Interim Long-Term Aquatic Monitoring Program for United Keno Hill Mines

Report Prepared for:

Elsa Reclamation and Development Company Ltd.
Whitehorse, YT

Report Prepared by:

Minnow Environmental Inc.
2 Lamb Street
Georgetown, Ontario
L7G 3M9

June 2011

Interim Long-Term Aquatic Monitoring Program For United Keno Hill Mines

Report Prepared for:

Elsa Reclamation and Development Company Ltd.
Whitehorse, YT

Report Prepared by:

Minnow Environmental Inc.

Cynthia Russel, B.Sc.
Project Manager

Patti Orr, M.Sc.
Technical Reviewer

June 2011

EXECUTIVE SUMMARY

United Keno Hill Mines Limited and UKH Minerals Ltd. were the previous owners of the properties located on and around Galena Hill, Keno Hill and Sourdough Hill, collectively known as the Keno Hill Mining Property. Although the mine has not operated since 1989, abandoned adits (more than 44), buildings/structures, and waste dumps associated with the site represent sources of contaminants to the downstream watersheds. The most significant of these sources include the lime-treated discharge from the tailings pond system, Galkeno 900 Adit, Galkeno 300 Adit, Bellekeno 600 Adit, Silver King Adit and Valley Tailings. The influence from these sources is largely limited to the tributaries that drain the properties (Christal, Flat and Lightning creeks), although some influence on water and sediment quality can be measured further downstream in the South McQuesten River (Minnow 2008, 2009a).

In June 2005, Alexco Resources Corp. was selected as the preferred purchaser of the UKHM assets. As required in the purchase agreement, Alexco formed a subsidiary company – Elsa Reclamation and Development Company Ltd. (ERDC), to own and manage the site. Another requirement of the purchase agreement is for ERDC to prepare and implement, to the satisfaction of the Governments, a Reclamation Plan to address historical mining liabilities on the UHKM claims. Funding for the development and implementation of the Closure Plan is primarily from the Government of Canada (represented by Indian and Northern Affairs Canada (INAC) with some cost sharing by ERDC.

Under the purchase agreement, ERDC is allowed to resume production at a historic mine by declaring it as a Production Unit. The terrestrial liability associated with historical mine operations within the Production Unit remains with the Government of Canada, however, ERDC becomes responsible for water related liabilities in addition to any new terrestrial liabilities associated with the redevelopment of mine operations within the Production Unit. Alexco Resources operates the Bellekeno Mine and is responsible for the BK625 treatment facility and new terrestrial liabilities associated with Bellekeno operations.

One of the mandates of ERDC is to develop a Reclamation Plan for the “Existing State of the Mine” such that historical mining liabilities may be address and future environmental conditions anticipated. ERDC is currently in the process of developing this reclamation plan.

Related to this, the ERDC has requested that Minnow Environmental Inc. assist in identifying the requirements of a comprehensive, site-wide Long-Term Aquatic Monitoring Program (LTAMP). Such a program will need to support the environmental assessment, closure planning, and regulatory processes in the short-term and provide adequate information to

evaluate environmental conditions relative to closure initiatives and redevelopment/ operations in the long-term.

Current environmental monitoring requirements at the site are stipulated in two site Water Licences. However, the scope of the monitoring requirements under the licenses is generally inadequate to quantify historic UKHM related effects relative to background or over-time. Therefore, a more robust monitoring design is required that will allow for conditions downstream of UKHM to be quantifiably assessed. Through a more robust and rigorous program, the mine and its stakeholders will be able to confirm trends and determine when conditions have achieved set goals or acceptability criteria.

To date, monitoring data has been collected through a number of independent programs which have largely been guided by the requirements of the water license. As a result, there is paucity of continuous and/or consistent data available on which to develop a statistical and robust monitoring design. Therefore, this document represents an interim long-term aquatic monitoring program that will need to be revised and updated as additional information is collected and evaluated. It is expected that the program will become more streamlined over-time as uncertainties are addressed through the provision of additional data.

The objective of this project was to develop an interim LTAMP for the UKHM complex. Review of historical study information for the UKHM indicated that there are key information gaps that will need to be addressed in order to optimize the LTAMP design. The costs associated with additional data collection over the short-term (e.g., two to three years) are expected to be greatly offset by savings realized through the implementation of a streamlined, scientifically defensible monitoring program over the longer term (e.g., decades).

This document outlines the general framework for an Interim LTAMP at the UKHM and identifies data gaps that will need to be addressed before details the LTAMP can be finalized. The program will integrate biological and chemical information for a weight-of-evidence approach, including the following components:

- water chemistry,
- hydrology (i.e., flow),
- sediment chemistry and toxicity,
- benthic invertebrate community monitoring, and
- fish community assessment.

These monitoring components are typical of those incorporated into closed mine monitoring in the Yukon and across Canada.

The initial scope of the LTAMP should reflect the current magnitude and spatial extent of mine-related effects (Minnow 2008, 2009a). The frequency of monitoring must be sufficient to provide early warning of changes, particularly degradation, so that appropriate responses can be made (e.g., changes to monitoring, mitigation, or remediation). Similarly, reductions in the scope or frequency of monitoring should be considered in response to improving conditions.

Surface Water Quality and Flow

Based on a review of existing surface water monitoring stations and available water quality data, 19 water quality stations are recommended (KV-1, KV-2, KV-3, KV-4, KV-5, KV-6, KV-7, KV9A, KV-9, KV-37, KV-38, KV-41, KV-60, KV-61, KV-64, KV-65, KV-72, WILC and FIEC). These stations include near-field, far-field and reference areas and encompass the current spatial extent of historic UKHM influence on surface water quality. The interim LTAMP will include measurement of 30 substances and *in situ* variables which represent either substances which have been shown to be indicators of historic UKHM influence or substances for which there was insufficient information to fully evaluate their relevance for future monitoring (too few data or high method detection limits). Measurements will be made on total (not filtered) samples since water quality guidelines are based on total concentrations. In addition it is recommended that flow (discharge m^3/sec) be measured at Christal Creek (KV-7), Flat Creek (KV-9), Lightning Creek (KV-41) and in the South McQuesten River (KV-4).

Water samples should be collected once per month during the ice-free period, at