfied. The Superintendent will be responsible for communications with government and community, including First Nations groups.

Employee

AuRico personnel and contractors working on the Project will receive a site orientation upon arriving to the Project area. This will include outlining environmental concerns and making employees aware of their roles and responsibilities with respect to communicating environmental concerns to the Environmental Superintendent.

Qualified Professional

AuRico will retain a qualified professional to conduct the Fish and Aquatic Effects Monitoring Plan. A qualified professional refers to a person who has training, experience, and expertise in a discipline relevant to the field of practice set out in the condition or regulation, and who is registered with the appropriate professional organization, is acting under that organization's code of ethics, and is subject to disciplinary action by that organization.

#### *8.3.2.2 Compliance Obligations*

Legislation and Regulations

This FAEMP was developed in accordance with applicable federal and provincial regulations and conformant to relevant guidelines. These include:

- Metal Mining Effluent Regulations (MMER) under the Fisheries Act (1985), which stipulates and details the requirements for environmental effects monitoring (EEM) if effluent (>50m$^3$/day) or deleterious substances are released into a receiving waterbody;
- Canadian Environmental Assessment Act (2012), which stipulates the implementation of environmental compliance monitoring programs;
- British Columbia Environmental Management Act (2003);
- British Columbia Water Sustainability Act (2016); and
- Mines Act (1996).

Environmental Assessment Certificate (EAC) and Federal Environmental Assessment (EA) Decision Conditions

On March 15, 2017 the Kemess Underground Project was issued an Environmental Assessment Certificate (#M17-01), which included a series of conditions required to be met by AuRico Metals Incorporated. This FAEMP was designed to satisfy Condition 22 and 23 of the EAC:

Condition 22:

*"The holder must retain a Qualified Professional to update the Fish and Aquatic Effects Monitoring Plan in section 24.7 of the Application. The plan must be developed in consultation with FLNRO, ENV and Aboriginal Groups.*

*The plan must include at least the following:*

*a) The means by which the holder will monitor for concentration for bio-accumulative contaminants in bull trout in Thutade Lake;*
*b) Monitoring locations, frequencies and duration for the monitoring required by bullet a);*
*c) Study parameters of fish health metrics and observations;*
*d) Comparison of fish and aquatic effects monitoring plan results to water quality monitoring results;*
*e) How and with who the results of the study will be shared; and*
*f) Remedial actions that must be implemented if the study finds excessive concentrations of bio-accumulative contaminants in bull trout in Thutade Lake are Project-related as determined by a Qualified Professional.*

*The holder must provide this draft plan to FLNRO, ENV, Aboriginal Groups and EAO for review a minimum of 45 days prior to the planned commencement of Construction.*

*The plan, and any amendments thereto, must be implemented to the satisfaction of a Qualified Professional throughout Construction, Operations and Closure and to the satisfaction of EAO."*

Condition 23:

*"Prior to installation of the effluent diffuser the Holder must demonstrate to the EMC how the design of the effluent diffuser to be installed in Attichika Creek has maximized effectiveness as determined by a Qualified Professional, using creek flow characteristic to minimize distance of the initial dilution zone from the discharge point on Attichika Creek.*

*The effluent diffuser must be designed so that the initial dilution zone of the discharge does not compromise salmonid spawning habitat as determined by a Qualified Professional.*

*The Holder must retain a Qualified Professional to develop a plan for monitoring fish and fish habitat use within the initial dilution zone in Attichika Creek. The plan must be developed in consultation with ENV, FLNRO and Aboriginal Groups.*

*The plan must include at a minimum:*

*a) Details (locations, frequency and duration) of monitoring prior to and after installation of the discharge pipeline into Attichika Creek to determine if bull trout are avoiding the initial dilution zone;*
*b) If results of monitoring indicate an adverse effect from the effluent discharge to fish habitat use, the Holder must identify and implement additional mitigation strategies to reduce such effect which may include offsetting as defined in ENV's Mitigation Policy; and*
*c) Details on how the monitoring results will be reported to EAO, ENV, FLNRO and Aboriginal Groups.*

*The Holder must provide this draft plan to FLNRO, ENV, Aboriginal Groups and EAO for review a minimum of 45 days prior to the planned commencement of Construction.*

*The plan, and any amendments thereto, must be implemented throughout Construction, Operations and Closure under the supervision of a Qualified Professional and to the satisfaction of EAO."*

Conditions under the Canadian Environmental Assessment Act, 2012 have also been considered and incorporated in relevant sections this FAEMP design document. An overview of all regulations and federal requirements are outlined within this document, despite the overarching goal of meeting provincially mandated monitoring requirements of the Project in this monitoring plan. The following conditions are applicable to monitoring Fish and Aquatic Habitats:

*Condition 3.5: The Proponent shall, in a manner that complies with the Metal Mining Effluent Regulations and 3.5 subsection 36(3) of the Fisheries Act, discharge water from the tailings storage facility into Attichika Creek during construction and the first year of operation such that flow rates downstream of the discharge location are within the range of minimum and maximum flow rates naturally occurring in Attichika Creek, and shall only discharge water into Attichika Creek during open water months;*

*Condition 3.7.1: Monitor quality of water discharged in Attichika Creek during the dewatering of the Kemess South Pit and treat that water to meet the requirements of subsection 36(3) of the Fisheries Act;*

*Condition 3.7.2: The Proponent shall monitor surface water quality in Amazay Lake and groundwater movement between the subsidence zone identified by the Proponent during the environmental assessment and Amazay Lake* (This monitoring will be outlined in a standalone Amazay Lake Monitoring Plan, but will contribute to the FAEMP Adaptive Management section);

*Condition 3.7.3: The Proponent shall monitor changes in channel form and sediment load downstream of the discharge location in Attichika Creek;*

*Condition 3.7.4: The Proponent shall monitor changes in water quality in Waste Rock Creek and the tailings storage facility, including changes in selenium concentrations;*

*Condition 3.7.5: The Proponent shall monitor the presence and use of spawning habitat by bull trout (Salvelinus confluentus) and rainbow trout (Oncorhynchus mykiss) downstream of the discharge location in Attichika Creek prior to and after the installation of the discharge pipeline into Attichika Creek. The Proponent shall offset any loss of spawning habitat for bull trout (Salvelinus confluentus) and rainbow trout (Oncorhynchus mykiss) in Attichika Creek if monitoring results show that spawning habitat loss has occurred* (Rainbow trout fry have historically not been found in lower Attichika Creek, suggesting that no spawning occurs in lower Attichika Creek)*; and*

*Condition 3.7.6: The Proponent shall monitor contaminants, including mercury, in the tissue of fish species harvested by Indigenous groups in Thutade Lake, including bull trout (Salvelinus confluentus).*

Permit Requirements

Relevant permits required for completion of monitoring will include Scientific Fish Collection Permits, which will need to be obtained prior to conducting any fish sampling outlined within this FAEMP.

Guidelines for Best Management Practices

Study design, field methodology, and data analysis and interpretation have been developed following standard procedures described in various best-practice documents widely used in the design and implementation of effective aquatic environmental monitoring and assessment programs. These include:

- Guidelines for Designing and Implementing a Water Quality Monitoring Program in British Columbia (Cavanagh et al. 1998);
- British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples (BC MOE 2013);
- Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators' (BC MOE 2012, BC MOE 2016b);
- Federal Metal Mining Technical Guidance for Environmental Effects Monitoring (Environment Canada 2012a);
- BC Resources Inventory Standards Committee (RISC) guidance for fish habitat inventory (BC MOE 2008);
- British Columbia Field Sampling Manual (Clark 2003);
- Environmental Code of Practice for Metal Mines (Environment Canada 2012b);
- Policy for Metal Leaching and Acid Rock Drainage in British Columbia (BC MEM and BC MOE 1998);
- Guidelines for Metal Leaching and Acid Rock Drainage at Mine Sites in British Columbia (Price and Errington 1998);
- Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (Price 2009); and
- Hatfield Consultants' Standard Operating Procedures (available for review upon request).

### 8.3.3 Support

#### *8.3.3.1 Training and Awareness*

All staff working at Kemess mine will be required to complete the general site orientation to ensure they are aware of applicable health and safety rules and requirements while working on the mine site. Specific training will be required for staff to effectively implement this monitoring plan. This will include experience in aquatic sampling protocols, safety procedures, data handling, and technical writing. More formal training, such as electrofishing certification and pleasure craft operator cards may be required while performing specific field tasks. All personnel implementing the FAEMP will be required to communicate any finding or immediate concerns discovered during the field program directly to AuRico's Environmental Department.

#### *8.3.3.2 Supporting Documentation*

Documentation to support the implementation of this FAEMP includes the sampling protocols listed in the Guidelines for Best Management Practice section (within Section 8.3.2.2). In addition to these protocols, historical reports are available to provide context to the FAEMP including Kemess South provincial and federal EEM programs, the selenium monitoring program, and the Environmental Assessment Application (AuRico 2016).

### 8.3.4 Implementation

#### *8.3.4.1 General Approach*

This Fish and Aquatic Effects Monitoring Program study design is intended to be a "living document", where the design may be adapted, as required, as further information from monitoring efforts becomes available. The FAEMP will follow a weight of evidence assessment approach, where information gained from all fish and aquatic components will be used cohesively to evaluate potential effect from the Project on the receiving environment. Linkages between the aquatic components used in the weight of evidence interpretation is described in the Conceptual Site Model following this section.

The study design presented in this document includes some initial years of intensive monitoring followed by a standard monitoring approach. The objectives of the rigorous sampling efforts are to provide further baseline information pre-discharge and to capture potential early effects of discharge on the receiving environment in the Construction and Operations phases. The intensive sampling will provide more extensive background information that will aid in determining effects of effluent on aquatic receptors in Attichika Creek prior to the implementation of the federal EEM monitoring. This intensive sampling will also provide a more comprehensive set of baseline data, which will be used gauge if cumulative effects of the project are occurring over the span of the Project, by allowing changes to be tracked over time in various sampling components. This rigorous sampling will occur during the first seven years (4 years of Construction and 3 years of Operations) of the Project. The overall sampling components for the FAEMP include:

- Effluent chemistry and characterization;

- Effluent toxicity;
- Surface water quality;
- Sediment quality;
- Periphyton biomass and community composition;
- Benthic invertebrate communities and tissue analysis; and
- Fish studies.

In addition to the above surveys, this FAEMP also incorporates an adaptive management approach, where some additional monitoring plans are linked to water quality triggers. As further information becomes available, refining the ongoing monitoring will help improve the database and facilitate refocusing of efforts into areas of concern, if necessary, to maximize sampling efforts. Further description of the triggers and adaptive management strategies are outlined in Section 8.3.7.1.

Conceptual Site Model

As identified in the EA, the primary pathways of interaction between the Project and fish and aquatic habitat Valued Components (VCs) in the Project area are through changes in water quantity and quality. Using residual and cumulative effect scoping, no significant effects were predicted due to shifting water quantity and quality conditions (EAC; AuRico 2016). Despite there being no expected effects, a conceptual site model (CSM) was created to demonstrate the potential linkages (pathways) between project activities and VCs in the receiving environment.

Traditionally conceptual site models are used in ecological risk assessments and contaminated site investigations focussing on contamination-mediated effects related to chemicals of potential concern (COPCs). Based on BC government guidance regarding model developments (Landis et al. 1998), a schematic using key ecological receptors and exposure pathways was used to demonstrate potential mine-related impacts on the project area. The CSM created for this FAEMP incorporates the traditional COPCs pathways, incorporating Project specific risks associated with water quantity and quality that may result from mine discharges to Attichika Creek and groundwater sink effects caused by the development of the cave zone potentially impacting flows to East Cirque, Central Cirque, and El Condor creeks. The relevant Kemess Underground CSM schematic is provided in Figure 8.3-1.

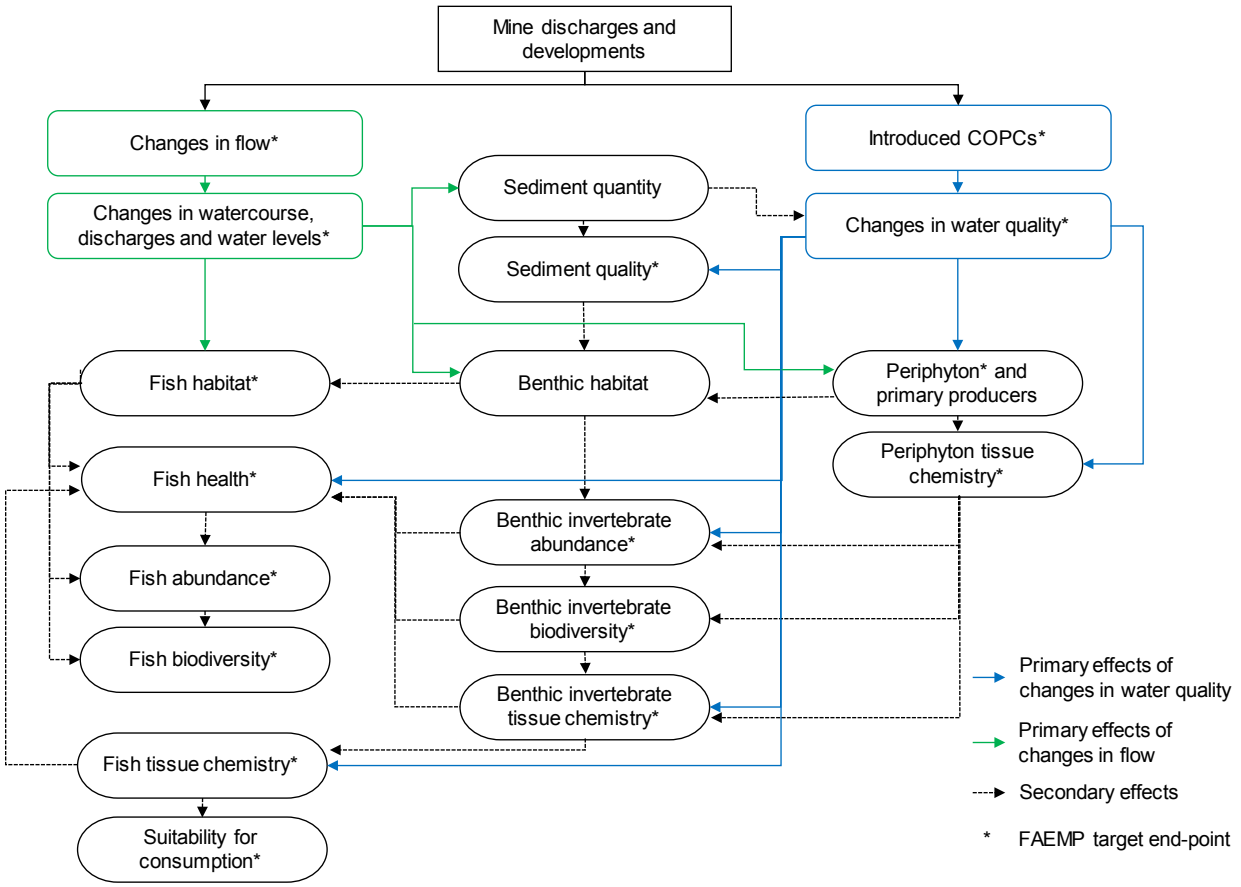
Although no residual or cumulative effects are predicted from discharge into Attichika Creek, the impact pathway for increased concentrations of COPCs into the creek could have both indirect and direct implications on aquatic biota in the receiving environment. Effects linked to increases in COPCs could include changes to periphyton (through toxicity or nutrient enrichment), and effects on the health of aquatic invertebrates and fish, which may lead to population and community-level changes to these organisms (either through direct toxicity or indirectly through enrichment mediated via stimulated periphyton growth). Increase in COPCs in receiving waters also interact with sediments, where they can equilibrate with or sequester, impacting sediment quality. Specific COPCs taken up by invertebrates and fish may bioaccumulate, affecting tissue chemistry suitability of fish tissues for consumption by humans or wildlife.

Water quantity changes due to Project activities were not predicted to cause residual or cumulative effects on fish and aquatic habitats in the receiving environment (EAC; AuRico 2016). Changes to

water quantity have the potential to shift the quantity and quality of fish and invertebrate habitats in creeks, with increasing flows in receiving waters (Attichika Creek and Waste Rock Creek during Post-Closure) and a decreasing effect expected in the north end of the Project through eliminating seepage connections to creeks (Central Cirque Creek (Inlet 6) and East Cirque Creek). Other potential effects of discharge-related changes in stream flow include effects of increased flows on sediment quantity (indirectly affecting water and sediment quality), and increases in periphyton growth through increased nutrient delivery.

Endpoints monitoring as part of this FAEMP are shown with asterisks in the Project CSM in Figure 8.3-1. When a specific component is not targeted for direct assessment in this FAEMP (e.g., benthic habitat), a connecting pathway for which more relevant and/or VC endpoint is used instead as a monitoring target (i.e., in the case of benthic habitat, periphyton and invertebrate communities will be assessed directly). A comprehensive baseline data set will be available to determine changes to measured endpoints over time and to identify any potential cumulative effects of the project in the receiving environment. Sampling multiple endpoints supports a weight of evidence approach to data interpretation, where connections outlined in the CSM are expected to respond to changes in either water quality or quantity in a systematic way.

**Figure 8.3-1 Conceptual site model diagram showing key exposure pathways for potential effects linked to the Kemess Underground Project.**



Triggers and Adaptive Management Responses

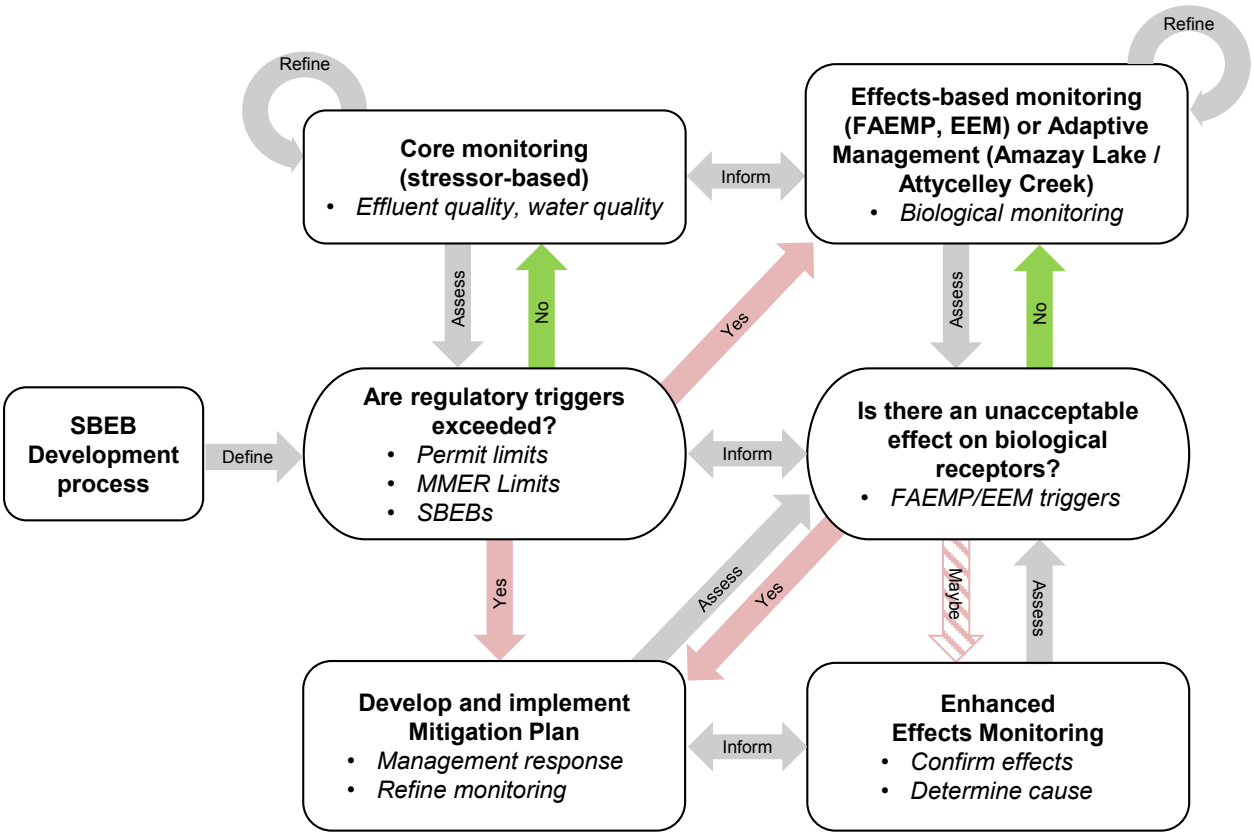
Environmental protection measures including actions to circumvent, regulate, or mitigate adverse environmental effects that are relevant to the FAEMP are incorporated in various environmental monitoring and management plans outlined in this Application. The design of the Project aims to control the quantity and quality of effluent released to the receiving environment in a manner that maintains environmental compliance throughout the Construction, Operation, Closure, and Post-Closure phases. The management approach will strive to minimize the number of pathways by which the Project can adversely affect the receiving aquatic environment.

The FAEMP was designed to help provide information to guide management approaches. Knowledge gained through aquatic monitoring will be used to identify potential mine-related effects on aquatic receiving environments, which in turn will be used to: (a) refine ongoing monitoring; (b) identify specific questions requiring more focused monitoring where necessary, such as determination of causes of any identified adverse effects; and (c) assist development, implementation and assessment of mitigative actions to address identified effects.

The FAEMP will begin during the first year of construction (year -4) and include an intensive monitoring program occurring every few years over a seven-year period, with infill years of slightly reduced monitoring requirements. During the seven-year period, the program should be re-evaluated if development of SBEBs occurs, or if water quality triggers (as outlined in 8.3.7.1) are exceeded, leading to implementing the proposed adaptive management plans on the north side (Attycelley Watershed) of the Project (See sections 8.3.7.2 and 8.3.7.3). Results of the first few federal EEM cycles also will contribute additional information and understanding to aquatic monitoring and management at Kemess Mine.

Knowledge gained through the FAEMP implementation will clarify important linkages between stressor and effects-based monitoring endpoints. This will provide necessary information for the development of measurable, meaningful, and reliable triggers for use in long-term future monitoring using an approach outlined in Figure 8.3-2.

**Figure 8.3-2 Pathways of exposure and potential effects of discharge at KUG Mine and relationship to Adaptive Management.**




### *8.3.4.2 Relationship of FAEMP with Other Aquatic Assessment Programs*

The Kemess South (KS) Mine site, which is currently under care and maintenance, overlaps with the KUG Project area. The care and maintenance of KS includes the continuation of ongoing fish and aquatic monitoring habitat programs around the mine.

The following sections outline the ongoing KS monitoring programs, including respective sampling locations and frequency. In addition, information is provided outlining requirements of the federal EEM program and the Integrated Waste Rock Creek Monitoring Program for KUG, which will function concurrently with the FAEMP once implemented. Timelines of projects are found in Figure 8.3-3, with the following projects outlined in sections below:

- Kemess Underground federal EEM program;
- Kemess Underground Integrated Waste Rock Creek Monitoring Program;
- Kemess South provincial EEM program; and
- Long-term fish monitoring program in lower Attichika Creek and Kemess Creek.

**Figure 8.3-3 Timeline of all Aquatic Monitoring Programs ongoing in Kemess Area, including those related to Kemess Underground and the Kemess South operations.**


*Note: discharge monitoring is to begin in 2018 for all elements except the fish telemetry study.*

Kemess Underground Federal Environmental Effects Monitoring Program

Kemess Underground mine will be required to undertake federal Environmental Effects Monitoring (EEM) studies once the mine triggers the Metal Mining Effluent Regulations (MMER). The MMER are triggered once effluent discharged reaches 50 $m^3$/day. The first EEM cycle interpretive report is due 30 months after the mine triggers the MMER, with each subsequent phase to follow occurring within a three (or six) year cycle. The EEM program will be developed to assess the adequacy of the mines effluent under the federal *Fisheries Act*. Specifically, EEM is designed to address possible effects of metal mining effluents on aquatic biota through conducting biological monitoring studies, effluent and water quality monitoring studies, and sublethal toxicology testing of effluent.

Environmental Effects Monitoring studies (MMER Schedule 5, Part 2) consist of:

- Effluent and water quality studies, including: effluent characterization, sublethal toxicity testing, and water quality monitoring; and
- Biological monitoring studies in the receiving environment to determine effluent effects on fish, fish habitat, or the use of fisheries resources, which are monitored as:
  - Fish population surveys;
  - Benthic invertebrate community surveys; and
  - Fish tissue surveys.

Although the federal EEM survey components and applicable regulations are mentioned within the FAEMP, this design document was created to specifically meet provincially mandated regulations. Additional independent design documents for federal EEM studies will be required six months prior to surveys being undertaken, with the first design due twelve months following the MMER being triggered (MMER Schedule 5, Part 2, 14 and 15). This FAEMP considers the timeline for federal EEM surveys and aims to reduce sampling redundancy by overlapping the programs together where possible. The FAEMP also contributes to the federal EEM requirements by providing further baseline information for Attichika Creek, which will be the focus of both programs.

Kemess Underground Integrated Waste Rock Creek Monitoring Program

As part of the MA/EMA permitting process, AuRico has developed Environmental Management Plans (EMPs) to support the Kemess Underground Project throughout its development, operations, and closure. All mine management plans are intended to be "living documents" that will be re-evaluated and upgraded throughout the life of the Project based on regulatory changes, changes to the Project, or changes to mitigation and management measures as a part of an adaptive management strategy. Mine and Environmental Management Plans are provided in Chapter 7 of this application.

Two monitoring plans, the Nitrate Management Plan (Appendix 7-N) and the Selenium Management Plan (Appendix 7-O), have been developed in support of the Project and include fish and aquatic monitoring in the Waste Rock Creek system. The Waste Rock Creek system has elevated concentrations of both nitrate and selenium in water caused by leaching from the Kemess South Waste Rock Storage Facility (Chapter 2.6.2; Appendix 7-O). Both monitoring plans target similar monitoring locations, so an integrated Kemess Underground Waste Rock Creek Monitoring Report

is expected to capture requirements of both plans, which will be produced annually with submission on March 31st of each year.

This new integrated monitoring program will incorporate previous sampling information available from the Kemess South Annual Selenium Monitoring Program (details provided in this section), while providing an additional focus surrounding impacts of elevated concentrations of nitrate in the Waste Rock Creek system. The following components will be included in the monitoring program:

- Monitoring of seepage water from the Kemess South Waste Rock Storage Facility;
- Surface water quality monitoring;
- Biological monitoring;
    - Benthic invertebrate monitoring;
    - Sediment pore water sampling;
    - Supporting sediment quality monitoring;
    - Periphyton monitoring;
    - Fish community and fish tissue monitoring; and
- Flow monitoring, which will remain ongoing in upper Waste Rock Creek at station WQ-14F and be added to lower Waste Rock Creek below the ORAR crossing at WQ-14ds to ensure flow needs in the creek are met for fish overwintering.

Further information regarding specifics of sampling can be found in the most current versions of the Selenium Management Plan and the Nitrate Management Plan. These "living document" will likely be subject to change, given the Project includes a Science-Based Environmental Benchmark (SBEB) Development Plan for selenium in the Waste Rock Creek watershed. Monitoring targets for the biological monitoring will be provided in greater detail through the creation of a harmonized monitoring approach, integrating requirements of both the Selenium Management Plan and Nitrate Management Plan.

Kemess South Provincial Environmental Effects Monitoring Program

The 1996 Kemess South Fisheries Impact and Compensation Agreement (FCA) included an EEM program, to be implemented for the life of the mine. This program is administered by the BC Ministry of Environment (BC MOE) separately from the federal EEM program. Kemess South Mine has conducted an annual provincial EEM program since 1997, to assess potential effects of the mine's operation on the aquatic receiving environment. During mine operations, the provincial EEM program focused on potential sedimentation effects on the quality of fish habitat, particularly conditions for bull trout spawning and over-winter egg incubation, in the Kemess Watershed and lower Attichika Creek. The program included assessments of substrate composition and two biological endpoints: periphyton (biomass and taxonomic composition) and benthic invertebrates (community structure). These studies were conducted and reported by various consultants from 1997 to the present: Hallam Knight Piesold (1998), AGRA (1999, 2000), AMEC (2001), McElhanney (2002 to 2005), and Hatfield Consultants (2006 to Present).

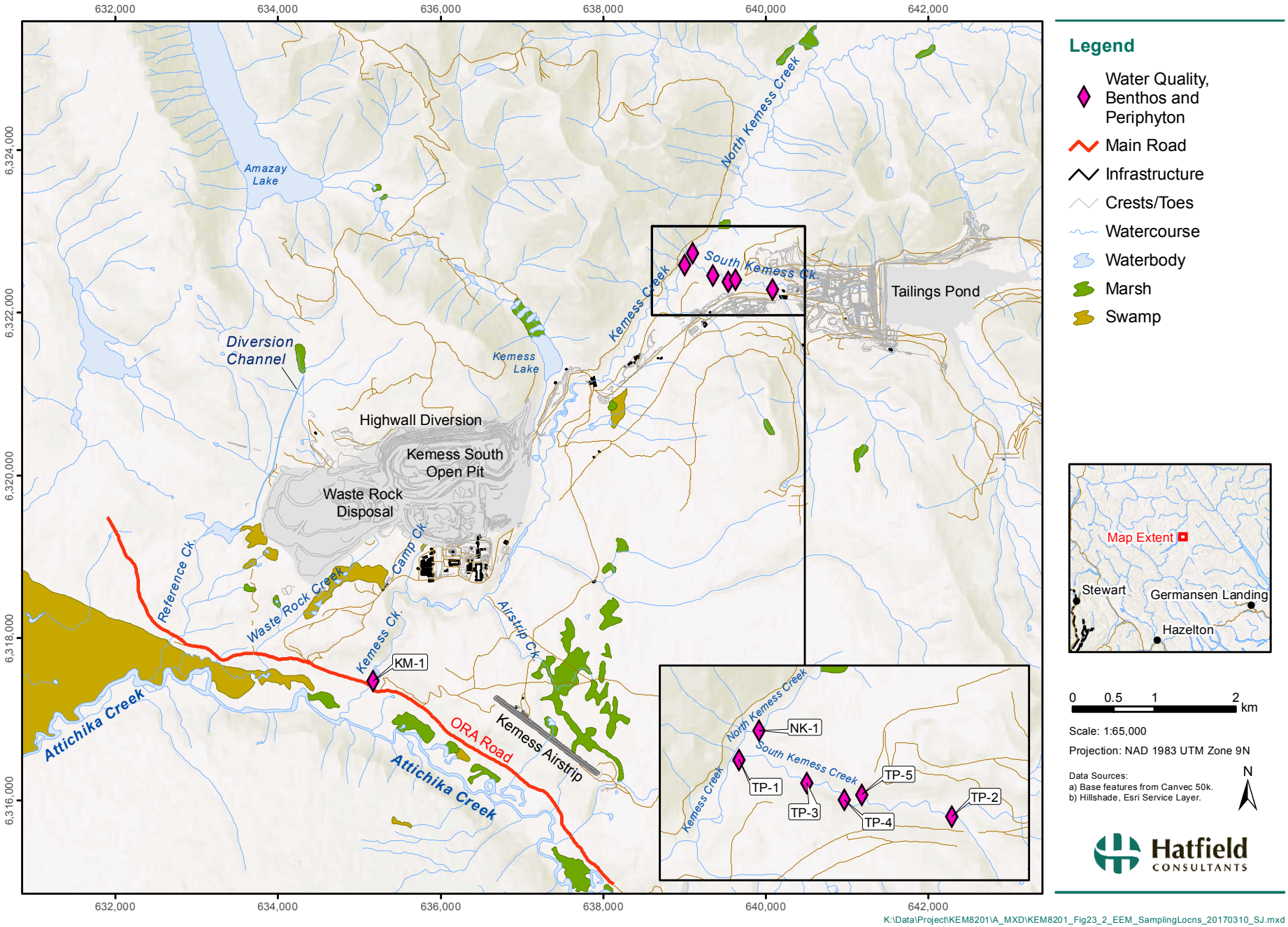
In advance of the Kemess South mine closure in March 2011, the EEM program was redesigned in 2010 to focus primarily on potential future effects of water release from the Kemess South TSF Pond to South Kemess Creek, with the first direct release occurring in June 2017. This re-designed program

focuses on South Kemess Creek downstream from the tailings impoundment (five stations), but also includes sampling in North Kemess Creek (control/reference site) and lower Kemess Creek mainstem. Station locations were relocated to include the same locations as juvenile fish sampling. The most current summary is presented in Hatfield (2018a), with sampling components and locations provided in Table 8.3-1 and Figure 8.3-4 respectively.

**Table 8.3-1 Kemess South Provincial Environmental Effects Monitoring sampling components (2010 to present).**

| Sampling Location | Water Quality | Periphyton Biomass | Periphyton Taxonomy | Benthic Invertebrate Taxonomy |
|---|---|---|---|---|
| North Kemess Creek (EEM-4 / WQ-04) | Quarterly sampling conducted by mine staff | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| South Kemess Creek (TP-2 / WQ-25) | Monthly sampling conducted by mine staff | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| South Kemess side-channel (TP-5) | - | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| Middle South Kemess Creek (TP-4) | - | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| lower-mid South Kemess Creek (TP-3) | - | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| Lower South Kemess Creek (TP-1) | - | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |
| Lower Kemess Creek (KM-1 / WQ-01) | Monthly sampling conducted by mine staff | Sampled annually (5 replicates) | Sampled annually (1 composite sample of 5 rock scrapings) | Sampled annually using a Hess sampler (3 replicates) |

**Figure 8.3-4 Locations of Kemess South Provincial Environmental Effects Monitoring sampling components (2010 to present).**



Long-term Kemess South Fish Monitoring Studies

The Fisheries Compensation Agreement (FCA) led to the creation of a long-term monitoring program for fish populations, including compensation projects in the Thutade Watershed with specific time frames and measures of success. The fish studies focused on juvenile and adult bull trout and Dolly Varden, and used a combination of juvenile fish index sites and adult bull trout redd surveys as key indicators of success, with most recent summaries presented in Bustard (2017).

Fisheries studies conducted up to 2009 included monitoring throughout the Thutade Watershed. With the successful completion of most fisheries components outlined in the 1996 FCA, the fisheries monitoring program was modified in 2010. This modified program focuses on the Kemess and Attichika watersheds and Tributary 4 upstream of the fishway, and addresses the remaining outstanding elements outlined in the Kemess South FCA[1]. These outstanding elements include: fish monitoring downstream from the flooded impoundment for five years post spillway operation, evaluating the self-sustainability of bull trout spawning sites in South Kemess Creek and upper Tributary 4, and operating the constructed fishway. The revised program is coordinated annually with the modified Kemess South provincial EEM monitoring program (Hatfield 2014) and hydrometric studies (Beaudry 2013). In support of the KUG Project, the long-term fish monitoring program was modified in 2014 through expanding the program to include juvenile index sites and adult bull trout redd surveys in lower Attichika Creek (Figure 8.3-5; Bustard 2017).

[1] The revisions to the program are based on joint decisions made by the Kemess Fisheries Management Committee following a series of meetings between November 2009 and June 2010.

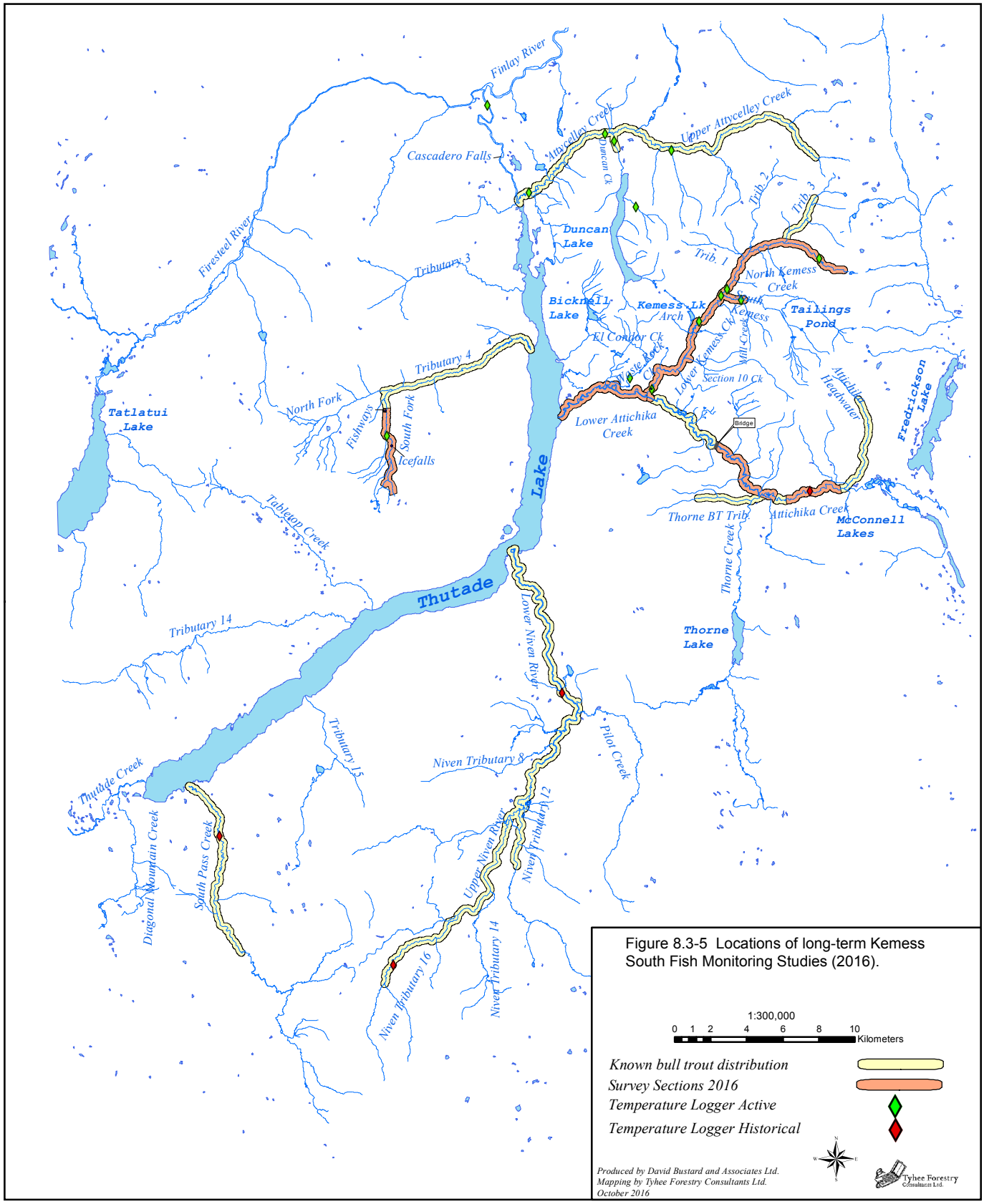



Figure 8.3-5 Locations of long-term Kemess South Fish Monitoring Studies (2016).

Document Name: figure-1-1-2016

Annual Selenium Monitoring Program

The Selenium Monitoring Program focuses on Waste Rock Creek and the lower Attichika wetland, an area that overlaps with the Project area and will provide relevant monitoring locations during the Post-Closure phase. At Post-Closure waters will be discharged to Waste Rock Creek from the KUG TSF and Waste Rock Creek will become more of a focus of the FAEMP monitoring. Ongoing monitoring from the Selenium Monitoring Program will contribute to satisfying the federal conditions outlined by the Canadian Environmental Assessment Agency under the Canadian Environmental Assessment Act (2012) as part of the Kemess Underground Project; specifically, Condition 3.7.4 "*Monitor changes in water quality in Waste Rock Creek and the tailings storage facility, including changes in selenium concentrations*". Sampling components and locations for the Selenium Monitoring Program are outlined in the Selenium Management Plan. Selenium monitoring in Waste Rock Creek will form a component of the integrated Waste Rock Creek monitoring program.

### 8.3.5 Monitoring

An overview of sampling activities to support the FAEMP is presented in Table 8.3-2, with corresponding sample locations outlined in Figure 8.3-6. The FAEMP biological monitoring generally uses a BACI (Before-After Control-Impact) design, where possible. It includes two reference locations (for most monitoring components), a near-field sampling site (just downstream of the IDZ) and a far-field sampling location within Attichika Creek. The second reference sampling location for the FAEMP, which is below the confluence with Kemess Creek (EEM-17), will help distinguish any potential cumulative effects in the Project area that may be related to Kemess South mine, which has been discharging into South Kemess Creek since June 2017. The upstream reference location above the confluence with Kemess Creek (EEM-13) will have no effects from either Kemess South or Kemess Underground mines.

Sampling and assessment methods for each study component are briefly outlined within their corresponding document sections, with comprehensive methodologies for each component provided in the Appendices. The overall sampling components for the FAEMP include:

- Effluent chemistry and characterization;
- Effluent toxicity;
- Surface water quality;
- Sediment quality;
- Periphyton biomass and community composition;
- Benthic invertebrate communities and tissue residue analysis; and
- Fish studies.

**Table 8.3-2 Summary of core sampling activities associated with Kemess Underground Fish and Aquatic Effects Monitoring Plan.**

| Sampling Location | Effluent Toxicity, Monitoring and Characterization | Water Quality | Sediment Quality | Periphyton Biomass | Periphyton Community Composition | Benthic Inverts (intensive Program) | Benthic Inverts (routine monitoring) | Fish Sentinel Species Survey | Adult Fish Survey[3] | Fry and Juvenile Survey |
|---|---|---|---|---|---|---|---|---|---|---|
| Mine Effluent – ATT-DIS | Acute toxicity: monthly<br>Sublethal toxicity: twice a year<br><br>Weekly effluent monitoring for select parameters<br><br>Effluent characterization studies | - | - | - | - | - | - | - | - | - |
| Upper Attichika Creek, upstream of Kemess Creek (WQ-13/EEM-13) | Water quality monitored as required by effluent characterization studies[5] | Annually with Benthic Invertebrate program and during sentinel species fish program[1] (1 sample)<br><br>PAH sampling pre-construction (2018) | Annually during construction and first three years of operations phase in conjunction with benthic invertebrate program (3 replicates)[2]<br><br>PAH sampling pre-construction (2018) | Annually in conjunction with benthic invertebrate survey (5 replicates) | Annually during benthic invertebrate survey until year 3 of operations (1 replicate)[2] | Every third year (starting in year -4 of construction) for three surveys (5 reps)[2]<br><br>And one composite sample for tissue analysis (including Se) | Annually (1 rep)<br><br>One sample for tissue analysis (including Se) | Every third year (starting in year -4 of construction) for three surveys (3 locations)[2]<br><br>Some fish to be used for tissue analysis | Annual counts of redds in Attichika Creek<br><br>Annual non-lethal tissue plug survey of adfluvial bull trout in Attichika Creek | Annual sampling for species composition and abundance (using historical sites upstream of the Attichika Bridge area). |
| Attichika Creek, upstream of the diffuser (WQ-17/EEM-17)[6] | Water quality monitored as required by effluent characterization studies[5] | Annually with Benthic Invertebrate program and during sentinel species fish program[1] (1 sample)<br><br>PAH sampling pre-construction (2018) | Annually during construction and first three years of operations phase in conjunction with benthic invertebrate program (3 replicates)[2]<br><br>PAH sampling pre-construction (2018) | Annually in conjunction with benthic invertebrate survey (5 replicates) | Annually during benthic invertebrate survey until year 3 of operations (1 replicate)[2] | Every third year (starting in year -4 of construction) for three surveys (5 reps)[2]<br><br>And one composite sample for tissue analysis (including Se) | Annually (1 rep)<br><br>One sample for tissue analysis (including Se) | - | Annual counts of redds in Attichika Creek<br><br>Annual non-lethal tissue plug survey of adfluvial bull trout in Attichika Creek | Annual sampling for species composition and abundance (using historical sites upstream of the Attichika Bridge area). |
| Attichika Creek downstream of discharge location (ATT-IDZ) | Water quality monitored as required by effluent characterization studies[5] | Annually with Benthic Invertebrate program and during sentinel species fish program[1] (1 sample)<br><br>PAH sampling pre-construction (2018) | Annually during construction and first three years of operations phase in conjunction with benthic invertebrate program (3 replicates)[2]<br><br>PAH sampling pre-construction (2018) | Annually in conjunction with benthic invertebrate survey (5 replicates) | Annually during benthic invertebrate survey until year 3 of operations (1 replicate)[2] | Every third year (starting in year -4 of construction) for three surveys (5 reps)[2]<br><br>And one composite sample for tissue analysis (including Se) | Annually (1 rep)<br><br>One sample for tissue analysis (including Se) | Every third year (starting in year -4 of construction) for three surveys (3 locations)[2]<br><br>Some fish to be used for tissue analysis | Annual counts of redds in Attichika Creek<br><br>Annual non-lethal tissue plug survey of adfluvial bull trout in Attichika Creek<br><br>Bull trout telemetry studies before and after discharge released to determine any impacts on migration patterns[4] | Annual sampling for species composition and abundance |
| Lower Attichika Creek, below Waste Rock Creek (WQ-18/EEM-18) | - | Annually with Benthic Invertebrate program and during sentinel species fish program[1] (1 sample)<br><br>PAH sampling pre-construction (2018) | Annually during construction and first three years of operations phase in conjunction with benthic invertebrate program (3 replicates)[2]<br><br>PAH sampling pre-construction (2018) | Annually in conjunction with benthic invertebrate survey (5 replicates) | Annually during benthic invertebrate survey until year 3 of operations (1 replicate)[2] | Every third year (starting in year -4 of construction) for three surveys (5 reps)[2]<br><br>And one composite sample for tissue analysis (including Se) | Annually (1 rep)<br><br>One sample for tissue analysis (including Se) | Every third year (starting in year -4 of construction) for three surveys (3 locations)[2]<br><br>Some fish to be used for tissue analysis | Annual counts of redds in Attichika Creek<br><br>Annual non-lethal tissue plug survey of adfluvial bull trout in Attichika Creek | Annual sampling for species composition and abundance |

[1] *If benthic program and sentinel species programs occur at same time, only one sample required.*

[2] *Follow for the timeline stated, then the frequency of sampling will be re-evaluated.*

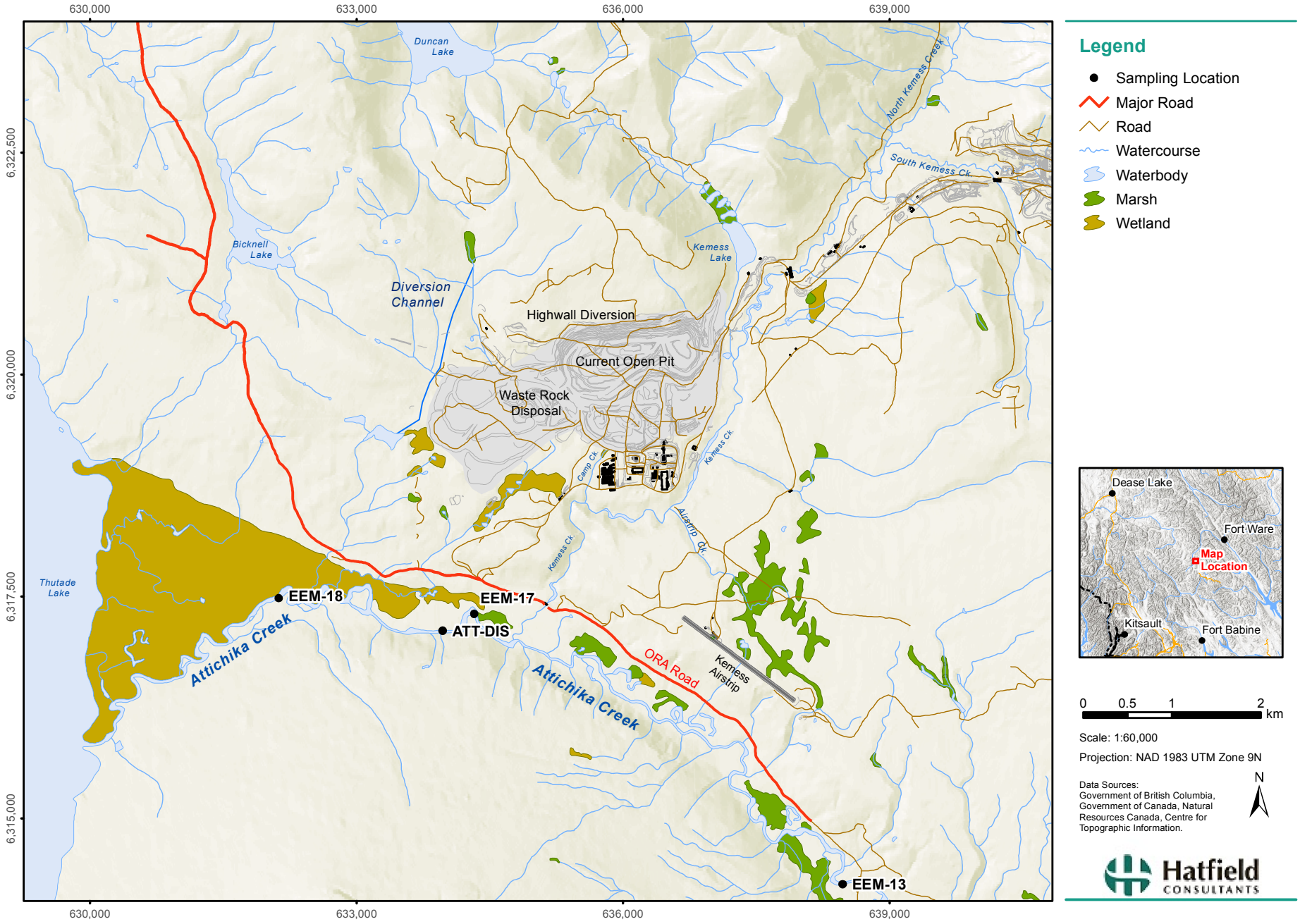
[3] *Non-lethal tissue sampling of adult bull trout will not occur at specified locations, but instead from fish collected at staging locations within the Attichika Watershed, typically located upstream from the diffuser.*

[4] *Telemetry study to monitor if changes in bull trout migration occur following discharge will be conducted by Chu Cho Environmental beginning in 2017 using bull trout captured in staging areas.*

[5] *Note: this location will vary from biological monitoring and will be defined by MMER requirements and guidance during EEM studies.*

[6] *No sentinel species study will be conducted between EEM-17/WQ-17 and the Kemess Creek confluence (second reference) given the limited fish habitats available likely mean not enough fish will be captured.*

**Figure 8.3-7 Aquatic resource sampling locations for the Kemess Underground Fish and Aquatic Effects Monitoring Plan.**



#### *8.3.5.1 Effluent Chemistry and Flow Monitoring*

Effluent Chemistry and Characterization Studies

The Metal Mining Effluent Regulations (MMER) under the Fisheries Act details the monitoring requirements for any effluent from any mine workings that contains a deleterious substance. As described in the MMER, monitoring must occur at any 'identifiable discharge point of a mine beyond which the operator of the mine no longer exercises control over the quality of the effluent'. The Kemess Underground Project has one identified final discharge point through the first three phases of the Project, namely the diffuser discharge to Attichika Creek. At Post-Closure, the discharge point becomes Waste Rock Creek, via the KUG TSF spillway (approximately Year 20 of the Project).

Monitoring for effluent chemistry will include weekly monitoring of effluent quality as well as effluent characterization studies, as required by the MMER. As part of the weekly effluent chemistry monitoring during discharge to Attichika Creek, deleterious substances, pH, and flow measurement will be collected, as specified in the MMER, Division 2, Sections 12 and 13. Deleterious substances include TSS and various metals outlined in Schedule 4 of the MMER (Appendix A, Table A1). The only COPCs identified through the EA process in Attichika Creek during the Construction and Operations phase, was cadmium, which is included in the MMER list of variables. Additionally, selenium will be added to this monitoring given it is a COPC in other areas of the Project. In addition to weekly monitoring of effluent, continuous flow measurements will also be conducted to allow calculations of monthly loadings of the measured parameters.

Effluent characterization studies, which include effluent and receiving water quality monitoring, are to be conducted at the final discharge point four times per calendar year, as outlined in the MMER Schedule 5, Part 1. Samples of effluent shall not be collected less than one month apart and are collected while the mine is discharging. Discharge into Attichika Creek will occur seasonally during Operations and Closure, between the months of May and October during the creeks highest flow periods. Discharge will switch to Waste Rock Creek during the Post-Closure phase, when effluent will enter Waste Rock Creek via a spillway and will be monitored similarly there. This monitoring will be initiated when the MMER is triggered and will be reported separately from the FAEMP.

Flow Monitoring of Effluent and Receiving Environment

Rate of discharges being released by the mine will be monitored to ensure permitted limits and conditions are met. A complete outline of this monitoring will be presented within the Discharge Monitoring Plan (Section 8.1 of Application).

In addition to monitoring of effluent released from the mine, hydrological measurements will be undertaken within the receiving environment. During the baseline surveys, hydrometric stations were established around the Project area for continuous monitoring. This included six stations in support of the Project and an additional five stations with ongoing monitoring initiated as part of the Kemess South operations (monitoring starting from 2009 to present). Ongoing hydrological monitoring is outlined in the Mine Site Water Management Plan (Section 7.3.11 of Application).

### *8.3.5.2 Effluent Toxicity*

Samples will be collected for acute-lethal toxicity and sublethal toxicity testing to fulfill the mine's permit requirements and the requirements of the federal Metal Mining Effluent Regulations (MMER). The following effluent toxicity samples will be collected:

- Acute toxicity sampling monthly during effluent discharge (with possible frequency reductions after 12 months of sampling):
  - *Daphnia magna*; and
  - Rainbow trout.
- Sublethal toxicity testing twice per year (with possible frequency reductions following three years of sampling):
  - Fish early-life-stage development using rainbow trout (*Oncorhynchus mykiss*);
  - Invertebrate reproduction and survival tests using *Ceriodaphnia dubia*;
  - Plant growth using *Lemna minor;* and
  - Algal growth using *Pseudokirchneriella subcapita*.

Acute lethality testing requirements for the mine are outlined in the MMER, Division 2, Section 14(1). Acute lethality testing is required to occur monthly, using a grab sample collected from the final discharge point, unless a reduced frequency designation is warranted (i.e., after the effluent is determined not to be acutely lethal over a period of 12 consecutive months). A sample for effluent characterization will be collected at the time of the acute lethality sampling to support the results of the test. As well, sampling dates must be selected and recorded 30 days in advance of sampling; however, if unforeseen circumstances arise that prevent sampling on the date selected, collection must occur as soon as possible. Grab samples shall not be collected less than 15 days apart.

Sublethal toxicity testing shall be conducted as per the reference methods detailed in the MMER Schedule 5, Part 1, Section 5, using a fish species (*Oncorhnychus mykiss* - rainbow trout), an invertebrate species (*Ceriodaphnia dubia*), an aquatic plant species (*Lemna minor*), and an algal species (*Pseuodkirchneriella subcapitata*). The exact species are subject to change as required by Environment Canada. Sublethal toxicity testing will be conducted two times per calendar year for three years and once each year after the third year. Grab samples will be collected at the final discharge point.

Toxicity testing methodology and frequency will be based on the Metal Mining Environmental Effects Monitoring Guidance Document (Environment Canada 2012a) and requirements of the MMER. All tests will be conducted using serial dilutions to allow for the calculation of relevant toxicity measurement endpoints (such as LC50).

### *8.3.5.3 Surface Water Chemistry*

Surface water chemistry monitoring will be ongoing as part of Kemess South closure requirements (permit PE15335) and in support of ongoing biological monitoring studies. In addition to ongoing sampling, water quality will be collected as part of the FAEMP to both support the biological monitoring components and fulfill the new amended permit (PE15335) requirements for the Project.

Sample collection methodology will be based around guidance provided by *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*' (BC MOE 2012). Standard *in situ* field parameters will be collected at all locations, including: dissolved oxygen, pH, hardness, alkalinity, conductivity, and water temperature. A full methodology, including Quality Assurance/Quality Control methods to be implemented during sampling, is provided in Appendix C.

Supporting Water Quality for Biological Monitoring Program

The following surface water quality sampling is designed to support the biological monitoring program outlined in this FAEMP by providing insight into any observed effects on aquatic biota. The following samples will be collected in conjunction with benthic invertebrate, periphyton, and sediment quality samples:

- The control location in upper Attichika Creek, upstream of the confluence with Kemess Creek (EEM-13/WQ-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17/WQ-17);
- The near-field location on Attichika Creek downstream of the diffuser (ATT-IDZ); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18/WQ-18).

These locations will also function as general areas of sampling for the sentinel fish species survey. During the sentinel fish program, additional water quality samples will be collected along, with effluent samples to help quantify percent effluent in the near- and far-field areas as part of an effluent tracer study. The water quality sampling locations to support results of the biological monitoring programs are shown in Figure 8.3-6.

Water Quality Sampling Requirements

A complete outline of Surface Water Chemistry monitoring for the Project will be provided in the Mine Site Water Management Plan (Section 7.2.6), Receiving Environment Monitoring (Section 8.2), and with provincial sampling requirements regulated by the new amended permit PE15335. Additional monitoring requirements have also been specified during the EA process by the Canadian Environmental Assessment Agency (under the Canadian Environmental Assessment Act, 2012). These include the following conditions relating to water quality monitoring:

Condition 3.7.1: *Monitoring quality of water discharged in Attichika Creek during dewatering of the Kemess South Pit and, if required, treat that water to meet subsection 36(3) of the Fisheries Act.*

Condition 3.7.2: *Monitoring surface water quality in Amazay Lake and groundwater movement between the subsidence zone identified by the Proponent during the environmental assessment and Amazay Lake.* This requirement will be fulfilled in a standalone Amazay Lake Monitoring Plan due to EAO prior to construction.

Condition 3.7.4: *Monitoring changes in water quality in Waste Rock Creek and the tailings storage facility, including changes in selenium concentrations;*

During the EA review, a monitoring requirement to provide baseline information relating to PAH in Attichika Creek (pre-construction) was recommended. To fulfill this requirement, additional samples collected at the four monitoring locations in Attichika Creek (EEM-13, EEM-17, ATT-DIS, and EEM-18) will be collected in the fall of 2018. Further details provided in Appendix C.

In addition to the above relevant conditions and permit requirements, water quality monitoring will be required as per MMER Schedule 5, Part 1, Section 7. Samples will be collected from three locations related to each final discharge point, (1) the effluent or final discharge point, (2) an exposure point downstream of the final discharge point (i.e., generally the point of entry of effluent into receiving water), and (3) a relevant reference area. Water quality monitoring will be conducted four times per calendar year not less than one month apart, and includes analysis of deleterious substances, pH, hardness, alkalinity, water temperature, and dissolved oxygen.

An overall summary of water quality monitoring included in the FAEMP is outlined in Table 8.3-3 below.

## Table 8.3-3 Water quality sampling and frequency for proposed and ongoing monitoring in the Project area.

| Type of Sampling | Site | Site Description | Frequency of Monitoring | | Monitoring Requirement |
|---|---|---|---|---|---|
| | | | Field Measurements[1] | Laboratory Analysis[2] | |
| **Attichika Creek / Waste Rock Creek watershed** | | | | | |
| Discharge | WR-S4 | Southern Collection System Discharge | Weekly[5] | Monthly | KS permit PE15335 |
| | WQ-WCSP | Western Collection System Pond Discharge | Weekly[5] | Monthly[4] | KS permit PE15335 |
| | ATT-DIS | Discharge from KUG TSF | Weekly | Monthly | KS permit PE15335 |
| Surface Water | WQ-13 | Attichika Creek 30 m downstream of ORAR bridge | Weekly[8] | Quarterly | KS permit PE15335 |
| | WQ-14F | Waste Rock Creek 250 m upstream of ORAR at flume | Weekly[3] | Monthly[4] | KS permit PE15335 |
| | WQ-14ds | Waste Rock Creek at ORAR crossing | Weekly[3] | Monthly[4] | KS permit PE15335 |
| | WQ-17 | Attichika Creek 0.8 km downstream of Kemess Creek | Weekly[8] | Monthly | KS permit PE15335 |
| | ATT-IDZ | Attichika Creek downstream of discharge from KUG TSF | | | |
| | WQ-18 | Attichika Creek approx. 100 m downstream of Waste Rock Creek wetland Outflow | Weekly[9] | Monthly | KS permit PE15335 |
| | WQ-RCb | Reference site upstream of Waste Rock Dump | Weekly[6] | Quarterly | KS permit PE15335 |
| | ATWL-1 | Attichika Wetland approx. 600 m d/s of WRC outlet | - | Monthly | KS permit PE15335 |
| | ATWL-1a | Attichika Wetland approx. 100 m d/s of WRC outlet | - | Monthly | KS permit PE15335 |
| Proposed for FAEMP | EEM-13 | Same as WQ-13 | Annually | Annually | FAEMP/MMER |
| | EEM-17 | Same as WQ-17 | Annually | Annually | FAEMP/MMER |
| | ATT-IDZ | Attichika Creek downstream of diffuser | Annually | Annually | FAEMP/MMER |
| | EEM-18 | Same as WQ-18 | Annually | Annually | FAEMP/MMER |
| **Kemess Creek watershed** | | | | | |
| Discharge | WQ-23a | Plunge Pool discharge to south Kemess Creek at South Dam Chamber | Weekly[3] | Quarterly | KS permit PE15335 |
| | WQ-SRP | Seepage recycle pond toe drain discharge at V-notch weir | Weekly[3] | Monthly | KS permit PE15335 |
| | WQ-SRPW | Seepage recycle pond artesian well discharge | - | Quarterly (if discharging) | KS permit PE15335 |
| | WQ-Pit | open water pit (proposed KUG TSF) | - | Quarterly | KS permit PE15335 |
| | WQ-TSP | Tailings dam sediment pond discharge | Weekly[3] | Monthly[4] | KS permit PE15335 |
| | WQ-BXL | BXL Creek Discharge at V-notch weir, 30 m upstream of Kemess Creek | Weekly[3] | Quarterly | KS permit PE15335 |
| | SRP-Pond | Discharge from Seepage Recycle Pond | Weekly[3] | Monthly[4] | KS permit PE15335 |
| | WQ-TSF Spill | Kemess South Tailings Storage Facility Discharge and Spillway Weir | Weekly[3] | Monthly[4] | KS permit PE15335 |
| Surface Water | WQ-01 | Kemess Creek 10 m downstream of ORAR Bridge | Weekly[6] | Monthly | KS permit PE15335 |
| | WQ-03 | Kemess Creek 10 m d/s ok Kemess Arch and u/s of the Kemess South closure pit spillway discharge location | Weekly[6] | Monthly | KS permit PE15335 |
| | WQ-04 | North Kemess Creek 10 m upstream of South Kemess creek | Weekly[7] | Quarterly | KS permit PE15335 |
| | WQ-24 | Mill Creek 10m upstream of South Kemess Creek | Weekly[6] | Quarterly | KS permit PE15335 |

| Type of Sampling | Site | Site Description | Frequency of Monitoring | | Monitoring Requirement |
|---|---|---|---|---|---|
| | | | Field Measurements[1] | Laboratory Analysis[2] | |
| | WQ-25 | South Kemess Creek 100m downstream of Mill Creek | Weekly[6] | Monthly[4] | KS permit PE15335 |
| | WQ-EC | El Condor Creek downstream of main haul road | Weekly[6] | Quarterly | KS permit PE15335 |
| | WQ-SDDI | South Arm Creek upstream of South Diversion Pond | Weekly[3] | Quarterly | KS permit PE15335 |
| **Additional FAEMP Sampling** | | | | | |
| Surface Water | DCB-1 | Amazay Creek upstream of Attycelley Creek Confluence | Monthly | Monthly | Adaptive Management Trigger |
| | ECB-1 | East Cirque Creek upstream of Attycelley Creek | Monthly | Monthly | Adaptive Management Trigger |
| | KN-11b | Attycelley Creek downstream of East Cirque Creek | Monthly | Monthly | Adaptive Management Trigger |

[1] Includes Field Turbidity and Temperature. Sampling is only conducted between May 1 and Sept. 30 at all stations, with the exception of WQ-14-F which is throughout the year.

[2] Conductivity, pH, ammonia, nitrate, nitrite, total nitrogen, chloride, orthophosphate, total dissolved phosphorus, alkalinity, hardness, sulphate, total and dissolved metals (must include selenium).

[3] Sampled daily for turbidity if field turbidity exceeds 20 NTU

[4] Additional biweekly TSS and Turbidity samples between May 1 and Sept 30, except at WQ-14F which is sampled biweekly throughout the year

[5] Sampled daily for turbidity if field turbidity exceeds 50 NTU

[6] Sampled daily for turbidity if field turbidity exceeds 10 NTU

[7] Sampled daily for turbidity if field turbidity at WQ-03 exceeds 10 NTU

[8] Sampled daily for turbidity if field turbidity at WQ-01 exceeds 10 NTU

[9] Sampled daily for turbidity if field turbidity at WQ-14F exceeds 30 NTU

Adaptive Management using Water Quality Targets

As part of the requirements for the Mine's permits (amended PE 15335), water quality samples will be collected regularly at various locations within the Project area by mine staff (see full description of water quality monitoring as part of KUG in the Mine Site Water Management Plan, Section 7.2.6). This Fish and Aquatic Effects Monitoring Plan currently excludes regular biological sampling in the north end of the Project, given no residual effects of mining activities were predicted on VCs and no COPCs are expected until the Post-Closure phase. Water quality samples will be collected in these areas to fulfil permit requirements and will be used as triggers for adaptive management programs for the early stages of the project (outlined in Section 8.3.7.1).

#### *8.3.5.4 Sediment Quality and Channel Form*

FAEMP Monitoring

Sediment quality and channel form samples will be collected during the Construction phase, prior to discharge (Year -4) and during the initial discharge to Attichika Creek (Years -3 to -1), and for three years during Operations (Years 1 to 3). Although Attichika Creek is primarily erosional habitat, small areas of the river where sediment is present will be selected as locations for sediment quality sampling. Sediment quality and channel form monitoring will help support the interpretation of any effects on aquatic biota and provide further baseline information to support data previously collected for the Project. The following sampling locations are proposed for the FAEMP and will be sampled annually in conjunction with the benthic invertebrate survey:

- The control location of upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek downstream of the diffuser (ATT-IDZ); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

Sediment quality and channel form monitoring requirements have been specified during the EA process by the Canadian Environmental Assessment Agency (under the Canadian Environmental Assessment Act, 2012). Although no sedimentation is expected in the creek due to discharge, monitoring conducted as part of this FAEMP will satisfy the following condition for sediment quality and channel form:

Condition 3.7.3: *Monitor changes in channel form and sediment load downstream of the discharge location in Attichika Creek.*

Additionally, to satisfy commitments made through the regulatory process, PAHs in sediments will be collected in Attichika Creek (EEM-13, EEM-17, ATT-DIS, and EEM-18) during 2018 to capture baseline conditions pre-construction. PAH and sediment metals analysis will be completed on the fine grain particulate size (<63 µm fraction) as per BC MOE (2016 b). Further information and analytes monitored are provided in Appendix D.

Sediment Quality sample collection methodology was based around guidance provided in the *British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples* (BC MOE 2013). Channel form will be monitored using McNeil Cores to determine percent fines and will follow *Guidelines for Monitoring Fine Sediment Deposition in Streams* (Rex and Carmichael 2002). Geometric mean diameter and Fredle number will be monitored over time to evaluate any changes to channel form. Full methodology and Quality Assurance/Quality Control implemented during sampling are provided in Appendix D.

Adaptive Management

Following the initial seven years (4 years of Construction, and 3 years of Operations) of data collection from Attichika Creek, a review to evaluate the relevance of information gained by this sampling component will occur. Sediment quality and channel form monitoring may be removed or reduced in frequency following this review, if sediments within Attichika Creek have remained stable over time and if there is no evidence of sedimentation or reduced sediment quality caused by the addition of effluent to the creek. Additional sediment quality sampling has been proposed in the north end of the project based on a trigger system, where adaptive management plans (found in Sections 8.3.7.2 and 8.3.7.3) are initiated if water quality conditions are found to degrade in regularly monitored sites (Section 8.3.7.1). The main purpose of including sediment quality in the adaptive management plans proposed is to support any help interpret any biological findings.

#### *8.3.5.5 Periphyton Biomass and Community Composition*

FAEMP Monitoring

Periphyton biomass and community composition surveys will be conducted annually in conjunction with benthic invertebrate sampling at the following locations:

- The control location in upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

Periphyton biomass and community composition results will be analyzed using a Before-After-Control-Impact (BACI) design following general guidelines outlined in Environment Canada (2012a). Periphyton biomass samples will be collected in sets of five, similar to those collected for the Kemess South provincial EEM program, and will be measured for chlorophyll *a* concentration. This will provide consistency and allow for long-term assessment of any changes, relative to the pre-Project conditions. Community composition samples will be collected as a composite of five rocks at each location for taxonomic analysis. Taxonomic analysis will be semi-quantitative, such that the proportion of major taxa groups and taxa richness will be evaluated. Sampling of periphyton communities and biomass will be conducted annually to allow for control charting and trend analysis

(Mann-Kendal) to determine shifts occurring over time. Further information regarding collection and QA/QC procedures can be found in Appendix E.

Adaptive Management

Similar to the sediment quality, samples for periphyton community composition will be conducted annually during both the Construction phase pre-discharge (Year -4), during the initiation of discharge (Years -3 to -1), and during the early Operation phase (Years 1 to 3). Following this seven-year sampling span, if community composition is stable and not demonstrating any shifts with effluent inputs into the creek, a reduced sampling regime may be implemented. Additionally, adaptive management plans for the north end of the project, outlined in Sections 8.3.7.2 and 8.3.7.3, include periphyton community composition and biomass measurements.

#### *8.3.5.6 Benthic Invertebrate Communities and Tissue Analysis*

FAEMP Monitoring

Benthic invertebrate surveys will be collected in single replicate samples annually for community composition at each sampling location, using CABIN protocols (Environment Canada 2012c, d). Annual sampling will provide the ability to track trends over time and determine potential shifts to community composition related to effluent discharge by comparing locations upstream and downstream of the diffuser. Additionally, to prepare for federal EEM requirements, the first sampling year (Year -4) will include five replicates per location. This will occur every third year following (for the first seven years of the program) to align with the federal EEM requirements. Following the initial seven-year intensive sampling program, sampling will drop down to an annual single replicate at each location, with five replicates collected only during federal EEM cycles (as required).

The benthic program will follow BACI design methodology and, for years that overlap with EEM and contain replication, a *post hoc* power analysis will be conducted following MMER EEM guidance, to ensure the quantity of replicates is satisfactory to determine a statistically significant effect (Environment Canada 2012a). The following sampling locations will be used for benthic invertebrate community analysis:

- The control location of upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

In addition to samples collected for invertebrate community analysis, one composite benthic sample at each location will be collected and submitted for tissue metals and moisture content analysis.

A full outline of methodology and QA/QC procedures to be implemented is provided in Appendix F. Methodology will follow the protocol outlined in the EEM Technical Guidance Document (Environment Canada, 2012a) and CABIN protocol (Environment Canada 2012c, d).

Adaptive Management

Similar to the approach outlined for periphyton community sampling, benthic communities should be sampled during the Construction phase pre-discharge (Year -4), during the initiation of discharge (Years -3 to -1) and during the early Operations phase (Years 1 to 3) to captured and identify if any early effects of effluent release or Project activities to the aquatic receiving environment. The intensive monitoring program (every third year) is designed to complement and support requirements of federal EEM prior to initiation. If evidence supports stable community composition during effluent inputs, the intensive sampling will be discontinued from the FAEMP and only required to fulfil federal EEM. Annual monitoring using one replicate should continue as an ongoing component of the FAEMP to monitor trends over time. Additionally, adaptive management plans outlined in Sections 8.3.7.2 and 8.3.7.3 include benthic invertebrate monitoring in the North end of the project, but are initiated based on water quality trigger exceedances (Section 8.3.7.1).

#### *8.3.5.7 Fish Monitoring Studies*

A robust and spatially representative fish and aquatics monitoring program has been ongoing in the Project area for the past two decades as part of the Kemess South Fisheries Compensation Agreement. An extended fish and aquatics monitoring program will be designed to assess further sections of Attichika Creek, and will be conducted through all phases of the Project. This program will include monitoring of fish populations within Attichika Creek including; a sentinel species study to evaluate resident communities, an adult fish survey including tissue metals analysis of Thutade Lake adfluvial bull trout in Attichika Creek, monitoring bull trout migration, and a fry and juvenile fish monitoring program. Specifics of each program are outlined in the sections below.

Sentinel Species Study

A sentinel fish species study will be conducted to help assess the effects of mine effluent on local fish populations. The sample design will follow EEM technical guidance (Environment Canada 2012a) methodology and will eventually lead into requirements of the federal EEM cycles. This FAEMP proposes using one fish species, slimy sculpin, as a target sentinel fish species given they are the only full-time resident fish in high enough numbers within Attichika Creek to be feasible and appropriate for this type of lethal study (Bustard 2017). Sampling will occur in the fall to maximize likelihood of capture success and follow the expected annual effluent exposure in Attichika Creek, during pre-effluent release (Year -4) and then again following effluent release in the Construction (Year -1) and Operations (Year +3) phases. Fish sampling will be conducted at the following locations:

- Reference area in upper Attichika Creek, upstream of the confluence of Kemess Creek (around EEM-13);
- Near-field exposure location on Attichika Creek, downstream of the diffuser (downstream of ATT-DIS); and

- Far-field exposure location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17), which has been included in all other biological monitoring components, will not be incorporated into the sentinel species program. This location is used to differentiate possible cumulative effects of the Kemess South discharge on Attichika Creek downstream of the Kemess Creek confluence. The area between EEM-17 and the Kemess Creek confluence would have functioned as the second reference location for this survey; however, this area is too small to support a sufficient population of sculpin to complete this survey. The initial survey (Year -4) will capture natural variability between the upstream reference (EEM-13), the near-field location at ATT-DIS (downstream of the IDZ), and the far-field location at EEM-18 to ensure comparability of sites.

The initial survey design will target 20 males, 20 females, and 20 immature fish from each location. Following the completion of the first cycle, a *post hoc* power analysis will be conducted to determine a target number of fish that will ensure enough statistical power for comparisons for the following cycles, as per the EEM technical guidance document (Environment Canada 2012a). The performance (e.g. growth, reproduction, survival or condition) of slimy sculpin inhabiting the effluent receiving environment will be characterized relative to unexposed or reference fish. Fish at each location will be sacrificed and measurements will be collected, including: total length, total weight, external and internal health conditions, gonad weights (and egg weights if possible), and otolith or fin rays will be collected for aging analysis. In addition to fish health and reproductive variables, ten fish of similar age and length from each of the three locations (for a total of thirty fish) will be retained for analysis of metals and moisture content in body tissue. A complete outline of methodology, QA/QC, and variables measured are outlined in Appendix G.

Adult Fish Monitoring Studies

Adult fish monitoring surveys are currently conducted annually in sections of lower and upper Attichika Creek to determine spawning locations for bull trout migrating into the creeks from Thutade Lake. These surveys are part of ongoing monitoring efforts in support of Kemess South, but will be expanded to include mid- and upper-Attichika Creek reaches in support of the KUG Project. To fulfill the EAC conditions, additional adult fish surveys also will be added to monitoring. Proposed adult fish monitoring studies will include the following components:

- Bull trout redd counts to evaluate key spawning areas within Attichika Creek for adult bull trout from Thutade Lake;
- Continuous water temperature loggers at select bull trout spawning sites;
- Evaluation of fish habitat and potential blockages to fish migration routes;
- Non-lethal fish tissue monitoring of adfluvial bull trout from Thutade Lake; and
- Monitoring during discharge pipeline installation and subsequent operation to determine if bull trout and rainbow trout are avoiding the initial dilution zone (IDZ).

### Redd Surveys

Bull trout redd surveys have been conducted as part of the Kemess South Project, and will continue to be monitored annually with additional monitoring locations added in support of KUG. Visual surveys are conducted by two trained individual and GPS coordinates of each observed redd collected. To compliment information collected during redd surveys, water temperature will be continuously monitored using data loggers at select key bull trout spawning areas. During redd surveys, fish habits will also be characterized, to assess for potential blockages to fish migratory routes. A particular focus around fish migrations and presence will be placed on areas surrounding the effluent diffuser in Attichika Creek, to satisfy requirements of EAC Condition 23 (see Section 8.3.2.2). This will include monitoring fish (rainbow trout and bull trout) presence and any notably avoidance behaviour due to the installation and operation of the discharge pipeline in the diffuser area. A telemetry study was initiated in 2017 to satisfy this monitoring requirement by targeting spawning adfluvial bull trout entering Attichika Creek and using radio telemetry to track their movements. It is specifically targeting lower Attichika fish movements prior to diffuser installation and following discharges with dewatering the Pit. The study would provide before and after discharge migration pattern around the diffuser.

No current salmonid spawning occurs in the habitat directly near the effluent diffuser and initial diffuser zone, but monitoring of redds around this area will continue. Full methodology of redd surveys and supporting data collection is outlined in Appendix G. This methodology could be augmented with observational snorkel surveys of possible bull trout habitats in the vicinity of the diffuser if, following construction and activation of the diffuser, if current redd-survey methods are found to be insufficient for full-channel assessment in the initial dilution zone.

### Fish Tissue Sampling

The non-lethal fish tissue sampling of adult adfluvial bull trout will be conducted to support EAC Condition 22 and federal Condition 3.7.6 provided from the Canadian Environmental Assessment Act, 2012. Both conditions address monitoring contaminants that can potentially bioaccumulate within fish species (including mercury). They focus specifically on bull trout *(Salvelinus confluentus)* in Thutade Lake, given this population importance as a food source for Indigenous groups in the area (conditions are listed in full in Section 8.3.2.2). To address these conditions, sampling for adfluvial adult bull trout will be conducted in Attichika Creek and Kemess Creek in several bull trout staging areas. These locations are holding areas for bull trout spawners, prior to moving on to spawning sites in Kemess and upper Attichika creeks. A target of eight fish will be captured by angling and non-lethal sampling will be conducted using dermal punches, following methodology described in Baker et al. (2004). Sampling will occur annually in conjunction with the telemetry study and be used to both monitor metal levels in fish muscle tissue over time and assess safety of fish consumption. Detailed methodology is available in Appendix G and Hatfield and Bustard 2015.

### Fry and Juvenile Fish Monitoring Studies

Fry and juvenile fish monitoring surveys are currently conducted annually in support of Kemess South, but will be expanded during the first year of construction (Year -4) to include an increased focus on Attichika Creek in support of the KUG Project. Current sampling associated with the Kemess South operations is focussed on lower Attichika Creek locations (below the confluence with Kemess

Creek) along with Kemess Creek. The historical sampling (1995 to 2009) and proposed additions for KUG will include mid and upper reaches of Attichika Creek where a long period of historical information is available.

Surveys will be done using a two-pass removal method and a backpack shocker with sites enclosed by stopnets (where possible). All fish captured will be sorted by species, measured for fork length, weight, and released back into the location of capture. Catch numbers and species present will be used to evaluate abundance in areas within the creek. Obvious external abnormalities on fish collected will be noted and used to evaluate changes in health resulting from the pre- and post- discharge in Attichika Creek. Further information regarding methods is outlined in Appendix G. Rainbow trout fry are not historically found in lower Attichika Creek currently, suggesting that no spawning occurs in lower Attichika Creek. If rainbow trout fry are observed in this area in the future, and therefore suspect of spawning in and around the vicinity of the diffuser, mitigation and monitoring plan discussions will be undertaken with BC MOE and FLNRO on appropriate sampling to fulfill CEAA condition 3.7.5.

Adaptive Management

Sentinel species surveys will follow a similar adaptive management sampling approach as outlined for periphyton and benthic community sections. Sampling during the Construction phase prior to discharge (Year -4), during the initiation of discharge (Year -1) and during the Operations phase (Year +3) will be conducted to captured and identify if any early effects are occurring based on effluent release or Project activities. This monitoring program will complement and support requirements of federal EEM. Following the initial three monitoring events, this survey will be excluded from the FAEMP and conducted only when required by federal EEM.

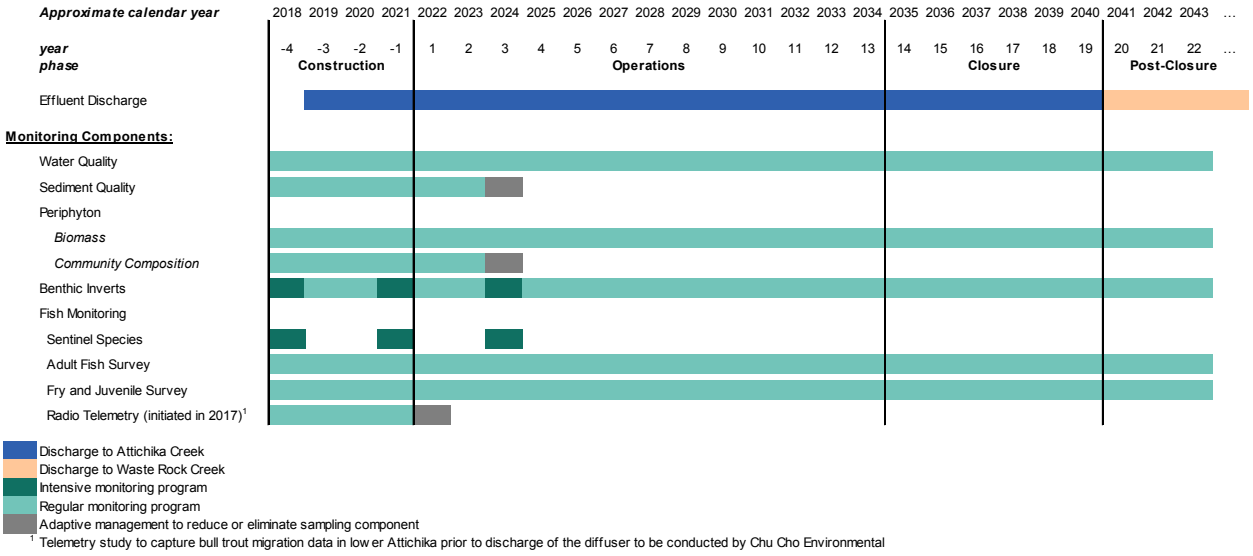
The Adult Fish Monitoring Studies and Fry and Juvenile Fish Monitoring Studies will be conducted annually. These programs will be modified throughout the FAEMP if requirements change or specific focused monitoring efforts are necessary to address study questions (e.g. determining what is causing adverse effects). As part of the Kemess South Fisheries Compensation Agreement, in 2011 the Kemess Fisheries Steering Committee outlined adaptive management targets for the ongoing long-term KS Fish monitoring (Section 8.3.4.2). These measures establish a target range of bull trout redds and juvenile densities within a system (Kemess watershed, South Kemess Creek, and Tributary 4) for the monitoring period. If the redd numbers and juvenile densities are maintained, additional management options are not required. If they are not achieved, additional monitoring and possible management options may be required depending upon a review. Additionally, adaptive management plans outlined in Sections 8.3.7.2 and 8.3.7.3 include fish monitoring programs, but are initiated when water quality trigger are exceeded (Section 8.3.7.1).

### *8.3.5.8 Monitoring Schedule*

The monitoring schedule for the FAEMP is outlined in Figure 8.3-7 below. Monitoring will be conducted on an ecologically relevant timeline and will match with previous baseline sampling and other ongoing monitoring activities to maximize comparability of data over time. The monitoring schedule outlines the entire duration of the Project, but the objective of this FAEMP is to focus on the first seven years of the Project (Year -4 to Year 3) to identify any early effects caused by mine effluent.

Following seven years (4 years of Construction and 3 of Operations), a re-evaluation of the program should occur and take into consideration reducing sample frequency for some of the components and inclusion of addition sampling if required through the adaptive management triggers.

**Figure 8.3-7 Gantt chart outlining schedule of individual monitoring components for the Kemess Underground FAEMP**




## 8.3.6 Reporting and Record Keeping

Annual reporting of environmental monitoring data is anticipated as a Provincial effluent permit requirement. Reports will be produced and submitted in accordance with the Provincial permit specifications to BC MOE, AuRico, and to the TKN EMC with a submission date of April 30th each year. The report will include analyses of key water quality trends and evaluation of potential Project impacts on the receiving environment, including screening of water quality compared against relevant guidelines, such as the British Columbia Approved Water Quality Guidelines for the Protection of Aquatic Life to identify elevated concentrations of water quality parameters (BCMOE 2014; BCMOE 2016a). This information will be included in a comprehensive Annual Interpretative Report of the FAEMP studies; separate from reports provided from other ongoing monitoring in the Project area.

Each Annual FAEMP Interpretive Report will draw conclusions regarding Project related effects using a weight of evidence approach. Based on assessment endpoints described in this document, result-based recommendations for refinement or modification of the monitoring program will be included within the report for regulator consideration. These reports will provide a summary of ambient monitoring results and an assessment of compliance with the permit, including a summary of any mitigation actions applied to rectify non-compliances, when required. Following the initial seven-year period (4 years during Construction and the first three of Operations), depending on whether effects were observed, frequency of reporting may switch to a three-year cycle where the years between become condensed data reports.

Data provided by qualified laboratories, field sheets, and field notebooks will be retained from each monitoring program and kept for the duration of the mine's life. Data will be maintained in a usable format for ease of annual comparison, with field data sheets and notes available to compliment laboratory data.

### 8.3.7 Evaluation and Adaptive Management

#### *8.3.7.1 Water Quality Triggers for Adaptive Management Approach*

Possible effects on the north side of the project (Amazay Lake and Attycelley Watershed), linked to changes in water quality and quantity caused by the underground mine, were identified during the EA process (EAC; AuRico 2016). Although neither the residual nor cumulative effects assessments indicated any probable effects on fish and aquatic habitats, water quality triggers have been included within this FAEMP to monitor potentially impacted areas, in the event water quality does degrade due to the Project. These water quality triggers will act to initiate additional fish and aquatic habitat Adaptive Management Monitoring Programs in either Amazay Lake or Attycelley Creek (outlined in Sections 8.3.7.2 and 8.3.7.3 respectively).

The water quality triggers have been designed in such a way that a single, new observation collected through a monitoring program may be compared with baseline or control conditions. Triggers must be created to be robust (based on sufficient data to describe variability), reliable (easily and consistently measurable), and meaningful (variables selected should have potential impacts on aquatic biota in mind) to be relevant, which are conditions that can be satisfied using a control charting approach.

Control charting takes into consideration a pre-existing "control" dataset, which in this case is data collected prior to construction of the underground cave zone, and evaluates whether new data collected falls within those parameters ("control limits") being deemed in control or acceptable. "Acceptable" in the context of this program is defined as the absence of data considered to be abnormal or outside the range of typical or acceptable natural variability. Morrison (2008) provides detailed methods and rules for applying this approach to screening environmental monitoring data.

Water quality data presents many unique challenges to making statistical data summaries, given they typically are highly variable, not normally distributed (i.e., highly positively skewed: there are often many low values and a few high values), and often contain non-detectable values. An approach that presents and screens water quality data based on percentiles of baseline ranges may be the most appropriate, given baseline data can be easily characterized using median (50$^{th}$ percentile), interquartile range (i.e., 25$^{th}$ to 75$^{th}$ percentile), and 5$^{th}$ and 95$^{th}$ percentile. Screening new data using these ranges would help to identify how typical new water quality values were relative to baseline-period data.

Control limits for water quality are proposed to be the following (based on guidance from Bartram and Balance, 1996 and Westgard et al 1981):

- **One observation exceeds ± 95th percentile and five times detection limit (DL)**: "Warning" limit reached; enhanced monitoring is not initiated, but potential cause should be investigated

(identify if issue with lab results, are increasing overall trends apparent, or part of the 5% of data would be expected to fall outside of these limits by definition of the 95$^{th}$ percentile being used).

- **Two consecutive observations exceed the upper 95th percentile and five times DL**: System is outside control limits (variability too high), enhanced monitoring should be initiated.
- **Ten consecutive observations fall on the same side of the control median and exceed five times DL**: System is outside control limits monitoring plan should be initiated and cause should be investigated.

Given seasonal variability is common with water quality measurements, it is proposed for this FAEMP that control limits are broken down into the following seasonal categories:

- **Summer/Fall (August to October)**: Characterized by low flows and open water conditions;
- **Winter (November to March)**: Characterized by overlaying or anchored ice with low flows under the surface;
- **Spring/Summer (April to July)**: Characterized by high flow and open water conditions.

All water quality data collected will be screened against background information to identify any concerns that may arise throughout the Project. Control limits will be applied to the following variables, which are requirements to be monitored through MMER or have been identified as COPCs during the residual effects predictions of the surface water quality section of the EA (EAC; AuRico 2016, Table 11.6-4), where variables with a star (*) indicate significant results from the residual effects screening using the predictive models:

- **Anions and Nutrients:** chloride, ammonia, alkalinity, nitrite, *nitrate, and sulphide.
- **Total Metals**: *aluminum, silver, arsenic, boron, barium, beryllium, *cadmium, *cobalt, *chromium, *copper, *iron, mercury, lithium, manganese, *molybdenum, nickel, lead, antimony, *selenium, strontium, titanium, thallium, uranium, vanadium, and *zinc.
- **Dissolved Metals**: *aluminum, *cadmium, *iron.
- **Physical tests**: pH, conductivity, hardness, total suspended solids, total dissolved solids.

Water quality trigger exceedances will prompt additional sampling programs in two sampling areas. The following trigger exceedance will guide which monitoring program is required:

- **Amazay Lake** sampling program, where sampling will be initiated by a water quality trigger exceedance at KN-08 (Amazay Creek) station;
- **Attycelley Creek** sampling program, where sampling will be initiated by the same water quality trigger exceedances at both KN-12c (East Cirque Creek) and KN-11b (Attycelley Creek) stations; and
- **Amazay Lake and Attycelley Creek** sampling programs, where both adaptive management plans will be initiated by the same water quality trigger exceedances occurring at both KN-08 (Amazay Creek) and KN-07 (Attycelley Creek) stations.

Further information about biological sampling initiated by trigger exceedances can be found in the Amazay Lake Adaptive Management Plan (Section 8.3.7.2) and the Attycelley Creek Adaptive Management Plan (Section 8.3.7.3). Although a brief overview of these plans is available within this document, once monitoring is initiated, it is recommended information from the FAEMP monitoring be used to refine the monitoring plans where appropriate.

### *8.3.7.2 Amazay Lake Monitoring Plan*

Central Cirque Creek (Inlet 6) is highly mineralized, with elevated background concentrations of water quality parameters, despite being natural and undisturbed by mining impacts. It does not support a fish population, and aquatic habitats are low quality, with poor sediment quality conditions. During the Environmental Assessment, Central Cirque Creek was predicted to decrease in streamflow and was therefore considered for residual and cumulative effects assessments with respect to fish and aquatic habitat Valued Components (VCs) (EAC; AuRico 2016, Chapter 14). The decreased stream flow, to occur during the Construction, Operation, and Closure phases, was predicted to be caused by development in the underground cave zone leading to reduced groundwater seepage entering the creek. During the Post-Closure phase levels are predicted to remain below baseline, with seepage from the flooding of the underground mine predicted to enter East Cirque Creek instead of Central Cirque Creek (see Section 6.5.1).

Given the poor fish and aquatic habitat provided by Central Cirque Creek, the EA scoping process was shifted to the Amazay Lake water quality node (at the Creek outlet), the first contact point between Central Cirque Creek water and fish and aquatic organisms. During the scoping process neither the water quality nor quantity changes in Central Cirque Creek were predicted to have effects on fish and aquatic resources found within Amazay Lake. However, because this is a location where potential effects could occur, conditions presented by the Canadian Environmental Assessment Agency under the Canadian Environmental Act (2012) include the requirement of a water quality monitoring program will be conducted in Amazay Lake:

Condition 3.7.2*: Monitor surface water quality in Amazay Lake and groundwater movement between the subsidence zone identified by the Proponent during the environmental assessment and Amazay Lake.*

The Amazay Lake Monitoring Plan is presented in the Mine Site Water Management Plan, which includes the requirement to monitor surface water quality and groundwater quantity entering the lake. Given the unlikely, but potential impact to fish and aquatic biota, Amazay Lake water quality data from the Amazay Lake Monitoring Plan will been integrated into this FAEMP as a key trigger for a fish and aquatic habitat Adaptive Management Monitoring Program. The following section of the report outlines a proposed monitoring program to identify effects of changes in water quality on aquatic communities.

<u>Amazay Lake Adaptive Management Biological Monitoring Program</u>

The Amazay Lake Adaptive Management Biological Monitoring Program is proposed to occur once, during the early Construction phase of the Project. The most recent sampling in Amazay Lake was conducted in 2003 and 2004 in support to the proposed Kemess North Mine Expansion Project (Hatfield 2004). An update of these baseline conditions is recommended to provide more relevant

background information in the unlikely event declining water quality initiates the Adaptive Management Program.

Beyond the initial baseline monitoring, this Amazay Lake biological monitoring program will only be implemented when routine water quality monitoring from the Amazay Lake Monitoring Plan initiates a trigger response (outlined in Section 8.3.7.1). This program will then occur annually in the fall until results-based rationale to discontinue the program are available and accepted by regulators. The monitoring program consists of benthic invertebrates, fish tissue analysis (using resident rainbow trout, given they are more abundant than Dolly Varden and mountain whitefish in the lake), and supporting water quality and sediment quality results. The overall sampling plan is outlined in Table 8.3-4.

If triggered, the Amazay Lake Adaptive Management Biological Monitoring program will be reported annually in its own section of the interpretive report, as part of the FAEMP. This plan is designed with the intent to determine if any potential mine-related effects are occurring on various aquatic endpoints. Similar to the other components of the FAEMP, knowledge gained from the Amazay Lake sampling will help refine and modify future monitoring programs through results-based recommendations.

**Table 8.3-4 Summary of sampling activities associated with Amazay Lake Adaptive Management Monitoring Plan.**

| Sampling Location | Water Quality | Sediment Quality | Benthic Inverts | Fish |
|---|---|---|---|---|
| Central Cirque Creek (Inlet 6) | Continue with FAEMP outlined Sampling at water quality node KN-09 | - | - | - |
| Amazay Lake (Water Quality node) | Continue with FAEMP outlined Sampling at water quality node 'Amazay Lake'<br><br>Include surface and bottom sampling | Collect 3 replicate samples using an Ekman grab | Collect 3 replicate samples using an Ekman grab | Angling for resident rainbow trout within Amazay Lake for tissue metals analysis (n=7) |
| Amazay Lake (LS1)[1] | collect water quality sample at same time as other sampling components<br><br>Include surface and bottom sampling | Collect 3 replicate samples using an Ekman grab | Collect 3 replicate samples using an Ekman grab | - |
| Amazay Lake (LS2)[1] | collect water quality sample at same time as other sampling components<br><br>Include surface and bottom sampling | Collect 3 replicate samples using an Ekman grab | Collect 3 replicate samples using an Ekman grab | - |
| Amazay Creek (KN-08) | collect water quality sample at same time as other sampling components | Collect 3 replicate samples using an Ekman grab | Collect 3 replicate samples using an Ekman grab | Alternative fish sampling: fish sampling index sites (2 years of historical data available for comparison) |

[1] *Historical sampling locations from the proposed Kemess North open-pit mining project (2003 to 2006). Locations represent the deepest point of each basin of the lake. Further information available in the Limnology and Water Quality of Amazay (Duncan) Lake Memo (Hatfield 2015) and Kemess North open-pit mining project baseline report (Hatfield 2004).*

### *8.3.7.3 Attycelley Creek Monitoring Plan*

East Cirque Creek is a shallow and narrow (3.0 m wetted width) channel that originates out from a highly mineralized gossan deposit, giving the creekbed a distinctive red colouration. It is currently 'undisturbed', but exhibits naturally poor water and sediment quality, with heavily cemented bed materials. These characteristics result in poor stream conditions for supporting benthic communities, periphyton biomass, and provide a low potential for fish habitat. East Cirque Creek flows into Attycelley Creek, with areas downstream of this confluence supporting fish communities, which include; slimy sculpins, rainbow trout, and adfluvial bull trout from Thutade Lake that spawn in the upper reaches of Attycelley creek (upstream of the East Cirque Creek confluence).

Similar to Central Cirque Creek, the Environmental Assessment water balance model predictions indicate the Project will contribute to a decreased in base flows in East Cirque Creek during mine

operations, potentially leading to changes in water quantity and quality in the creek (EAC; AuRico 2016, Chapter 14). These decreases relate to underground dewatering of the mining area, leading to reductions in groundwater seepage flow to East Cirque Creek. Decreased flow was predicted to occur during the Construction, Operations, Closure, and a portion of the Post-Closure phases. During Closure and Post-Closure, the underground mine will be allowed to flood and water in the subsidence zone, and water from the mine will be able to interact with creek water via seepage (further information available in Section 6.5.1).

Given East Cirque Creek is barren of fish and baseline survey's indicated aquatic habitat quality is low, assessments for residual and cumulative effects on fish and aquatic habitats in the EA were shifted to Attycelley Creek at the confluence with East Cirque Creek. These assessments indicated no residual or cumulative effects on fish and aquatic valued components were predicted within Attycelley Creek over the durations of the Project. Despite no expected effects, regular water quality monitoring will be conducted in both East Cirque Creek (KN-12c) and in Attycelley Creek downstream of the East Cirque Creek confluence (water quality node KN-11b) as part of the FAEMP.

Although very unlikely, there is a possibility that reductions in water quality and quantity on East Cirque Creek could impact valued components in Attycelley Creek, which has prompted the creation of this Adaptive Monitoring Program within the FAEMP. Baseline conditions of aquatic receptors in East Cirque Creek and Attycelley Creek have been updated and reported most recently in support of the Fish and Aquatics Habitat Baseline Report (Hatfield and Bustard 2015), which will provide reference conditions for the area in the event the monitoring program is implemented. The following section outlines a proposed monitoring program designed to identify effects of relating to changes in water quality on aquatic communities.

Attycelley Creek Adaptive Management Biological Monitoring Program.

The East Cirque Creek (KN-12c) and Attycelley Creek (KN-11b) routine water quality monitoring nodes will provide the locations where trigger responses (outlined in Section 8.3.7.1) initiate the implementation of the Attycelley Creek Adaptive Management Biological Monitoring Program.

If triggered, the biological monitoring program would occur annually in the fall until results-based rationale to discontinue the program are available and accepted by regulators. The program will consist of benthic invertebrate community monitoring and fish monitoring, with supporting water quality and sediment quality sampling. The fish monitoring program will include either a slimy sculpin sentinel species survey or a community-level fish survey. Sentinel species monitoring will be conducted downstream of the Amazay Creek confluence as an exposure location. Given the absence of sculpin in the upstream section of the creek (upstream of Amazay Creek confluence), Attichika Creek (upstream reference area) will be required as a comparison reference location. As an alternate sampling approach, a community-level survey conducted both upstream and downstream of the East Cirque Creek confluence in Attycelley Creek could be undertaken, as information is available from previous juvenile fish surveys to compare against historical results to monitor changes over time. The overall sampling plan is outlined in Table 8.3-5.

The East Cirque Creek and Attycelley Creek Adaptive Management Biological Monitoring program will be reported annually and included as a section within the interpretive report for the FAEMP. The monitoring plan is designed with the intension of determining if any potential mine-related effects

are occurring on various aquatic receptor endpoints. Similar to the other components of the FAEMP, knowledge gained from the East Cirque Creek and Attycelley Creek sampling will be used to refine and modify future monitoring programs through results-based recommendations.

**Table 8.3-5 Summary of sampling activities associated with East Cirque and Attycelley Creek Adaptive Management Monitoring Plan.**

| Sampling Location | Water Quality | Sediment Quality | Benthic Inverts | Periphyton | Fish |
|---|---|---|---|---|---|
| East Cirque Creek, west fork (KN-12) | Continue with FAEMP outlined Sampling at water quality node KN-12 | - | - | - | - |
| East Cirque Creek following confluence between east and west fork (KN-12c) | Collect water quality sample at same time as other sampling components | 3 replicates for metals and particle size analysis | Collect 3 replicates for community composition (using Hess sampler - consistent with baseline approach) | 5 replicate samples for biomass, 1 composite sample for taxonomic analysis | - |
| Attycelley Creek (KN-11b) | Continue with FAEMP outlined Sampling at water quality node KN-11b | - | - | - | - |
| Attycelley Creek, upstream of confluence with East Cirque Creek (ACB-2)[1] | Collect water quality sample at same time as other sampling components | 3 replicates for metals and particle size analysis | Collect 3 replicates for community composition (using Hess sampler - consistent with baseline approach) | 5 replicate samples for biomass, 1 composite sample for taxonomic analysis | Juvenile fish community survey (reference) |
| Attycelley Creek, upstream of confluence with Amazay Creek (ACB-3) [1] | Collect water quality sample at same time as other sampling components | 3 replicates for metals and particle size analysis | Collect 3 replicates for community composition (using Hess sampler - consistent with baseline approach) | 5 replicate samples for biomass, 1 composite sample for taxonomic analysis | Juvenile fish community survey (exposure) |
| Attycelley Creek, downstream of confluence with Amazay Creek (ACB-4) [1] | Collect water quality sample at same time as other sampling components | 3 replicates for metals and particle size analysis | Collect 3 replicates for community composition (using Hess sampler - consistent with baseline approach) | 5 replicate samples for biomass, 1 composite sample for taxonomic analysis | Sentinel fish species program targeting sculpin (exposure site) |
| Attichika Creek, upstream of the diffuser | Collect water quality sample at same time as other sampling components | - | - | - | Sentinel fish species program targeting sculpin (reference site) |

[1] Sampling locations used for the KUG baseline monitoring.

### 8.3.8 Qualified Professionals

Under the direction of AuRico Metals Inc., a team of consultants have supported preparation of this management plan. This management plan has been prepared and reviewed by, or under the direct supervision of, the following qualified professionals:

Prepared by:

<original signed by>

Kristy Wade, M.Sc., R.P.Bio.
Hatfield Consultants

Reviewed by:

<original signed by>

Martin Davies, M.E.S., R.P.Bio.
Hatfield Consultants

### 8.3.9 References

Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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# Appendix A

# Effluent Chemistry and Flow Monitoring

# EFFLUENT CHEMISTRY AND CHARACTERIZATION STUDIES OVERVIEW

Effluent chemistry monitoring will be required weekly to determine concentrations of deleterious substances, pH, and flow measurement of effluent being released once the MMER is triggered, as specified in Division 2, Sections 12 and 13. Deleterious substances, as outlined in Schedule 4 of the MMER, include:

- Total Metals: arsenic, copper, lead, nickel, and zinc;
- Total Cyanide;
- Total Suspended Solids (TSS); and
- Radium 226.

Effluent characterization studies will also be a requirement of the MMER and will be conducted four times per calendar year, as outlined in the MMER Schedule 5, Part 1, Section 4 once the MMER is triggered for the mine. These studies include sampling effluent, as well as receiving water to better understand effluent characteristics within receiving environment. Samples shall not be collected less than one month apart and are collected while the mine is discharging. Effluent characterization parameters and their corresponding detection limits, methods and guidelines are listed in Table A1. Effluent chemistry and characterization studies will be reported separately from the FAEMP.

Considerations for effluent characterization sampling will include (as per MMER requirements):

- Seasonal variability based on composition and flow;
- The time of year when previous effluent samples have been collected;
- The time of year when sampling for water quality monitoring is being conducted; and
- The time of year when concentrations of the contaminants are expected to be the highest in the exposure area.

## Table A1. Effluent characterization variables, analytical methods, and detection limits.

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| **Physical Tests** | | | | | | |
| Conductivity | µS/cm | 2.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Hardness (as $CaCO_3$) | mg/L | 0.50 | APHA 1030E | - | - | - |
| pH | pH | 0.10 | APHA 4500-H, 2510, 2320 | 6.0 to 9.5 | 6.5-9 | 6.5-9 |
| Total Suspended Solids | mg/L | 1.0 | APHA 2540 D | 30 | 30 | [4]narrative |
| Total Dissolved Solids | mg/L | 10 | APHA 1030E | - | - | - |
| Turbidity | NTU | 0.1 | SM 22 2130 B m | - | [5]narrative | [5]narrative |
| **Anions and Nutrients** | | | | | | |
| Alkalinity, Total (as $CaCO_3$) | mg/L | 1.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Ammonia, Total (as N) | mg/L | 0.0050 | APHA 4500 NH3-NITROGEN (AMMONIA) | - | - | 1.8 |
| Nitrate (as N) | mg/L | 0.0050 | EPA 300.1 | - | 3 | 32.8 |
| **Total Metals** | | | | | | |
| Aluminum | mg/L | 0.0030 | EPA 200.2/6020A (mod) | - | - | - |
| Cadmium | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | - | - |
| Iron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | 1 |
| Mercury | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | [6]WQG = MeHg/total Hg | - |
| Molybdenum | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | ≤1 | 2 |
| Selenium* | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | 0.0020 | - |

[1] *Analysis will be conducted by ALS (Burnaby, British Columbia).*

[2] *MMER (2012); maximum concentration in a grab (mg/L).*

[3] *Working water quality guidelines for British Columbia; Water Quality Guidelines for the Protection of Aquatic Life (WQGPAL).*

[4] *See BCMOE (2016) for details on total suspended sediments levels, streambed substrate composition metrics, and interpretations.*

[5] *Guideline is dependent on background turbidity levels, see BCMOE (2016) for details.*

[6] *Where MeHg is concentration of methylmercury and Total Hg is concentration of mercury in a given water volume.*

**Selenium included as an additional parameter given it is a COPC for other areas of the project.*

As part of the effluent characterization, water quality monitoring will be conducted in the exposure area within the creek. This will not correspond to biological sampling and should occur where the concentration of effluent in the receiving environment is the highest. For water quality monitoring, the following factors should be taken into consideration to decide when water samples are collected in the receiving environment:

- Seasonal variability in water quality and flow in the exposure area;
- The time of year when concentrations in the exposure area of contaminants are expected to be highest;
- The time of year when previous water quality monitoring samples have been collected;
- The time of year when samples for effluent characterization are collected; and
- The time of year when the biological monitoring is conducted.

## Table A1. Effluent characterization variables, analytical methods, and detection limits.

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| **Physical Tests** | | | | | | |
| Conductivity | µS/cm | 2.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Hardness (as $CaCO_3$) | mg/L | 0.50 | APHA 1030E | - | - | - |
| pH | pH | 0.10 | APHA 4500-H, 2510, 2320 | 6.0 to 9.5 | 6.5-9 | 6.5-9 |
| Total Suspended Solids | mg/L | 1.0 | APHA 2540 D | 30 | 30 | [4]narrative |
| Total Dissolved Solids | mg/L | 10 | APHA 1030E | - | - | - |
| Turbidity | NTU | 0.1 | SM 22 2130 B m | - | [5]narrative | [5]narrative |
| **Anions and Nutrients** | | | | | | |
| Alkalinity, Total (as $CaCO_3$) | mg/L | 1.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Ammonia, Total (as N) | mg/L | 0.0050 | APHA 4500 NH3-NITROGEN (AMMONIA) | - | - | 1.8 |
| Nitrate (as N) | mg/L | 0.0050 | EPA 300.1 | - | 3 | 32.8 |
| **Total Metals** | | | | | | |
| Aluminum | mg/L | 0.0030 | EPA 200.2/6020A (mod) | - | - | - |
| Cadmium | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | - | - |
| Iron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | 1 |
| Mercury | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | [6]WQG = MeHg/total Hg | - |
| Molybdenum | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | ≤1 | 2 |
| Selenium* | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | 0.0020 | - |

[1] *Analysis will be conducted by ALS (Burnaby, British Columbia).*

[2] *MMER (2012); maximum concentration in a grab (mg/L).*

[3] *Working water quality guidelines for British Columbia; Water Quality Guidelines for the Protection of Aquatic Life (WQGPAL).*

[4] *See BCMOE (2016) for details on total suspended sediments levels, streambed substrate composition metrics, and interpretations.*

[5] *Guideline is dependent on background turbidity levels, see BCMOE (2016) for details.*

[6] *Where MeHg is concentration of methylmercury and Total Hg is concentration of mercury in a given water volume.*

**Selenium included as an additional parameter given it is a COPC for other areas of the project.*

As part of the effluent characterization, water quality monitoring will be conducted in the exposure area within the creek. This will not correspond to biological sampling and should occur where the concentration of effluent in the receiving environment is the highest. For water quality monitoring, the following factors should be taken into consideration to decide when water samples are collected in the receiving environment:

- Seasonal variability in water quality and flow in the exposure area;
- The time of year when concentrations in the exposure area of contaminants are expected to be highest;
- The time of year when previous water quality monitoring samples have been collected;
- The time of year when samples for effluent characterization are collected; and
- The time of year when the biological monitoring is conducted.

## Table A2. Receiving water quality monitoring variables, analytical methods, and detection limits.

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| **Physical Tests** | | | | | | |
| Conductivity | µS/cm | 2.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Hardness (as CaCO3) | mg/L | 0.50 | APHA 1030E | - | - | - |
| pH | pH | 0.10 | APHA 4500-H, 2510, 2320 | 6.0 to 9.5 | 6.5-9 | 6.5-9 |
| Total Suspended Solids | mg/L | 1.0 | APHA 2540 D | 30 | 30 | [4]narrative |
| Total Dissolved Oxygen | mg/L | 0.1 | Field measured (YSI, Winkler kit) | - | - | - |
| **Anions and Nutrients** | | | | | | |
| Alkalinity, Total (as $CaCO_3$) | mg/L | 1.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Ammonia, Total (as N) | mg/L | 0.0050 | APHA 4500 NH3-NITROGEN (AMMONIA) | - | - | 1.8 |
| Nitrate (as N) | mg/L | 0.0050 | EPA 300.1 | - | 3 | 32.8 |
| **Cyanides** | | | | | | |
| Cyanide, Total | mg/L | 0.0050 | ISO 14403:2002 | 2 | ≤0.005 | 0.010 |
| **Total Metals** | | | | | | |
| Aluminum | mg/L | 0.0030 | EPA 200.2/6020A (mod) | - | - | - |
| Antimony | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Arsenic | mg/L | 0.00010 | EPA 200.2/6020A (mod) | 1 | 0.005 | - |
| Cadmium | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | - | - |
| Copper | mg/L | 0.00050 | EPA 200.2/6020A (mod) | 0.6 | [5]WQG=(0.094*(hardness)+2)/1000 | [5]<0.002 |
| Iron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | 1 |
| Lead | mg/L | 0.000050 | EPA 200.2/6020A (mod) | 0.4 | [6]WQG ≤ (3.31+EXP(1.273*LN(hardness)-4.704))/1000 | [6]WQG ≤ (EXP(1.273*LN(hardness)-1.46))/1000 |
| Mercury | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | [7]WQG = MeHg/total Hg | - |
| Molybdenum | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | ≤1 | 2 |
| Nickel | mg/L | 0.00050 | EPA 200.2/6020A (mod) | 1 | 0.025 (W) | 0.110 (W) |
| Selenium* | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | 0.0020 | - |

[1] *Analysis will be conducted by ALS (Burnaby, British Columbia).*

[2] *MMER (2012); maximum concentration in a grab (mg/L).*

[3] *Working water quality guidelines for British Columbia; Water Quality Guidelines for the Protection of Aquatic Life (WQGPAL)*

[4] *See BCMOE (2016) for details on total suspended sediments levels, streambed substrate composition metrics, and interpretations.*

[5] *Hardness dependent; Long-term applies to water hardness (mg/L CaCO3) between 50-250 mg/L; For hardness >250 mg/L, use 0.01 mg/L.*

[6] *Hardness dependent; Long-term average and short-term maximum WQGs apply to water hardness range of 8 to 360 mg/L. See BCMOE (2016) for details.*

[7] *Where MeHg is concentration of methylmercury and Total Hg is concentration of mercury in a given water volume.*

**Selenium included as an additional parameter given it is a COPC for other areas of the project*

## SAMPLING PROCEDURES

Samples will be collected by Mine staff at the Attichika Creek discharge point for a suite of *in situ* and water quality analytes listed above, following current Mine protocols consistent with BCMOE requirements. Water quality samples to accompany the effluent characterization will be collected following the *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*' (BC MOE 2012). Sampling will include standard *in situ* field parameters, including: dissolved oxygen, pH, hardness, alkalinity, conductivity, and water temperature. *In situ* sampling will measured using either an YSI multi-parameter sonde or a combination of Hanna pen and Winkler dissolved oxygen kit. At all water quality stations, grab samples for chemical analysis will be collected by submerging each sample bottle to a depth of approximately 30 cm (where feasible), removing the cap, allowing the bottle to fill, and then reapplying the cap submerged. Samples will be preserved and transported based on specifications provided by the laboratory.

## LABORATORY ANALYSES

Samples collected will be preserved and shipped according to protocols specified by consulting laboratories. Analytes, detection limits, laboratory methods, and applicable guidelines measured for each type of sample are listed in Table A1 and Table A2.

## QUALITY ASSURANCE/QUALITY CONTROL

Appropriate numbers of field duplicates, field blanks and travel blanks will be collected during each sampling event to ensure good quality assurance and quality control (QA/QC) (i.e., approximately 10% of total samples). For chemical characterization, field duplicate, field blank, and trip blank samples are defined as:

- **Trip Blanks** are prepared by the analytical laboratory prior to sampling and kept sealed for the duration of the sampling trip. These are used to evaluate potential contamination from the sample container and efficacy of storage conditions;
- **Field Blanks** are prepared in the field by filling a complete sample bottle set with de-ionized water provided by the analytical lab. Field blanks are used to assess potential contamination of samples during collection, handling and transport; and
- **Field Duplicates** are prepared in the field by filling a second complete set of sample bottles congruently with the standard field sample set. These bottles are submitted to the lab using "dummy" site codes and used to assess lab testing methods and provided an assessment of the homogeneity of sampled water.

In each annual report, QA/QC results will be screened for potential anomalous values. A value of 20% mean relative percent difference (RPD) will be applied as a data quality objective (DQO) when comparing field test samples to the corresponding duplicate sample results (BC MOE 2013), based on acceptable within-laboratory variability.

The RPD between duplicate samples, where at least one of the results exceeds five times the Laboratory's detection limit. RPD will be calculated as: RPD = 2*(Sample A – Sample B) / (Sample A + Sample B) * 100%. The main intent of DQO is to act as a benchmark in the initial data screening process. Data showing RPD >20% will be further investigated for any cause of any discrepancies and when necessary, checked with the laboratory.

## DATA ANALYSES AND ASSESSMENT

Effluent chemistry will be assessed against provincial discharge limits (PE15335) and federal discharge limits (MMER), and used to support analysis and assessment of surface water quality in creeks receiving effluent discharges. Use of conservative water quality variables, such as major ions, may be used to estimate effluent concentrations in waters sampled at downstream monitoring locations.

Water quality samples collected in the receiving environment will compared to the *British Columbia Approved Water Quality Guidelines* (BC MOE 2016). In addition, results will be compared with: (a) historical results to identify step changes or emerging trends; (b) effluent quality data for relevant discharges affecting each ambient monitoring station; and (c) relevant biological data collected through the FAEMP.

# Appendix B

# Effluent Toxicity

# ACUTE TOXICITY

Acute toxicity tests will be conducted monthly on samples from the mine discharge, and tested for acute toxicity to *Daphnia magna* and rainbow trout.

## SAMPLING PROCEDURES

Samples will be collected by mine staff concurrently with surface water for chemical characterization, in pre-rinsed 20-L plastic carboys or pails. Samples will be shipped by courier to the consulting laboratory within prescribed holding times and following guidelines found in Environment Canada (2000a,b).

## LABORATORY ANALYSIS

Toxicity tests will be conducted by Nautilus Environmental Ltd. (Burnaby, BC) in accordance with Environment Canada approved protocols, using serial dilutions of effluent, with laboratory water as the dilutent. Acute lethality to rainbow trout will be conducted in accordance with Environment Canada (2000a) test protocol *Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow trout) EPS 1/RM/13*, Second Edition. The test entails exposing fish to a series of effluent concentratios for 96 hours, with dead fish counted and removed daily over the span of testing.

Acute lethality to *Daphnia magna* will be conducted following the procedures outlined in Environment Canada (2000b) test protocol *Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Daphnia magna) EPS 1/RM/14,* Second Edition. The test involves exposing Daphnia to a series of effluent concentrations diluted with lab water for 48 hours.

## DATA ANALYSES AND ASSESSMENT

Analyses of acute toxicity results will follow the procedures outlined in federal EEM Technical Guidance Document (Environment Canada 2012). Briefly, acute tests are reported as an LC50, which is the "lethal concentration" that will result in the death of 50% of the population of test organisms after a defined period of exposure. Acute toxicity for various periods (i.e., 24-hour, 48-hour, 96-hour LC50s) can be calculated from daily observations of mortality (Environment Canada 2000a,b). For tests with an LC50>100%, percent survival also will be reported.

The lower the LC50 value, the more toxic the effluent. For instance, an LC50 >100 implies that full-strength test concentration or effluent did not kill 50% of the test organisms. Similarly, an LC50=50% means that half-strength test solution resulted in the mortality of 50% of test organisms.

# SUBLETHAL TOXICITY

Sublethal toxicity of effluent discharge will be assessed twice annually, using standard the tests for fish, invertebrates, algae, and aquatic plants required for federal EEM studies, including the following:

- Fish early-life-stage development test using rainbow trout (*Oncorhynchus mykiss*);
- Invertebrate reproduction and survival test using *Ceriodaphnia dubia*;
- Plant growth using *Lemna minor*; and
- Algal growth using *Pseudokirchneriella subcapitata*.

Analyses will be conducted by Nautilus Environmental (Burnaby, BC) using serial dilutions, with laboratory water used as the dilutant.

Sublethal toxicity tests report LC50, EC25, or IC25 endpoints. The EC25 endpoint, reported by the fish early-life-stage development test, is an estimate of the effective concentration of a test solution that causes 25% of embryos to be non-viable. Algal, macrophyte, and invertebrate tests provide IC25 endpoints, which are estimates of the concentration of test solution that causes 25% inhibition of a quantitative biological function, such as reproduction or growth. The invertebrate test also yields an LC50 endpoint.

General procedures for conducting the rainbow trout early life-stage tests will be based on the document: *Biological Test method: Toxicity Tests Using Early Life Stages of Salmonid Fish (Rainbow Trout)* (Environment Canada 1992). This 7-day static renewal test uses less than 24-hour-old rainbow trout larvae to assess the toxicity of a sample by comparing the viability of exposed embryos to that of the control organisms. The endpoint reported is the test-solution concentration at which embryo viability is reduced by 25% (EC25) over the test period, relative to controls.

Invertebrate reproduction tests will be conducted as three brood (7±1 day) static renewal tests using the cladoceran *Ceriodaphnia dubia.* General procedures for culturing *C. dubia* and conducting tests were based on Environment Canada's *Biological Test Method: Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia* (Environment Canada 1997a). Daphnids are exposed to a series of different test-solution concentrations to assess the survival of the first generation (LC50) and to compare the reproductive success (IC25) of a sample to a control.

Algae toxicity tests will be conducted as 72-hour algal growth inhibition tests using the freshwater alga *Pseudokirchneriella subcapitata*. The general procedures used for conducting tests and culturing algae are based on Environment Canada's *Biological Test Method: Growth Inhibition Test Using a Freshwater Alga* Second Edition (Environment Canada 1997b). Algal cells are grown in various concentrations of test solution for 72 hours, after which cell populations of each replicate are calculated. Test results (growth IC25 endpoints) represent the algal cell growth of the experimental concentrations compared to the growth of a control. Test solution concentrations that indicate hormesis (an enhancement of growth that often occurs at lower test-solution concentrations due to the presence of nutrients in the sample) are excluded from the statistical calculation of the IC25

endpoint, as per Environment Canada's *Guidance Document on Statistical Methods for Environmental Toxicity Tests* Second Edition (Environment Canada 2007a). To calculate any IC25 corrected for hormesis, the control value is assigned to all test concentrations exhibiting greater growth than the control.

Macrophyte toxicity tests will be conducted as 7-day growth inhibition tests using the freshwater plant *Lemna minor*. The general procedures used for conducting tests and culturing plants were based on Environment Canada's *Biological Test Method: Tests for Measuring the Inhibition of Growth Using the Freshwater Macrophyte, Lemna minor* (Environment Canada 2007b). Three-frond plants are grown in various concentrations of test solution for seven days, after which growth of each replicate is calculated. Test results (IC25) represent the number and dry weight of fronds in experimental concentrations relative to the growth and weight of controls.

### SAMPLING PROCEDURES

Samples will be collected by mine staff concurrently with surface water for chemical characterization, in pre-rinsed 20-L plastic carboys or pails. Samples will be shipped by courier to the consulting laboratory within prescribed holding times and following guidelines found in Environment Canada protocols listed above.

### LABORATORY ANALYSIS

Toxicity tests will be conducted by Nautilus Environmental Ltd. (Burnaby, BC) according to Environment Canada approved protocols, using laboratory water as dilutent for all tests.

## DATA ANALYSES AND ASSESSMENT

Analyses of toxicity results will follow the procedures outlined in the *Metal Mining Technical Guidance for Environmental Effects Monitoring* document (Environment Canada 2012). Endpoints for sublethal toxicity tests are described in the sections above.

Acute and sublethal toxicity thresholds observed in these tests will be considered in conjunction with estimated effluent-dilution ratios observed at downstream monitoring locations to determine the likelihood of acute or sublethal effects occurring in these downstream receiving environments.

## QUALITY ASSURANCE/QUALITY CONTROL

Nautilus Environmental Ltd. adopts a comprehensive and rigorous QA/QC program to ensure that generated data are of high quality and scientifically defensible, and this process meets the requirements of established and approved standards stipulated by Environment Canada.

# Appendix C

# Surface Water Chemistry

# SURFACE WATER CHEMISTRY SAMPLING OVERVIEW

Surface water chemistry samples will be collected in the Kemess mine area to support the biological sampling program outlined in the FAEMP design, and to satisfy requirements of permits for Kemess South (KS) and the Kemess Underground (KUG) projects. In support of the biological program, samples will be collected in conjunction with benthic invertebrate, periphyton, and sediment quality at the following locations:

- The control location of upper Attichika Creek, upstream of the confluence with Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

Sampling for PAHs at the above locations will occur once during the fall of 2018 (pre-construction) to satisfy regulatory commitments, requesting further baseline information in Attichika Creek.

## SAMPLING PROCEDURES

Sample collection methodology was based around guidance provided by in *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*' (BC MOE 2012). Sampling will include standard *in situ* field parameters at all locations, including: dissolved oxygen, pH, hardness, alkalinity, conductivity, and water temperature. *In situ* sampling will measured using either a YSI multi-parameter sonde or a combination of Hanna pen and Winkler dissolved oxygen kit. At all water quality stations, grab samples for chemical analysis will be collected by submerging each sample bottle to a depth of approximately 30 cm (where feasible). Samples will be preserved and transported based on specifications provided by the laboratory.

## LABORATORY ANALYSIS

Water samples will be inventoried on a chain-of-custody (COC) form and shipped to an accredited laboratory, where they will be analyzed for conventional variables, nutrients, and total metals in accordance with standard laboratory methods. A list of standard water quality analytes, detection limits, and applicable guidelines to be completed annually are provided in Table C1.

**Table C1. Water Chemistry analytes, detection limits, analytical methods, and applicable guidelines.**

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER Requirements[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| **Physical Tests** | | | | | | |
| Conductivity | µS/cm | 2.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Hardness (as $CaCO_3$) | mg/L | 0.50 | APHA 1030E | - | - | - |
| pH | pH | 0.10 | APHA 4500-H, 2510, 2320 | 6.0 to 9.5 | 6.5-9 | 6.5-9 |
| Total Suspended Solids | mg/L | 1.0 | APHA 2540 D | 30 | 30 | [4]narrative |
| Total Dissolved Solids | mg/L | 10 | APHA 1030E | - | - | - |
| Turbidity | | | SM 22 2130 B m | - | [5]narrative | [5]narrative |
| **Anions and Nutrients** | | | | | | |
| Alkalinity, Bicarbonate (as $CaCO_3$) | mg/L | 1.0 | APHA 2320 | - | - | - |
| Alkalinity, Carbonate (as $CaCO_3$) | mg/L | 1.0 | APHA 2320 | - | - | - |
| Alkalinity, Hydroxide (as $CaCO_3$) | mg/L | 1.0 | APHA 2320 | - | - | - |
| Alkalinity, Total (as $CaCO_3$) | mg/L | 1.0 | APHA 4500-H, 2510, 2320 | - | - | - |
| Ammonia, Total (as N) | mg/L | 0.0050 | APHA 4500 NH3-NITROGEN (AMMONIA) | - | - | 1.8 |
| Bromide (Br) | mg/L | 0.050 | EPA 300.1 | - | - | - |
| Chloride (Cl) | mg/L | 0.50 | APHA 22 4500-Cl G or EPA 300.1 | - | 150 | 600 |
| Fluoride (F) | mg/L | 0.020 | EPA 300.1 | - | - | - |
| Nitrate (as N) | mg/L | 0.0050 | EPA 300.1 | - | 3 | 32.8 |
| Nitrite (as N) | mg/L | 0.0010 | EPA 300.1 | - | 0.02 to 0.20 (Cl<2 to >10) | 0.06 to 0.60 (Cl<2 to >10) |
| Orthophosphate-Dissolved (as P) | mg/L | 0.0010 | APHA 22 4500-P A,B,F | - | - | - |
| Phosphorus (P) -Total Dissolved | mg/L | 0.0020 | APHA 22 4500-P A,B,F | - | - | - |
| Phosphorus (P) -Total | mg/L | 0.0020 | APHA 22 4500-P A,B,F | - | - | - |
| Sulfate ($SO_4$) | mg/L | 0.30 | EPA 300.1 | - | [6']128 to 429 | [6']128 to 429 |
| **Cyanides** | | | | | | |
| Cyanide, Weak Acid Dissolved | mg/L | 0.0005 | APHA 4500-CN CYANIDE | - | - | - |

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER Requirements[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| Cyanide, Total | mg/L | 0.0005 | ISO 14403:2002 | 2 | ≤0.005 | 0.010 |
| Cyanide, Free | mg/L | 0.0005 | ASTM 7237 | - | - | - |
| **Total Metals** | | | | | | |
| Aluminum | mg/L | 0.0030 | EPA 200.2/6020A (mod) | - | - | - |
| Antimony | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Arsenic | mg/L | 0.00010 | EPA 200.2/6020A (mod) | 1 | 0.005 | - |
| Barium | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | 1.0 (W) |
| Beryllium | mg/L | 0.000020 | EPA 200.2/6020A (mod) | - | - | - |
| Bismuth | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Boron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | 1.2 | - |
| Cadmium | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | - | - |
| Calcium | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Chromium | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Cobalt | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | 0.004 | 0.110 |
| Copper | mg/L | 0.00050 | EPA 200.2/6020A (mod) | 0.6 | [8]WQG=(0.094*(hardness)+2)/1000 | [8]<0.002 |
| Iron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | 1 |
| Lead | mg/L | 0.000050 | EPA 200.2/6020A (mod) | 0.4 | [9]WQG ≤ (3.31+EXP(1.273*LN(hardness) - 4.704))/1000 | [9]WQG ≤ (EXP(1.273*LN(hardness) - 1.46))/1000 |
| Lithium | mg/L | 0.0010 | EPA 200.2/6020A (mod) | - | - | - |
| Magnesium | mg/L | 0.10 | EPA 200.2/6020A (mod) | - | - | - |
| Manganese | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | [10]WQG≤ 0.0044*(hardness)+0.605 | [10]WQG≤ 0.01102*(hardness)+0.54 |
| Mercury | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | [11]WQG = MeHg/total Hg | - |
| Molybdenum | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | ≤1 | 2 |
| Nickel | mg/L | 0.00050 | EPA 200.2/6020A (mod) | 1 | 0.025 (W) | 0.110 (W) |
| Phosphorus | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Potassium | mg/L | 0.10 | EPA 200.2/6020A (mod) | - | - | - |
| Selenium | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | 0.002 | - |
| Silicon | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Silver | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | 0.00005 (H≤100 mg/L); 0.0015 (H>100 mg/L) | 0.001 (H≤100 mg/L); 0.003 (H>100 mg/L |
| Sodium | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Strontium | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | - | - |
| Sulfur | mg/L | 0.50 | EPA 200.2/6020A (mod) | - | - | - |

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER Requirements[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| Thallium | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | - | - |
| Tin | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Titanium | mg/L | 0.00030 | EPA 200.2/6020A (mod) | - | - | - |
| Uranium | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | - | - |
| Vanadium | mg/L | 0.00050 | EPA 200.2/6020A (mod) | - | - | - |
| Zinc | mg/L | 0.0030 | EPA 200.2/6020A (mod) | 1 | [12]WQG=7.5+0.75(hardness*-90) | [12]WQG=33+0.75(hardness*-90) |
| Zirconium | mg/L | 0.00030 | EPA 200.2/6020A (mod) | - | - | - |
| **Dissolved Metals** | | | | | | |
| Aluminum | mg/L | 0.0010 | EPA 200.2/6020A (mod) | - | [7]WQG= EXP(1.6-3.327*(median pH)+0.402*(median pH)^2) | [7]WQG= EXP(1.209-2.426*(pH)+0.286*(pH)^2) |
| Antimony | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Arsenic | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Barium | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Beryllium | mg/L | 0.000020 | EPA 200.2/6020A (mod) | - | - | - |
| Bismuth | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Boron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | - |
| Cadmium | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | WQG=(EXP(0.736*LN(hardness)-4.943))/1000 | WQG=(EXP(1.03*LN(hardness)-5.274))/1000 |
| Calcium | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Chromium | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Cobalt | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Copper | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | - | - |
| Iron | mg/L | 0.010 | EPA 200.2/6020A (mod) | - | - | 0.35 |
| Lead | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Lithium | mg/L | 0.0010 | EPA 200.2/6020A (mod) | - | - | - |
| Magnesium | mg/L | 0.10 | EPA 200.2/6020A (mod) | - | - | - |
| Manganese | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Mercury | mg/L | 0.0000050 | EPA 200.2/6020A (mod) | - | - | - |
| Molybdenum | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Nickel | mg/L | 0.00050 | EPA 200.2/6020A (mod) | - | - | - |
| Phosphorus | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Potassium | mg/L | 0.10 | EPA 200.2/6020A (mod) | - | - | - |
| Selenium | mg/L | 0.000050 | EPA 200.2/6020A (mod) | - | - | - |
| Silicon | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |

| Variables | Units | Detection Limits | Analytical Methods[1] | MMER Requirements[2] | BC Long-term Average WQGPAL[3] | BC Short-term Max WQGPAL[3] |
|---|---|---|---|---|---|---|
| Silver | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | - | - |
| Sodium | mg/L | 0.050 | EPA 200.2/6020A (mod) | - | - | - |
| Strontium | mg/L | 0.00020 | EPA 200.2/6020A (mod) | - | - | - |
| Sulfur | mg/L | 0.50 | EPA 200.2/6020A (mod) | - | - | - |
| Thallium | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | - | - |
| Tin | mg/L | 0.00010 | EPA 200.2/6020A (mod) | - | - | - |
| Titanium | mg/L | 0.00030 | EPA 200.2/6020A (mod) | - | - | - |
| Uranium | mg/L | 0.000010 | EPA 200.2/6020A (mod) | - | - | - |
| Vanadium | mg/L | 0.00050 | EPA 200.2/6020A (mod) | - | - | - |
| Zinc | mg/L | 0.0010 | EPA 200.2/6020A (mod) | - | - | - |
| Zirconium | mg/L | 0.00030 | EPA 200.2/6020A (mod) | - | - | - |

[1] *Analysis will be conducted by ALS (Burnaby, British Columbia).*

[2] *MMER (2012) deleterious substances; values indicate maximum concentration in a grab (mg/L).*

[3] *Working water quality guidelines for British Columbia; Water Quality Guidelines for the Protection of Aquatic Life (WQGPAL)*

[4] *See BCMOE (2016) for details on total suspended sediments levels, streambed substrate composition metrics, and interpretations.*

[5] *Guideline is dependent on background turbidity levels, see BCMOE (2016) for details.*

[6] *Hardness-dependent Guideline = 128 mg/L at hardness 0-30 mg/L, 218 mg/L at hardness 31-75 mg/L, 309 at hardness 76-180 mg/L, 429 mg/L at hardness 181-250 mg/L, and at >250 mg/L hardness, site specific guideline.*

[7] *Aluminum is pH dependent; See BCMOE (2016) for details.*

[8] *Copper-hardness dependent; Long-term applies to water hardness (mg/L CaCO3) between 50-250 mg/L; For hardness >250 mg/L, use 0.01 mg/L.*

[9] *Hardness dependent; Long-term average and short-term maximum WQGs apply to water hardness range of 8 to 360 mg/L. See BCMOE (2016) for details.*

[10] *For long-term average, hardness 37-450 mg/L $CaCO_3$; for short-term maximum, 25-259 mg/L CaCO3.*

[11] *Where MeHg is concentration of methylmercury and Total Hg is concentration of mercury in a given water volume.*

[12] *Long-term average applies to hardness 90-330 mg/L CaCO3; Short-term maximum applies to 90-500 mg/L CaCO3.*

In addition to the standard set of water quality variables, PAHs samples will be collected only in 2018 and will be analyzed by AXYS Analytical Services Ltd. in Sidney, BC. The list of parameters to be measured and their applicable analytical methods are provided in Table C2 below. It is important to note, detection limits have not been provided given reported limits are highly variable for PAH analysis.

**Table C2. PAH variables measured in water collected in support of the KUG baseline during pre-construction 2018.**

| Analyte | Units | Analytical Method |
|---|---|---|
| Biphenyl | ng/L | LR GC/MS |
| Naphthalene | ng/L | LR GC/MS |
| Acenaphthylene | ng/L | LR GC/MS |
| Acenaphthene | ng/L | LR GC/MS |
| Fluorene | ng/L | LR GC/MS |
| Phenanthrene | ng/L | LR GC/MS |
| Anthracene | ng/L | LR GC/MS |
| Retene | ng/L | LR GC/MS |
| Dibenzothiophene | ng/L | LR GC/MS |
| Fluoranthene | ng/L | LR GC/MS |
| Pyrene | ng/L | LR GC/MS |
| Benz[a]anthracene | ng/L | LR GC/MS |
| Chrysene | ng/L | LR GC/MS |
| Benzo[b,j,k]fluoranthene | ng/L | LR GC/MS |
| Benzo[a]pyrene | ng/L | LR GC/MS |
| Indeno[1,2,3-c,d]-pyrene | ng/L | LR GC/MS |
| Dibenz[a,h]anthracene | ng/L | LR GC/MS |
| Benzo[g,h,i]perylene | ng/L | LR GC/MS |

## QUALITY ASSURANCE/QUALITY CONTROL

Appropriate numbers of field duplicates, field blanks, and travel blanks would be collected during each sampling event to ensure good quality assurance and quality control (QA/QC) (i.e., approximately 1 set for every 10 samples collected). For chemical characterization, field duplicate, field blank, and trip blank samples are defined as:

- **Trip Blanks** are prepared by the analytical laboratory prior to sampling and kept sealed for the duration of the sampling trip. These are used to evaluate potential contamination from the sample container and efficacy of storage conditions;
- **Field Blanks** are prepared in the field by filling a complete sample bottle set with de-ionized water provided by the analytical lab. Field blanks are used to assess potential contamination of samples during collection, handling and transport; and

- **Field Duplicates** are prepared in the field by filling a second complete set of sample bottles congruently with the standard field sample set. These bottles are submitted to the lab using "dummy" site codes and used to assess lab testing methods and provided an assessment of the homogeneity of sampled water.

In each annual report, QA/QC results include will be screened for potential anomalous values. A value of 20% mean relative percent difference (RPD) will be applied as a data quality objective (DQO) when comparing field test samples to the corresponding duplicate sample results (BC MOE 2013), based on acceptable within-laboratory variability.

The RPD between duplicate samples, where at least one of the results exceeds five times the Laboratory's detection limit. RPD will be calculated as: RPD = 2*(Sample A – Sample B) / (Sample A + Sample B) * 100%. The main intent of DQO is to act as a benchmark in the initial data screening process. Data showing RPD >20% will be further investigated for any cause of any discrepancies and when necessary, checked with the laboratory.

## DATA ANALYSIS AND WATER QUALITY ASSESSMENT

Water quality conditions will be assessed by comparing data from exposure sites to reference sites and the *British Columbia Approved Water Quality Guidelines* (BC MOE 2016). In addition, results will be compared with: (a) historical results to identify step changes or emerging trends; (b) effluent quality data for relevant discharges affecting each ambient monitoring station; and (c) relevant biological data collected through the FAEMP.

# Appendix D

# Sediment Quality and Channel Form

# SEDIMENT QUALITY SAMPLING OVERVIEW

Several sediment quality studies have been conducted at the mine and have been summarized in Chapter 2.7 of this Application. Additional sediment quality is proposed as a component of the FAEMP design, to further characterize sediment quality in receiving aquatic environments, and provide supporting data to the benthic invertebrate study. Where possible, sediment sampling will be co-located with water quality and benthic invertebrate sampling sites. Attichika Creek is mostly erosional in nature, so sediment sampling will occur as close as feasible possible to benthic invertebrate sites, based on sampling suitability. Sediment quality surveys will be conducted annually in Attichika Creek (up to year 3 of the Operations phase) at the following locations:

- The control location of upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

Sampling will include determining PAHs concentrations in sediment at the above locations once in the fall of 2018 (pre-construction), to satisfy regulatory commitments to provide further baseline information in Attichika Creek.

## SAMPLING PROCEDURES

Sediment quality sampling procedures will follow guidance available in the *British Columbia Field Sampling Manual for Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater, Soil, Sediment, and Biological Samples* (BC MOE 2013). At all sampling locations, water quality sampling will occur prior to sediment quality sampling, to avoid disturbing overlying waters. At each location, the top 2 to 5 cm of each sediment grab will be collected using a pre-cleaned stainless-steel Ekman sampler or spoon and transferred to a stainless-steel pan, homogenized, and scooped into labelled sterilized glass jars. All equipment will be cleaned using metals free soap, with additional cleaning procedures including rinsing all equipment with hexane and acetone prior to collection of PAH samples. If required, additional grab samples should be collected until a sufficient amount of sediment is acquired.

At all sites, the following information will be recorded on the field datasheets/field notebook:

- The number of grab samples collected for composite samples;
- The general appearance of the sediments, including grain size, texture, colour, any odour, presence of a hydrocarbon or biogenic sheen, and presence of debris, plant material, or biota;
- Details pertaining to unusual events that might have occurred during the operation of the sampler (e.g., possible sample contamination, equipment failure, unusual appearance, control of vertical descent of the sampler, etc.); and
- Any deviations from standard operating procedures or Field Work Instructions (FWIs).

## LABORATORY ANALYSIS

Sediment samples will be inventoried on a chain-of-custody (COC) form and shipped to an accredited laboratory (Maxxam Analytics, Burnaby) for analyses of total metals (full ICP metals scan), particle size distribution, and total organic carbon (TOC). Sediment samples will be analyzed in accordance with standard laboratory procedures. Sediment quality analytes, methods, detection limits, and applicable guidelines appear in Table D1.

**Table D1. Sediment quality analytes, detection limits, analytical methods, and applicable guidelines.**

| Analyte | Units | Detection Limit | Method | Guidelines | | |
|---|---|---|---|---|---|---|
| | | | | CCME | | BC working Guidelines |
| | | | | ISQG | PEL | |
| **Total Metals** | | | | | | |
| Total Aluminum (Al) | mg/kg | 100 | ICPMS | - | - | - |
| Total Antimony (Sb) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Arsenic (As) | mg/kg | 0.50 | ICPMS | 5.9 | 17 | [a] |
| Total Barium (Ba) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Beryllium (Be) | mg/kg | 0.40 | ICPMS | - | - | - |
| Total Bismuth (Bi) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Cadmium (Cd) | mg/kg | 0.050 | ICPMS | 0.6 | 3.5 | [a] |
| Total Calcium (Ca) | mg/kg | 100 | ICPMS | - | - | - |
| Total Chromium (Cr) | mg/kg | 1.0 | ICPMS | 37.3 | 90 | [a] |
| Total Cobalt (Co) | mg/kg | 0.30 | ICPMS | - | - | - |
| Total Copper (Cu) | mg/kg | 0.50 | ICPMS | 35.7 | 197 | [a] |
| Total Iron (Fe) | mg/kg | 100 | ICPMS | - | - | 21,200[b], 43,766[c] |
| Total Lead (Pb) | mg/kg | 0.10 | ICPMS | 35 | 91.3 | [a] |
| Total Lithium (Li) | mg/kg | 5.0 | ICPMS | - | - | - |
| Total Magnesium (Mg) | mg/kg | 100 | ICPMS | - | - | - |
| Total Manganese (Mn) | mg/kg | 0.20 | ICPMS | - | - | - |
| Total Mercury (Hg) | mg/kg | 0.050 | ICPMS | 0.17 | 0.486 | [a] |
| Total Molybdenum (Mo) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Nickel (Ni) | mg/kg | 0.80 | ICPMS | - | - | 16[b],75[c] |
| Total Phosphorus (P) | mg/kg | 10 | ICPMS | - | - | - |
| Total Potassium (K) | mg/kg | 100 | ICPMS | - | - | - |
| Total Selenium (Se) | mg/kg | 0.50 | ICPMS | - | - | 2[d] |
| Total Silver (Ag) | mg/kg | 0.050 | ICPMS | - | - | 0.5 |
| Total Sodium (Na) | mg/kg | 100 | ICPMS | - | - | - |
| Total Strontium (Sr) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Thallium (Tl) | mg/kg | 0.050 | ICPMS | - | - | - |
| Total Tin (Sn) | mg/kg | 0.10 | ICPMS | - | - | - |
| Total Titanium (Ti) | mg/kg | 1.0 | ICPMS | - | - | - |

| Analyte | Units | Detection Limit | Method | Guidelines | | |
|---|---|---|---|---|---|---|
| | | | | CCME | | BC working Guidelines |
| | | | | ISQG | PEL | |
| Total Uranium (U) | mg/kg | 0.050 | ICPMS | - | - | - |
| Total Vanadium (V) | mg/kg | 2.0 | ICPMS | - | - | - |
| Total Zinc (Zn) | mg/kg | 1.0 | ICPMS | 123 | 315 | [a] |
| Total Zirconium (Zr) | mg/kg | 0.50 | ICPMS | - | - | - |
| **Physical Properties** | | | | | | |
| % sand | % | 2.0 | Hydrometer | - | - | - |
| % silt | % | 2.0 | Hydrometer | - | - | - |
| Clay Content | % | 2.0 | Hydrometer | - | - | - |
| Gravel | % | 2.0 | Hydrometer | - | - | - |
| Total Organic Carbon | mg/kg | 500 | CAM SOP-00468 | - | - | - |

[a] *BC Working guidelines are the same as the CCME ISQG and PEL for this analyte*

[b] *Lowest effect level based on screening level concentration (BCMOE 2006)*

[c] *Severe effect level based on screening level concentration (BCMOE 2006)*

[d] *This value represents the chronic sediment quality alert concentration threshold for the protection of aquatic life (BCMOE 2014)*

In addition to the set of sediment quality variables outlined in Table D1, PAHs samples will be collected once in Attichika Creek during the fall of 2018 and will be submitted to ALS in Burnaby, BC for analysis. The list of PAH parameters to be measured and their applicable analytical methods are provided in Table D2. It should be noted that detection limits vary in PAH sediment quality samples based on moisture content, and have therefore not been included in the table.

**Table D2. PAH variables measured in sediment in support of the KUG baseline during pre-construction in 2018.**

| Analyte | Units | Analytical Method (VMV code) |
|---|---|---|
| Acenaphthene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Acenaphthylene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Anthracene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Benz[a]anthracene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Benzo[a]pyrene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Benzo[b,j,k]fluoranthene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Benzo[g,h,i]perylene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Biphenyl | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Chrysene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Dibenz[a,h]anthracene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Dibenzothiophene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Fluoranthene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Fluorene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Indeno[1,2,3-c,d]-pyrene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Naphthalene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Phenanthrene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Pyrene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |
| Retene | mg/kg | MLA021, based on USEPA methods 1625 and 82701 |

## QUALITY ASSURANCE/QUALITY CONTROL

Sediment QA/QC samples will be collected to assess potential sample contamination at 10% of the sample locations (i.e., one every ten field samples). Two QA/QC sediment samples will be collected at a randomly selected station and submitted to the laboratory along with the other samples for analysis, namely:

- A split sample, which is a sub-sample taken from one large sample that has been homogenized and divided into two (BC MOE 2003), the intent of which is to assess laboratory analytical variability; and
- A sampling-equipment rinsate blank, the intent of which is to assess field cleaning techniques. Collecting this sample involves washing down sampling equipment using standard techniques, then rinsing with deionized water, which is collected into a cleaned tray and decanting into sample analysis bottles for analysis of water quality.

QA/QC samples will be submitted to the lab blind using "dummy" site codes. Analytical results for the split samples will be compared, using the relative percent difference (RPD, difference between data values/average of data values, multiplied by 100%) calculated for each sediment quality variable. RPDs greater than 20% (i.e., acceptable level of lab precision) will be noted as potentially unacceptable levels of precision, and checked with the analytical laboratory. Concentrations of metals in rinsate waters will be compared against five times their analytical detection limit, to assess potential sample contamination related to equipment cleaning techniques.

## DATA ANALYSIS AND SEDIMENT QUALITY ASSESSMENT

Initially, all data will be screened for outliers or inaccurate entries. Sediment quality will then be assessed by comparing chemistry data from sampled stations to both *British Columbia Working Sediment Guidelines* (BC MOE 2011), and the CCME *Interim Sediment Quality Guideline for the protection of aquatic life* (CCME ISQG; CCME 2007, with updates to 2016). Any guideline exceedances in sediment chemistry may serve as a chemical of potential concern (COPCs) and will be evaluated using a weight of evidence approach to determine if this exceedance is causing an effect in aquatic receptors. The CCME guidelines combine an ISQG and probable effect level (PEL). These guidelines are considered benchmarks for managing the current or future use of water, and are available for total metals (Table D1). Definitions for these values are as follows (CCME 2007, updates to 2016):

- ISQG: generally reflective of threshold effect levels (TELs), where the concentrations below this threshold are unlikely to cause adverse biological effects; and
- PEL: concentration above the PEL are expected to frequently cause adverse effects.

Project-related effects on sediment quality will also be evaluated by assessing differences in sediment chemistry from upstream reference areas compared with downstream exposure areas to determine if discharge is having an effect on sediment chemistry downstream of the diffuser. Comparisons with historical data will be made to allow understanding of spatial and temporal patterns present in in sediment chemistry data over time.

This sediment-quality component should be reviewed at the end of Year 3 of the Project (Operations phase) to evaluate whether discharge is changing sediment quality in the areas downstream of the diffuser, with consideration to reduced or eliminating this component of sampling from the program moving forward if no impacts are noted.

## MCNEIL CORES

A McNeil-Anhell core sampler (core diameter 6", or approximately 150 mm) will be used to assess the percentage of fines present within the streambed in Attichika Creek at (EEM-13, EEM-17, ATT-DIS, EEM-18). Cores will be collected following the *Guidelines for Monitoring Fine Sediment Deposition in Streams* (Rex and Carmichael 2002). The core sampler includes a 15 cm diameter cylinder with an attached basin, which is used to store sediments from the substrate and trap suspended fines. Three replicate cores will be collected at each station. The McNeil corer will be kept perpendicular to the streambed as it is turned and driven into the streambed, the core sample will then be agitated with a trowel, and the bed materials will be removed and placed into a labeled bucket. A cylinder plunger will be inserted into the core and used to retain suspended sediments. The sampler will then be removed with the plunger in place and suspended materials will be added to the sample bucket. A 1L water sample will also be collected to capture suspended sediments. Supporting data, including velocity and depth, will be measured and recorded for each replicate core.

Sediments and river water will be strained through a series of sieves to determine the particle size distribution, percent fines, or geometric mean diameters (GMD) of the distribution; analyses will be performed at the Kemess Mine laboratory. The weight of suspended sediments in the river water samples will be added to the finest fraction (i.e., < 0.075 mm) of the particle-size distribution before calculation of mean or percentile diameters.

Data generated from the McNeil cores were used to calculate Fredle numbers and GMD, as follows:

- **Geometric mean diameter**, which provides an estimate of the average size of sediments found in the top 15 cm of streambed, is calculated as follows:

$$D_g = (d_{84} \times d_{16})^{0.5}$$

  where: $d_{84}$ is the 84$^{th}$ percentile particle size and the $d_{16}$ is the 16$^{th}$ percentile particle size (estimated from log-probability plots of the particle size distribution for McNeil cores); and

- **Fredle number**, which provides an estimate of the general composition of pore size of the top 15 cm of the streambed, was calculated as follows:

$$\text{Fredle number} = D_g/S_o$$

  where: $d_g$ is the geometric mean diameter, $S_o$ is the sorting coefficient, calculated as $(d_{75}/d_{25})^{0.5}$, and $d_{75}$ and $d_{25}$ are the 75$^{th}$ and 25$^{th}$ percentile particle sizes, respectively, estimated from log-probability plots of the particle size distribution for McNeil cores.

Trend analysis and monitoring over time of GMD and Fredle number will be used to satisfy the following condition:

*Condition 3.7.3: Monitor changes in channel form and sediment load downstream of the discharge location in Attichika Creek.*

Similar to the sediment-quality component, monitoring of changes to channel form should be reviewed at the end of Year 3 of the Project (Operations phase) to evaluate whether discharge from the diffuser is leading to any physical alteration to the receiving environment. Consideration to reduced or eliminating this sampling should be given during the review if no impacts are noted within the first seven years of sampling.

# Appendix E

# Periphyton Biomass and Community Composition

# PERIPHYTON SAMPLING

In addition to more detailed, higher-resolution nutrient analyses planned as part of the surface water chemistry component for the Project, periphyton biomass (chlorophyll *a*) and taxonomic structure (semi-quantitative inventory of major taxa present) will be monitored annual in the fall to evaluate any potential effects of nutrients enrichment on periphyton communities.

**Sampling Procedures**

Periphyton samples will be collected for biomass (as chlorophyll *a*) and taxonomic composition following BCMOE guidance (Cavanagh et al. 1998) and standard protocols (BC MOE 2012). At each site, five (5) replicates will be collected for analysis of algal biomass (as chlorophyll-a), with an additional bulk sample collected for taxonomic analysis, as follows:

Five rocks will be randomly selected to represent the variability of periphyton (benthic algal) growth at the site.

- Selected rocks, relatively flat, small enough to lift, and large enough to collect a sufficient sample, will be brought to shore;
- A 4-cm × 4-cm (16-cm$^2$) template will be placed over the selected rocks from each site. Typically, the template will be placed in the center of the upside face of the rock to ensure consistency among samples. A scalpel will be used to scrape periphyton from the area within this template;
- For chlorophyll *a* analyses, scrapings from five rock will be transferred directly onto five separate 0.45µm membrane filter paper. Filter paper will then be folded, wrapped in a large piece of labeled aluminum foil, placed in Ziploc bag, and frozen. Frozen samples will be shipped on ice to an accredited laboratory at the end of the sampling program. Periphyton biomass analyses will be conducted; and
- For periphyton community (taxonomic) analyses, one composite sample per site will be collected from five rocks, preserved with Lugol's solution and shipped to a qualified taxonomist for analysis.

Periphyton biomass and community composition surveys will be conducted annually at the following locations:

- The control location in upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

**Laboratory Analyses**

Periphyton biomass samples will be submitted to an accredited laboratory for measurement of biomass using the fluorometric method.

Taxonomic analyses of periphyton community will be completed by a qualified taxonomist. Periphyton will be identified to species where practical, and assessed semi-quantitatively, including presence / absence observations and assessment of the relative abundance of major algal taxa.

**Quality Assurance / Quality Control**

Laboratory QA/QC procedures will be conducted during periphyton biomass sample analysis to test for accuracy and ensure no potential contamination is introduced into the samples. These QA/QC samples will include spike blanks, which test accuracy by adding a known amount of an analyte to a blank matrix sample, and method blanks which are blank matrix treated with all reagents used during the analytical procedure to ensure reagents are not a source of contamination.

Taxonomic analysis QA/QC will include replicate aliquots taken from the samples to verify relative proportions of diatom and non-diatom species.

**Data Analyses and Assessment**

Periphyton biomass will be reported as average mass of chlorophyll *a* per sample per site. Conversion of absolute mass to per-unit-area mass (µg/cm$^2$) will be completed by dividing the absolute mass by the sampled area (cm$^2$). Chlorophyll *a* data collected from all stations were compared with BC water quality criteria for nutrients and algae which provide a guideline of a maximum biomass of 10 µg/cm$^2$ for the protection of aquatic life in streams (BC MOE 2001). This guideline is designed to protect fish habitat and changes in communities of organisms such as benthic invertebrates (BC MOE 2001).

Taxonomic analyses of periphyton community data will be semi-quantitative, consisting of presence and absence observations and an overall assessment of the proportion of major taxa groups. Given that these data will be semi-quantitative, community metrics that can be assessed are the proportion of major taxa groups and taxa richness (number of taxa present).

Potential effects on periphyton (i.e., toxicity or enrichment) will be assessed by quantitative comparisons of periphyton biomass and community composition among exposure and reference areas, with consideration to nutrient concentrations.

# Appendix F

# Benthic Invertebrate Communities and Tissue Analysis

# BENTHIC INVERTEBRATE SAMPLING OVERVIEW

## SAMPLING PROCEDURES

Benthic invertebrate samples will be collected in accordance with CABIN field protocols (Environment Canada 2012b) using a 400-µm kick-net with a detachable collection cup to collect each sample. The kick-net sampling method will involve a single composite sample collected over a three-minute sampling duration, with the sample collected by disturbing the substrate with the sampler's feet to a target depth of approximately 5 cm. The sampler will travel in an upstream, zig-zag pattern while continuing to capture the disturbed sediments in the kick-net. To minimize potential confounding factors, an effort will be made to collect benthic samples at stations of similar substrate size, water depth, and current velocity.

Following sample collection, the cup will be removed and its contents emptied into a labeled plastic container. Residual material in the cup was rinsed into the same container by washing the exterior surface of the mesh on the bottom of the collection cup. The samples will be then be preserved with 10% buffered formalin and shipped to Cordillera Consulting Inc. (Summerland, BC) for taxonomic identification.

The benthic program will follow a BACI design (Environment Canada 2012a) and will include the following sampling locations:

- The control location of upper Attichika Creek, upstream of the confluence of Kemess Creek (EEM-13);
- The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17);
- The near-field location on Attichika Creek just downstream of the diffuser (ATT-DIS); and
- The far-field location on lower Attichika Creek, below the confluence with Waste Rock Creek (EEM-18).

Annual sampling will include one replicate sample each year, with the exception of one sampling event during pre-construction (Year -4), one during early-discharge (Year -1), and one in early-Operations (Year +3) of the Project, when five replicate samples will be collected to compliment and lead into the KUG EEM program. In reaches where replicate kick-net samples will be collected, replicates must be separated longitudinally by a minimum distance of approximately six times wetted width of the Creek. Additional samples will be collected annually, if required, to ensure enough sample is available for tissue metals and moisture content analysis at each location.

## LABORATORY ANALYSES

Benthic community samples will be analyzed by Cordillera Consulting Inc. (Summerland, BC). Upon receipt of samples, contents will be checked for appropriate preservation and labeling, jar number, and codes. Preservation solutions will be drained and replaced with 80% ethanol and the samples will be elutriated to remove inorganic material. Elutriate will be examined under low-power magnification to ensure the removal of molluscs and trichopterans cases. Each sample will be washed thoroughly using a 400-µm sieve. The contents will then be examined to estimate the total number of invertebrates.

If the estimated total number of individuals in the sample exceeds 600, then subsampling will be used to modify the sorting effort. A guideline of a minimum number of 300 individuals be used for subsampling, following CABIN and EEM guidance. A Marchant box will be used to complete subsampling.

Identification of organisms will be done using a variety of keys, with species identified to genus-species level when possible. Non-insect organisms (except those not included in the count) will be identified to genus/species where possible and to a minimum of family level with intact and mature specimens. Standard Taxonomic Effort lists compiled by SAFIT (2006) will be used as a guideline for what level of identification to achieve where the condition and maturity of the organism enabled.

Samples collected for residue tissue analysis will be shipped to ALS Environmental (Burnaby, BC) for analysis of total metals and moisture content. Results will be provided by the laboratory as both wet weight and dry weight.

## QUALITY ASSURANCE/QUALITY CONTROL

Quality Assurance/Quality Control will follow the standard procedures in Environment Canada (2012) and will be assessed by the following techniques for benthic community analysis:

- **A split sample**, used to assess the difference in counts between two sub-fractions of the same sample. The split check helps assesses taxonomist precision; and
- **A re-sort Sample**, used to evaluate sorting efficiency, where a minimum of 10% of samples will be resorted and checked to ensure ≥90% sorting efficiency is reached.

The analytical laboratory uses the following internal QA/QC procedures assess results and maintain their laboratory accreditation:

- **Laboratory Duplicate**, used to assess laboratory precision by analyzing two subsamples of a larger sample to determine relative percent difference;
- **Method Blanks,** which are blank matrix treated with all the reagents required in the analytical procedure to ensure reagents are not a source of contamination; and
- **Standardized Reference Materials,** which are samples used to evaluate accuracy, with known concentrations with an associated range of acceptable values to test analytical equipment and calibrations and ensure comparability between laboratories.

## DATA ANALYSIS AND ASSESSMENT

Several approaches will be used to analyze benthic invertebrate community data, to allow for an assessment of community condition using multiple lines of evidence. These analytical approaches were drawn from CABIN guidance, federal EEM guidance and requirements, and included other accepted approaches to examining benthic community data.

### Federal EEM Metrics: Biotic Indices

The federal MMER EEM program requires calculation of a variety of biotic indices for each location sampled. The indices describe benthic community composition in each area and facilitate comparisons between study areas. These biotic indices provide regulatory assessment end-points for EEM studies conducted under the MMER and will be calculated using taxonomic data at a Family level, following EEM guidance (Environment Canada 2012c).

To allow meaningful conclusions to be drawn from reference-versus-exposure comparisons of benthic community structure, consistent with federal EEM requirements, five replicate kick-net samples will be collected at each location during the more intensive program years (years -4, -1, and +3). This within-treatment replication ensures statistical comparisons can be made with sufficient statistical power (i.e., power of 0.9, $\alpha=\beta=0.1$, following EEM requirements). During years when only one CABIN sample is planned, index calculations will be compared qualitatively rather than statistically between areas, due to the lack of replication and will be used to contribute to a long-term trend analysis data set.

*Total Abundance*

The total number of individual organisms in each sample will be summed. Because CABIN kick-net samples do not provide an area-based estimate of invertebrate density, total invertebrate abundance will be measured as the total number of individuals per kick-net sample (i.e., per three-minute sample).

*Richness*

Taxonomic richness (i.e., the number of different taxa or families) for each station will be calculated by summing the number of taxa present at each station. Where replicate samples are collected, both the average number of taxa per replicate (i.e. average richness of five replicates) and total taxa across all replicates (representing taxa present across a sampling area) will be used for comparisons.

*Simpson's Diversity Index*

Simpson's Diversity index considers both the abundance pattern and taxonomic richness of the benthic community. This will be calculated at each station by determining the proportion of individuals of each taxonomic group that contributes to the total. This diversity index can range from 0 to 1, with a value of 1 representing the highest diversity. Simpson's diversity index is calculated as:

$$D = 1 - \sum_{i=1}^{s} \left[p_i\right]^2$$

where: D = Simpson's diversity index;

$p_i$ = the proportion of the $i^{th}$ taxon at the station; and

S = number of taxa (families) in the sample.

*Evenness (Simpson's Evenness Index)*

The Simpson's Evenness index takes into consideration the abundance of each taxon in proportion to total abundance and the taxonomic richness at the station. Evenness is calculated:

$$E = \frac{1}{\frac{\sum_{i=1}^{S}(p_i)^2}{S}}$$

where: E = evenness;

$p_i$ = the proportion of the $i^{th}$ taxon at the station; and

S = the number of taxa in the sample.

*Bray-Curtis Dissimilarity Coefficient*

The Bray-Curtis dissimilarity coefficient is a distance measurement that reaches a maximum value of 1 for two sites that are entirely different and a minimum of 0 for two sites that possess identical descriptors. Bray-Curtis dissimilarity coefficients measure the amount of association between sites and will be calculated to compare the degree of similarity in density of individual taxa between individual stations and the reference median. Dissimilarity coefficients for the reference median and individual stations will be calculated using the statistical program R (R Core Development Team 2013). The Bray-Curtis index is calculated as follows (Environment Canada 2012c):

$$B\text{-}C = \frac{\sum_{i=1}^{n} |y_{i1} - y_{i2}|}{\sum_{i=1}^{n} (y_{i1} + y_{i2})}$$

where: B-C = Bray-Curtis distance between sites 1 and 2;

$y_{i1}$ = count for species i at site 1;

$y_{i2}$ = count for species i at site 2; and

n = total number of species present at the two sites.

Because indices of density, richness, and evenness provide no quantitative information on what kind of organisms are present, the Bray-Curtis dissimilarity index is useful as it summarizes the overall difference in community structure between reference and exposed sites into a single number (Environment Canada 2012c).

Environment Canada has recently proposed changing the Bray-Curtis calculation and statistical approach for EEM (Borcard and Legendre 2013), in response to concerns that the very high incidence of significant "effects" found in EEM studies related only to the Bray-Curtis end-point may reflect false positives arising from structural issues with the application of the Bray-Curtis, such as spatial autocorrelation (Huebert 2012).

In an Environment Canada funded study, Borcard and Legendre (2013) confirmed that the traditional Bray-Curtis calculation is prone to high Type I error, but they also found that it is prone to Type II error (i.e., the test also has a high likelihood of reporting false positives, and lower statistical power than previously stated).

As an alternative, Borcard and Legendre (2013) recommended the use of a Bray-Curtis Mantel test. This test uses a multivariate approach to calculate differences in community structure and is more powerful and reliable than the traditional EEM univariate method. The Bray-Curtis Mantel test provides a linear correlation between two dissimilarity matrices:

- One that uses the Bray-Curtis index to compare all possible pairs of sites (reference and exposure, among and within); and
- The other that is a model in which all pairs of sites belonging to the same group (i.e., reference-reference and exposure-exposure) receive a dissimilarity value of 0, and all pairs of sites belonging to different groups (i.e., reference-exposure) receive a dissimilarity value of 1. These two dissimilarity matrices are correlated using the Pearson r correlation coefficient and significance is determined based on 999 permutations (Borcard and Legendre 2013).

Both the traditional ANOVA-based calculation and a Mantel test will be used to assess differences in Bray-Curtis outputs. Both tests will be conducted in R (R Development Core Team 2013) at a significance level of $\alpha = 0.10$.

*EEM Statistical Analyses*

Two-tailed t-tests will be conducted to assess differences in benthic community metrics (i.e., density, richness, diversity and evenness) between the upstream near-field, far-field, and the reference areas in Attichika Creek. Data for t-tests will be analyzed visually using residual plots to ensure that assumptions of normality and homogeneous variance are met. If data failed to meet assumptions, variables will be transformed using a natural log (or other appropriate transformation) and re-evaluated for normality and homogeneity prior to conducting a t-test. All tests were conducted at $\alpha=0.1$ level of significance, consistent with MMER technical guidance (Environment Canada 2012a).

*Assessment of Critical Effects*

EEM-prescribed assessments of critical effects will be assessed when multiple replicates are collected. Following EEM guidance, tests of statistical significance (t-tests) will be undertaken using values of $\alpha=\beta=0.10$. Power will be calculated based on the area and number of stations for each comparison. Critical effect sizes (±2 standard deviations of the reference mean) will be evaluated for all four effects endpoints (abundance, richness, diversity and evenness).

## CABIN Ordination Analyses: Reference Condition Approach (RCA)

*BEAST*

Data collected will be analyzed using BEAST (BEnthic Assessment of SedimenT) software program developed by Reynoldson et al. (1995) and operated by Environment Canada. This analytical program runs the benthic and environmental data through a series of steps, as outlined in Figure F1. These steps comprise the three stages of the reference condition approach (RCA), and help develop a multi-location reference description with which the study data can be compared.

In the first step of the analysis, reference stations that span the range of catchment physiographies encompassed by the test stations were selected from the regional database.

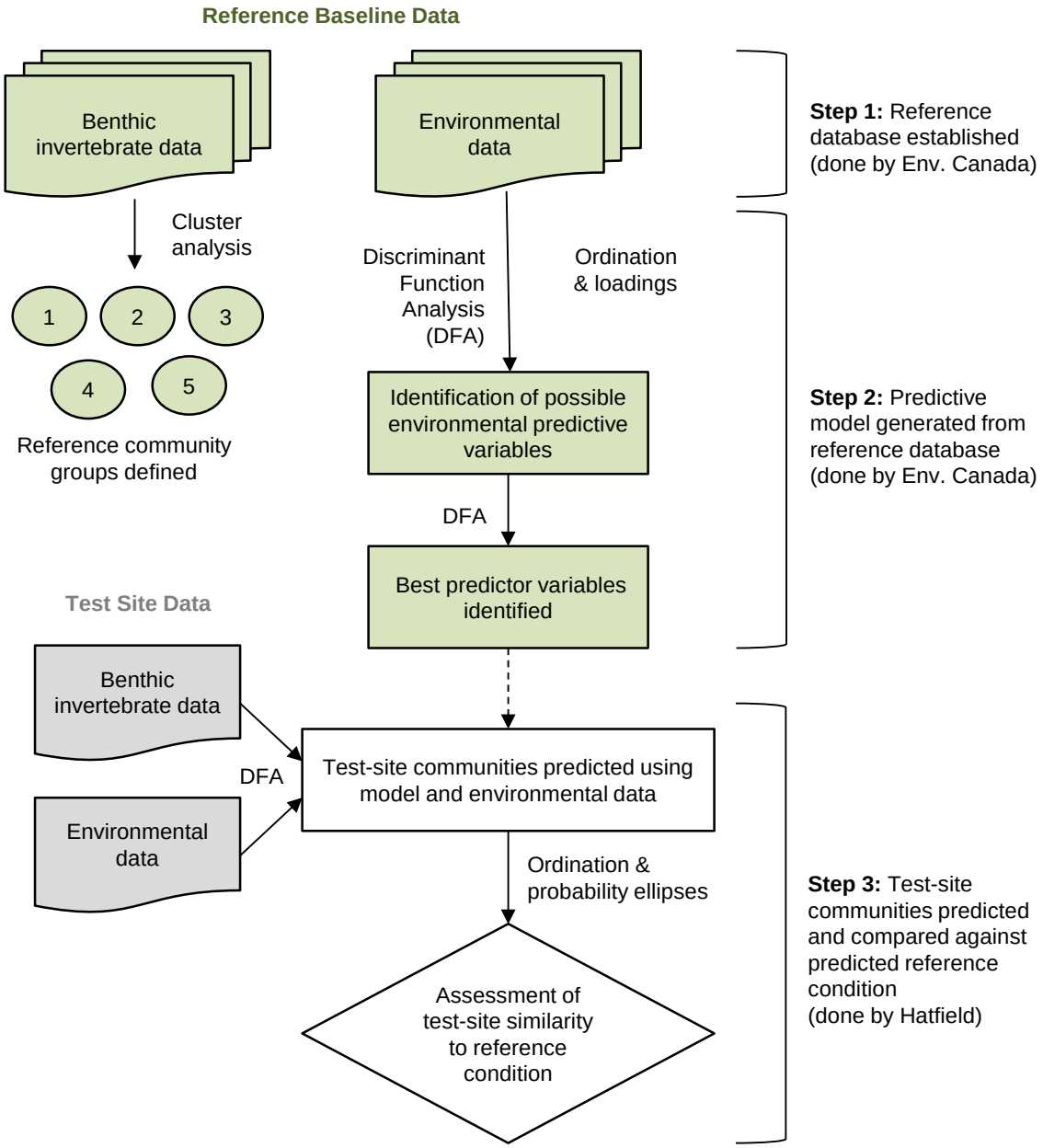
In the second step of the RCA analysis, a predictive model will be generated using corresponding benthic invertebrate and habitat data from the reference stations. The development of the predictive model will follow two main steps:

1. Biological data from reference stations are separated into several biological groups based on the similarity of their benthic invertebrate communities; and

2. The relationship between biological groups and the habitat data is quantified to determine which habitat characteristics best discriminate the biological groups.

In the third step, the model created with the reference stations will be used to predict what the benthic community composition at the test station should look like, by using reference stations with habitat characteristics most similar to the test station. The predicted community will then be compared to the observed community composition at the test station, such that the degree of divergence from the predicted community will indicate level of impairment.

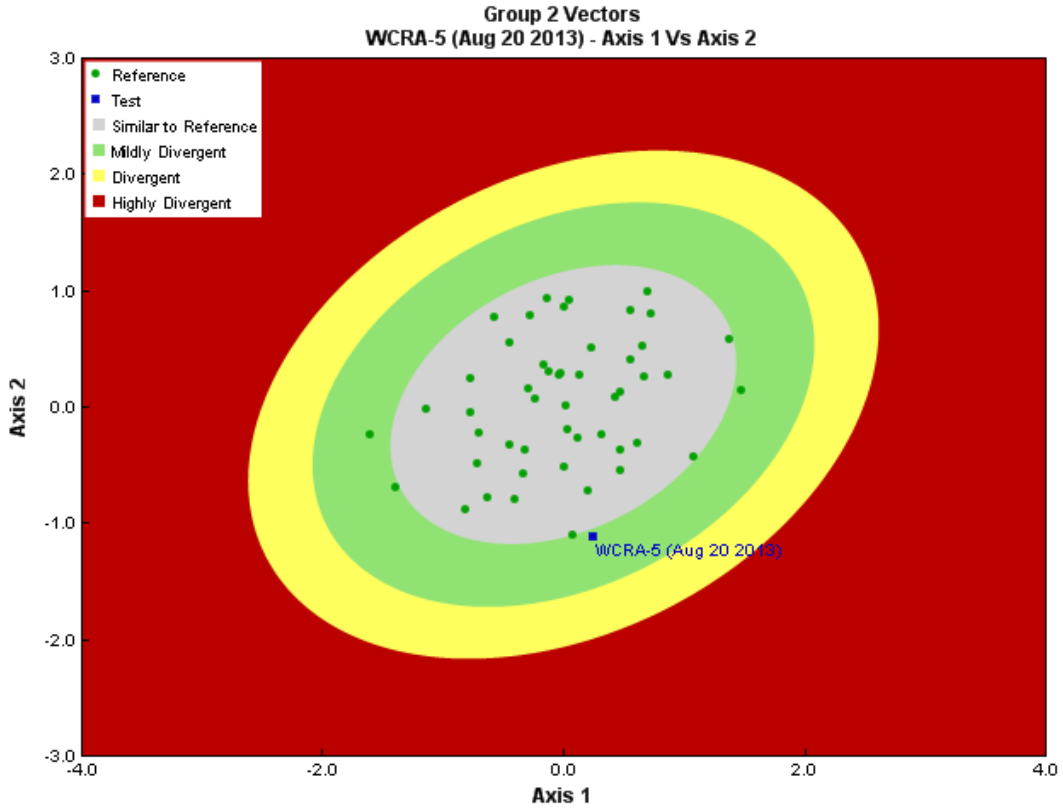
**Figure F1. Steps involved in the RCA analysis of benthic invertebrate data (modified from Reece and Richardson 2000).**




Interpretation will be accomplished using ordination plots output by the CABIN database (http://www.ec.gc.ca/rcba-cabin), which graphically depict the position of test station relative to the group of reference stations. This group of reference stations provides the range of reference conditions. The further the test station is from the centre of this range, the more different it is from the representative subset of reference stations. An example below demonstrates plotting of probability using ellipses (90, 99, 99.9%) based on the reference stations. Positions of test stations within the ellipse bands will be used to indicate the degree of divergence along a gradient (Figure F2), where:

- Stations that fall within the 90% ellipse are classified as *similar to baseline*, because the tested community is measurably similar to 90% of reference-station communities in the dataset;
- Stations that fall outside the 90% ellipse are classified as *mildly divergent*, because the tested community is measurably different than 90% of communities in the reference-station dataset;
- Stations that fall outside the 99% ellipse are classified as *divergent*, because the tested community is measurably different than 99% of reference station communities in the dataset; and
- Stations that fall outside the 99.9% ellipse are classified as *highly divergent*, because there is judged to be only a 1-in-1,000 chance that the tested community is similar to reference-station communities.

**Figure F2. Example ordination plot, with probability ellipses around reference stations and positioned test stations.**




*RIVPACS*

The BEAST analysis also includes other methods to assess the environmental condition of benthic invertebrate communities, such as the River Invertebrate Prediction and Classification System (RIVPACS). RIVPACS is a biological-assessment method that uses the BEAST software to predict the probability of a taxon occurring at a test site by adding the weighted probabilities of each taxa belonging to a group (Environment Canada 2012c). Ratios of observed to expected taxa (O:E) are calculated and the site is assessed based on the premise that if the expected taxa are not present, the

community may be impacted (Environment Canada 2012c). RIVPACS calculations will be conducted using the lowest-level (genus/species) taxonomic data.

**Other Measures of Community Composition**

*Cluster Analysis*

Cluster analysis is a multivariate procedure for detecting natural groupings within data. Cluster analysis will be conducted on Bray-Curtis dissimilarity coefficients. Bray-Curtis dissimilarity coefficients are pairwise comparisons of abundance data at all replicates from all stations.

*Percent EPT*

The percent EPT in a sample indicates the total percentage of organisms belonging to the insect orders taxa Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). These taxa are generally considered to be sensitive to pollution, and their abundance can indicate environmental quality. For example, Appalachian stream communities exposed to coal-mine discharges with high dissolved ion concentrations exhibited greater declines and extirpation of EPT taxa than other taxa (Bernhardt and Palmer 2011).

*Functional Feeding Groups*

Aquatic biota pursue a wide variety of life-history and feeding strategies, which examined in aggregate may provide information about food availability and dynamics and trophic conditions in a waterbody (Barbour et al. 1999). The sum of feeding group memberships for taxa individuals represented in the benthic dataset will be added to analysis to help indicate the range and balance of feeding strategies for benthic invertebrates at each location. Data used to define functional feeding groups for all taxa is most comprehensively reported in Merritt et al. (2008).

*Hilsenhoff Biotic Index*

The Hilsenhoff Biotic Index (Hilsenhoff 1987) is a measure of the aggregate sensitivity of benthic invertebrates (arthropods, specifically) within a sample to organic pollution. It is an average of pollution-tolerance values for all arthropod taxa within a sample. Tolerance values for individual taxa range from 0 to 10, with 0 being most sensitive and 10 being most tolerant. The index is calculated as follows:

$$HBI = \sum_{i=1}^{s} \left[ y_i \times T_i \right]$$

where: HBI = Hilsenhoff's Biotic Index;

$y_i$ = the count of the $i^{th}$ taxon in the sample;

$T_i$ = the pollution-tolerance value for that taxon, from 0 to 10 (from Hilsenhoff 1987); and

S = number of individuals in the sample.

HBI scores can range from 0 to 10, with the following guidance from Hilsenhoff (1988) regarding classification of results:

| | | |
|---|---|---|
| 0.00 to 3.75 | Excellent | Organic pollution unlikely |
| 3.76 to 4.25 | Very Good | Possible slight organic pollution |
| 4.26 to 5.00 | Good | Some organic pollution probable |
| 5.01 to 5.75 | Fair | Fairly substantial pollution likely |
| 5.76 to 6.50 | Fairly poor | Substantial pollution likely |
| 6.51 to 7.25 | Poor | Very substantial pollution likely |
| 7.26 to 10.00 | Very poor | Severe organic pollution likely |

**Benthic Tissue Analysis**

Selenium concentrations found in benthic tissue will be compared against the BC interim guideline (4 µg/g dwt) (BC MOE 2014).

## SUPPORTING VARIABLES

In each CABIN reach, detailed habitat data will be collected, following CABIN protocols. These will include:

- A description of reach characteristics such as instream and overhead vegetative coverage, and classification of aquatic habitat types (i.e., riffle, run, pool) present in the reach;
- Characterization of stream substrate using a 100-pebble count, substrate embeddedness, and size of surrounding material;
- Measurement of stream channel characteristics such as channel width (bankfull and wetted), depth, velocity, and slope; and
- Various *in situ* water quality variables, including water temperature, current velocity, dissolved oxygen, pH, and conductivity.

In sampling areas where replicate CABIN samples will be taken within a reach, all field measurements (including water quality) will be collected at each replicate location except pebble count, which will be done through the overall reach.

# Appendix G

# Fish Monitoring Studies

# SENTINEL SPECIES STUDIES OVERVIEW

A sentinel fish species study will be conducted to help assess the effects of mine effluent on local fish populations. The sample design will follow EEM technical guidance (Environment Canada 2012a) methodology and include one fish species, slimy sculpin. Slimy sculpin were selected as a target sentinel fish species, given they are the only full-time resident fish in high enough numbers within Attichika Creek to be practical to use in a sentinel species study (Bustard 2017). Sampling is planned three times as part of the FAEMP; pre-construction (year -4) to provide baseline, and during effluent release in the Construction phase (year -1) and during the Operations phase (year +3). Sampling will occur in the fall to maximize likelihood of capture success and follow the expected annual effluent exposure in Attichika Creek, previous to effluent release (Year -4) and then again following effluent release in the Construction (Year -1) and Operations (Year +3) phases. Fish sampling will be conducted at the following locations:

- Reference area, which will be in upper Attichika Creek, upstream of the confluence of Kemess Creek (in a similar location to EEM-13);
- Near-field exposure area, which will be located on Attichika Creek downstream of the diffuser (downstream of ATT-DIS); and
- Far-field exposure area, which will be in lower Attichika Creek in an area below the confluence with Waste Rock Creek (in a similar location to EEM-18).

The control location in Attichika Creek, downstream of the confluence with Kemess Creek (EEM-17), will not be incorporated into the sentinel species program. The area between EEM-17 and the Kemess Creek confluence would have functioned as the second reference location for this survey, however this area is too small to support an adequate population size to provide a proper statistical comparison between locations. The initial survey (Year-4) will investigate natural difference between the upstream reference (EEM-13), the near-field location at ATT-IDZ (downstream of the IDZ), and the far-field location at EEM-18 to ensure comparability of sites and to highlight any natural variability between the populations at each location.

## FISH COLLECTION

Fish will be collected using a backpack electrofisher with voltage, frequency, and pulse width settings adapted to creek conductivity levels to maximize fish capture efficiency, while minimizing potential injury to non-target species. Stunned fish will be collected using dip nets and kept in aerated pails and coolers filled with ambient river water until dissected or released. Twenty adult males, twenty adult females, and twenty immature slimy sculpin will be targeted for collection from each sampling area, based guidance provided in Environment Canada (2012). The twenty immature individuals will be collected in addition to adult fish to assist in clarifying size-at-age and age-at-maturity end points. All captured fish, other than slimy sculpins, will be released following enumeration of juvenile and adult fish for each species captured. Fish collection data, fishing effort, and habitat characteristics in each area will be recorded on field data sheet for all fish collection activity and summarized in the FAEMP interpretive report.

## FISH DISSECTION

Fish dissections will be undertaken in the laboratory at Kemess mine to ensure that required numbers of mature male (20) and female (20) specimens of slimy sculpin were obtained from each sample area. If collection of 20 specimens of one sex was achieved, external determination of sex will be attempted to prevent sacrificing more fish than necessary, by applying pressure to the abdomen to force eggs or milt out of the fish. To maximize precision of fish measurements, field dissections will be conducted in a climate-controlled facility. This allowed processing of fish samples day or night regardless of weather conditions.

Prior to dissection, fish will be monitored closely in a shaded holding container containing at least 20 L of well oxygenated (maintained with electric aquarium bubblers) ambient river water. River water will be exchanged regularly to ensure temperature changes and pH shifts don't stress captured fish.

Sacrificed fish will be measured for total length (±1 mm), weighed (±0.01 g), and examined for external condition. External condition measurements will include information about abnormalities in eyes, skin, fins, gills, opercles, pseudobranchs, and thymus, which will be recorded on fish dissection sheets.

Dissection equipment will include scalpels, scissors, and forceps and will be cleaned frequently and thoroughly between different sampling areas. Aging structures from all dissected specimens will be collected and include otoliths and/or the left pectoral fin ray. To remove otoliths, slimy sculpins will be placed their dorsal side, gills will be removed using a knife or scalpel, and then the base of the cranium will be severed. The exposed otoliths can then be removed using forceps. Aging structures will be stored dry in coin envelopes, labeled with species, sample number, date captured, and other relevant information prior to being shipped off to the consultant laboratory for age determination.

Sex and maturity will be determined by visual examination during dissection, where gonad development in individuals of both sexes will be classified as immature, maturing, mature, spawning, or spent. Gonad weight (±0.002 g) will be recorded for all fish and fecundity measurements in maturing and mature female fish will be conducted, which will involve collecting three subsamples of 100 eggs per fish and weighing them (±0.002 g) to establish an average weight per egg. Livers will carefully be removed from the fish and weighed (± 0.002 g). Internal health inspections will be conducted on each specimen and include characterizing the condition of liver, kidney, spleen, hindgut, amount of fat, parasite presence, and gall bladder (i.e., fullness and colour).

Following dissection, ten of the fish of similar size (length and age) will be retained from each sampling location (30 fish total) for tissue analysis. Fish will be placed in labelled clean bags (whirl packs), frozen, and submitted as whole-body samples for metals tissue and percent moisture analysis. Metal concentration analysis will be conducted by an accredited laboratory (ALS Burnaby) and reported as mg/kg dry or wet weight.

# DATA ANALYSIS

## Biological Indices

A variety of indices are available for interpreting fish condition and health. These indices are derived by calculating the ratio of one variable to another, but generally have unusual and undesirable statistical properties and are not always recommended as a result. However, within this FAEMP sentinel species study, the following common indices are proposed for use (Environment Canada 2012a):

- Condition (K), which is defined by the relationship between body weight and body length, and essentially describes how "fat" fish are at each sampling area;
- The liver somatic index (LSI), which is an expression of liver weight as a proportion of body weight. The liver serves as a storehouse for glycogen, is sensitive to the rate of feeding over short periods of time, may provide an indication of nutritional status (Nielson and Johnson 1983), and detoxifies substances that enter the bloodstream; as such, exposure to toxic substances may increase liver size; and
- The gonadosomatic index (GSI), which is an expression of gonad weight as a percentage of body weight, indicating the state of gonad development.

K, LSI and GSI will be estimated using the following formulae:

- $K = (\text{total body weight} / (\text{fork length})^3) \times 100$;
- LSI = (liver weight/total body weight) x 100; and
- GSI = (gonad weight/total body weight) x 100.

Fecundity will also be calculated during the fish survey, representing the number of eggs produced per mature female. This value will be determined by using the weight of the entire egg skeins of individual females and weights of subsamples of known number of eggs (100 eggs each) to approximate the total number of eggs in an individual fish.

When comparing condition, relative liver weight (or LSI) and relative gonad weight (or GSI) amongst areas, percent differences of exposed fish values from reference fish values of ±10% for condition and ±25% for liver and gonad size will be used. These values represent degrees of difference between exposed and reference populations that may be considered caused by natural variability, rather than a potential effect of effluent (Environment Canada 2012a).

In addition to the above biological indices, age-at-maturity will also be calculated and compared for each location. Data will be sorted into histograms by age and the percentage of mature fish in each age category then calculated. Age ($\log_{10}$) versus the probit of the percent of adults (determined using values derived from a probit table value) will be plotted and the probit value of 5.0 (equivalent to 50% of data) will be calculated from a linear line of best fit to determine the age where 50% of fish reach maturity (Environment Canada 2012a).

### Analysis of Reproductive Variables

Analysis of reproductive variables (i.e., relative gonad size) will be limited to mature males and females with a GSI>1%. This approach, outlined in the Metal Mining EEM Technical Guidance Document (Environment Canada 2012a), will be used to ensure that results are representative of sexually mature fish with fully developed gonads.

### Fish Health Assessment

Fish health will also be assessed using a fish health assessment index, described by Goede (1993). An external and internal pathology examination will be conducted for each fish. The percentage of fish with one or more abnormalities will be calculated. Observations related to food availability and quality, such as percent mesenteric fat present or fatty livers will be excluded from the calculation.

### Statistical Analysis

Sentinel fish species data will be analyzed using Analysis of variance (ANOVA) and Tukey's multiple comparison procedure to compare fork length, total body and carcass weights, and ages between reference, near-field, and far-field areas. If data are not normally distributed, a non-parametric Kruskal-Wallis test will be used in place of the ANOVA, followed by a post hoc multiple comparisons test.

Analysis of covariance (ANCOVA) and Tukey's multiple comparison procedure will be used to compare relationships for the following whole-organism metrics between reference, near-field and far-field areas:

- Size-at-age — fork length, total weight, or carcass weight against age for mature males and females and immature fish;
- Condition — body weight against fork length for mature males and females and immature fish;
- Relative gonad size — gonad weight against total body weight, carcass weight, or gonad weight against length for mature males and females with a GSI > 1%;
- Relative fecundity and egg size — fecundity or egg weight against body weight, carcass weight, or length for mature females with a GSI > 1%; and
- Relative liver size — liver weight against body weight, carcass weight, or length for mature females and males and immature fish.

Total body weight, carcass weight, and length will be used separately as covariates to adjust for any differences related to size.

All variables will be $\log_{10}$-transformed prior to analysis. An assumption of the ANCOVA model is that the slopes of the regression lines are equal between areas. Therefore, differences in slopes will be tested prior to conducting the ANCOVA. Generally, ANCOVA are robust even when slopes are not equal, so slopes will be considered different when $p<0.01$ (Paine 1998).

Biological variables examined will be organized into broad subgroups, drawn from a theoretical effects-assessment framework presented by Gibbons and Munkintrick (1994). This framework focuses on types of effect that a stressor, such as water pollution, may have on fish populations, namely:

- **Survival** – Response to a stressor that caused direct or indirect mortality of exposed fish or reduced recruitment of new adult fish to the population would be manifested as an increase in mean age in exposed fish relative to reference fish;
- **Energy use or expenditure** – Response to a stressor that affected energy expenditure, either positively or negatively (e.g., through an increase or decrease in available food resources), would be manifested as differences in growth rate, gonadal weight, fecundity, or age-at-maturity between exposed and reference fish, with these variables increasing or decreasing with increases or decreases in energy expenditure of fish examined; and
- **Energy storage** – Response to a stressor that affected energy storage would be manifested as differences in condition (i.e., "fatness") and liver weight (i.e., glycogen storage) between exposed and reference fish, with these variables indicating more or less storage of energy by the fish.

**Table G1. Definition of fish variables to be used in the sentinel fish survey.**

| Type of Response | Variable | Dependent Variable (Y) | Covariate (X) | Statistical Procedure[1] |
|---|---|---|---|---|
| Survival | Age | Age | None | ANOVA |
| Energy Use | Size | Fork Length | None | ANOVA |
| | | Total Weight | None | ANOVA |
| | | Carcass Weight | None | ANOVA |
| | Size-at-age | Total Weight | Age | ANCOVA |
| | | Carcass Weight | Age | ANCOVA |
| | | Fork Length | Age | ANCOVA |
| | Relative Gonad Size | Gonad Weight | Total Weight | ANCOVA |
| | | Gonad Weight | Carcass Weight | ANCOVA |
| | | Gonad Weight | Fork Length | ANCOVA |
| | Fecundity | # Eggs/Female | Total Weight | ANCOVA |
| | | # Eggs/Female | Carcass Weight | ANCOVA |
| | | # Eggs/Female | Fork Length | ANCOVA |
| | | # Eggs/Female | Age | ANCOVA |
| | Egg Size | Egg Weight | Total Weight | ANCOVA |
| | | Egg Weight | Carcass Weight | ANCOVA |
| | | Egg Weight | Age | ANCOVA |
| Energy Storage | Condition | Body Weight | Fork Length | ANCOVA |
| | Relative Liver Size | Liver Weight | Total Weight | ANCOVA |
| | | Liver Weight | Carcass Weight | ANCOVA |
| | | Liver Weight | Fork Length | ANCOVA |

[1] *A Kruskal-Wallis non-parametric test will be used in place of ANOVA when data is not normally distributed.*

*Assessment of Statistical Significance*

As recommended by the Metal Mining EEM Technical Guidance Document (Environment Canada 2012a), statistical significance will be analyzed using $\alpha = \beta = 0.10$. This level of significance for both $\alpha$ and $\beta$ yields an equal probability of finding a false positive as a false negative (i.e., 1 in 10 chance in each case); this approach has been suggested to provide equal certainty and protection to both the metal mine (i.e., related to the likelihood of finding a false positive) and to the environment (i.e., related to the likelihood of finding a false negative). Statistical results will be assessed at a level of significance of $p \leq 0.10$.

*Power Analysis*

Power analysis was used to evaluate the possibility of false negative results (i.e., concluding that no difference in fish response exists when in fact it does). Peterman (1990) has argued that the consequences of false negative may be greater that the dangers of false positives (i.e., concluding a difference when none exist), and that environmental impact assessments should have adequate statistical power to detect meaningful differences. In other words, it is necessary to determine whether a comparison that did not show a statistical difference actually had sufficient power to detect a given difference, if one did exist.

Statistical power is a function of sample size, variability, and magnitude of difference (i.e., effect size) one wishes to detect. The effect size of ±25% will be used for relative gonad size, relative liver size, weight-at-age, and age, and ±10% effect size will be used for fish condition, as per the EEM Technical guidance document (Environment Canada 2012a). The mean squared error (MSE) term from the ANCOVA statistical model provided the estimate of between-area variance. Statistical comparisons between the three areas will be considered to have sufficient power ($P=1-\beta$, probability of detecting and effect size) when $P>0.90$ (Environment Canada 2010). Power analyses will not be conducted in cases where the ANCOVA is significant, given sufficient power existed to allow a statistically significant outcome. All analyses will be conducted using G*Power software (Faul and Erdfelder 1992), using methods described in Cohen (1988).

**Fish Tissue Concentration Comparisons with Available Guidelines and Literature**

Fish tissue samples will be analyzed for total metal concentrations and percent moisture (Table G2). Metal concentrations in slimy sculpin whole-body samples will be compared against applicable provincial and federal fish tissue guidelines found in Table G3.

**Table G2. Summary of analytical methods and detection limits for fish tissue chemistry variables.**

| Variable | Detection Limit (mg/kg, wet weight) | Method of Analysis |
|---|---|---|
| **Moisture** | | |
| % moisture in tissue | 0.5 | ASTM D2974-00 Method A |
| **Total Metals** | | |
| Aluminum (Al) | 0.4 | EPA 200.3/6020A |
| Antimony (Sb) | 0.002 | EPA 200.3/6020A |
| Arsenic (As) | 0.004 | EPA 200.3/6020A |
| Barium (Ba) | 0.01 | EPA 200.3/6020A |
| Beryllium (Be) | 0.002 | EPA 200.3/6020A |
| Bismuth (Bi) | 0.002 | EPA 200.3/6020A |
| Boron (B) | 0.2 | EPA 200.3/6020A |
| Cadmium (Cd) | 0.001 | EPA 200.3/6020A |
| Calcium (Ca) | 4 | EPA 200.3/6020A |
| Cesium (Cs) | 0.001 | EPA 200.3/6020A |
| Chromium (Cr) | 0.01 | EPA 200.3/6020A |
| Cobalt (Co) | 0.004 | EPA 200.3/6020A |
| Copper (Cu) | 0.02 | EPA 200.3/6020A |
| Iron (Fe) | 0.6 | EPA 200.3/6020A |
| Lead (Pb) | 0.004 | EPA 200.3/6020A |
| Lithium (Li) | 0.1 | EPA 200.3/6020A |
| Magnesium (Mg) | 0.4 | EPA 200.3/6020A |
| Manganese (Mn) | 0.01 | EPA 200.3/6020A |
| Mercury (Hg) | 0.001 | EPA 200.3, EPA 245.7 |
| Molybdenum (Mo) | 0.004 | EPA 200.3/6020A |
| Nickel (Ni) | 0.04 | EPA 200.3/6020A |
| Phosphorus (P) | 2 | EPA 200.3/6020A |
| Potassium (K) | 4 | EPA 200.3/6020A |
| Rubidium (Rb) | 0.01 | EPA 200.3/6020A |
| Selenium (Se) | 0.01 | EPA 200.3/6020A |
| Silver (Ag) special request | 0.001 | EPA 200.3/6020A |
| Sodium (Na) | 4 | EPA 200.3/6020A |
| Strontium (Sr) | 0.01 | EPA 200.3/6020A |
| Tellurium (Te) | 0.004 | EPA 200.3/6020A |
| Thallium (Tl) | 0.0004 | EPA 200.3/6020A |
| Tin (Sn) | 0.02 | EPA 200.3/6020A |
| Titanium (Ti) special request | 0.02 | EPA 200.3/6020A |
| Uranium (U) | 0.0004 | EPA 200.3/6020A |
| Vanadium (V) | 0.02 | EPA 200.3/6020A |
| Zinc (Zn) | 0.1 | EPA 200.3/6020A |
| Zirconium (Zr) | 0.04 | EPA 200.3/6020A |

**Table G3. Summary of guidelines and toxicity thresholds for slimy sculpin whole body sampling.**

| Metal | Guideline | Units | Type | Source | Tissue Screened |
|---|---|---|---|---|---|
| Mercury (Hg) | 0.033 | mg/kg wwt | Protection of Wildlife | BCMOE (2001b), CCME (2001b) | Liver, Muscle, and Whole Body |
| Selenium (Se) | 4.0 | mg/kg dwt | Protection of Aquatic Life | BCMOE (2014) | Muscle & Whole Body |
| Selenium (Se) | 11 | mg/kg dwt | Protection of Aquatic Life | BCMOE (2014) | Egg/ovary |

*Note: wwt= wet weight, dwt=dry weight*

### SUPPORTING ENVIRONMENTAL SAMPLES AND EFFLUENT TRACING

In each sampling area, water quality measurements will be collected as supporting environmental variables, with the same variables as outlined in (Appendix C). *In situ* field measurements of dissolved oxygen, temperature, conductivity, and pH will also be collected prior to fishing in each area, with conductivity measurements used to adjust electrofisher settings.

Water samples will also be collected for sulphate as potential chemical indicator of effluent presence and exposure level. Sulphate is present in high concentrations in effluent, relative to ambient receiving waters. This characteristic allows it to be used as an indicator to determine the approximate concentration of effluent in a river, provided knowledge exists regarding upstream sulphate concentrations and concentrations in effluent. Sulphate samples will be collected daily from the receiving environment and of mine effluent during the sentinel species surveys and analysis by an accredited laboratory. This will not be completed during the first survey given there is no effluent released during Year -4.

## ADULT FISH MONITORING SURVEYS

### REDD SURVEYS

The proposed adult fish monitoring study will be conducted using ground surveys, following similar methodology to the Kemess South surveys. Observations will be taken from stream banks and used to assess the number of spawning bull trout in the Project area. A field crew of two individuals wearing polarized glasses will conduct the redd surveys in the key bull trout spawning sections after spawning is completed (typically the second week of September). The current extent of the survey includes only the Kemess Watershed, sections of Tributary 4, and Attichika Creek. This FAEMP recommends expanding the survey area to mid- and upper- Attichika Creek sections to support the KUG project.

The procedures for redd surveys and the criteria for redd identification are outlined in greater detail in Bustard (1996) and Bustard and Associates and Hallam Knight Piesold (1995). Generally, a minimum size of 0.6 m x 1.0 m is needed for a site to be considered a bull trout redd. A discernible pit and suitable gravel deposit at the tail of the redd must be present. Smaller test digs are not

included and very large redds (greater than 1.0 x 3.0 m) may be counted as two redds depending upon pit and deposit configuration. GPS locations will be recorded for bull trout redds, allowing sites to be mapped using data derived from digital files (1:20,000 TRIM) and ArcInfo.

Detailed measurements of spawning habitat characteristics at redd sites will be made throughout the surveys. These measurements will include water depth and velocities at redd locations, bed material descriptors including D50, D90, and b-axis diameters of bed material in the redd sites, as well as distance to cover and potential groundwater influences. Information from these measurements will be used in determining suitability of spawning habitat.

## NON-LETHAL TISSUE SAMPLING OF THUTADE LAKE BULL TROUT

Non-lethal sampling of adfluvial bull trout was included in the FAEMP to satisfy EAC and CEAA conditions concerned with human consumption of bull trout from Thutade Lake. Adult bull trout from Thutade Lake migrate into Attichika Creek and temporarily reside in holding areas, prior to relocating to spawning sites in the mid- and upper reaches of the creek. Fish in these holding areas (three locations) will be targeted for collection by angling, similar to baseline studies presented in Hatfield and Bustard (2015).

Non-lethal tissue sampling will be conducted on adult bull trout using dermal punches following the methodology described in Baker et al. (2004). Their studies found that for mercury in fish tissue analyses, the dermal punch method did not reduce survival and provided a comparable accuracy to traditional methods requiring lethal sampling of fish. Prior to KUG baseline studies, discussion with Parks Canada staff (Gary Scrimgeour, pers. comm. July 2014) indicated that two dermal punches from bull trout exceeding 1.5 kg were effective to characterize metal concentrations in their studies in the Northwest Territories in 2013.

Captured fish will be anaesthetized using clove oil. Fork length, weight, and aging structures (fin rays) will then be collected from each captured fish. Muscle tissue plugs will be removed from fish using an Acuderm dermal biopsy punch (4 mm diameter). Two dermal punches will be taken from the upper dorsal area posterior to the connection of the dorsal fin to the back of the fish (15 mm down). The punch will be inserted into the fish to a depth of 7 mm and twisted to remove the tissue sample. The extracted tissue sample will be placed on a microscope slide and the skin will be removed from the sample using sterile scissors (Chemisol solution). The sample will then be placed in 2 mL plastic micro-vials, and immediately put on ice and later frozen. Following removal of the tissue samples, fish will be placed into a recovery water bath for observation and subsequently released. All samples will be sent to a qualified accredited laboratory (ALS laboratories Burnaby) for metals analyses.

The dermal punches taken from the dorsal position in the Thutade Lake bull trout are assumed to be representative of whole body muscle tissue. Studies conducted by Pearson (2000) evaluated mercury concentrations in biopsy (punch) samples (anterior, dorsal, and posterior) against mercury concentrations in whole filets of walleye and northern pike. Pearson (2000) concluded that mercury concentrations in biopsy samples and filets from the same fish were not significantly different. Pearson (2000) further concluded that dorsal muscle biopsies were slightly more accurate predictors of filet mercury concentrations than biopsies from the anterior or posterior areas of the filet.

### Comparison with Available Guidelines and Literature

Metal concentrations found in tissue plugs will be analyzed for the same parameters as whole-body sculpin samples (Table G2) and will be compared against applicable provincial and federal fish tissue guidelines (Table G4).

**Table G4. Summary of guidelines and toxicity thresholds used for fish egg and muscle and liver tissue chemistry.**

| Metal | Guideline | Units | Type | Source | Tissue Screened |
|---|---|---|---|---|---|
| Mercury (Hg) | 0.033 | mg/kg wwt | Protection of Wildlife | BCMOE (2001b), CCME (2001b) | Liver, Muscle, and Whole Body |
| Selenium (Se) | 4.0 | mg/kg dwt | Protection of Aquatic Life | BCMOE (2014) | Muscle |
| Selenium (Se) | 11 | mg/kg dwt | Protection of Aquatic Life | BCMOE (2014) | Egg/ovary |

*Note: wwt= wet weight, dwt=dry weight*

### Quality Assurance/Quality Control (QA/QC)

Special precautions will be exercised during fish tissue collection to prevent contamination of fish samples. When collecting dermal punches, care will be taken to remove skin from samples using sterile scissors (Chemisol solution). Direct contact between tissue and gloves will be avoided. All equipment will be cleaned, and gloves will be washed between tissue plug collection.

Tissue samples collected will be kept frozen and shipped to ALS laboratories (Burnaby, BC) as soon as possible to ensure sample integrity. A QA/QC duplicate sample should also be collected from one fish and submitted for analysis. This duplicate, along with ALS in-house laboratory QA/QC protocols, can be used to identify potential contamination and to determine the precision and accuracy of the QA/QC sample analyses.

## FRY AND JUVENILE FISH MONITORING STUDIES

The FAEMP includes sampling juvenile fish populations in Project area creeks, with the addition of Attichika Creek to the current Kemess South monitoring program. Creeks will be electrofished using a two-pass removal method with a backpack electrofisher. Sites are typically enclosed with stopnets and an upstream and downstream sweep constituted a single pass. If creeks are too large to allow the entire channel to be blocked, stopnets can be used to enclose margin sites or side channels. Electrofisher settings will be adjusted to ensure they were appropriate for the conductivity of the water and the size of the fish being targeted.

Fish captured will be sorted by species, measured to the nearest millimeter fork length and subsequently returned to the location of capture. Weights will be retained from nearly all fish sampled during the program and will be used to calculate biomass and condition for some locations.

## HABITAT SURVEY

To provide data consistency, habitat information for all juvenile index site sampling will be recorded on Stream Information Summary forms, similar to the format used since 1994 when fish studies were initiated on site. Characteristics recorded at each site will include bed material descriptors, slope, depth, wetted and channel width, and instream cover descriptions. Efforts will be made to sample the identical stream locations each year and the timing of sampling will be kept consistent to allow for monitoring comparisons.

## DATA ANALYSIS

Prior to fish population estimations, juvenile and adult fish data will be entered into Microsoft Excel spreadsheets and summary statistics (i.e., mean, standard deviation, t-test) for each sample site will be conducted using Excel data analyses tools.

Population estimates within sample sites will be derived mainly from two-pass removal estimates developed by Seber and LeCren (1967). Three-pass estimates will be derived when capture declines were poor after two passes using Schnute's (1983) removal approach to maximum likelihood population estimates. These methods will provide quantitative estimates of fish abundance and species separation that are designed for assessing background abundances and monitoring of future fish populations.

A linear mixed-effects model (Bolker 2007) will be used to determine changes in population estimates over time. Trend analyses of bull trout redd abundance will be conducted using the Mann-Kendall test (Hollander and Wolfe 1973) and Sen's slope estimate (Gilbert 1987) to evaluate temporal trends in bull trout redd counts in each system over time.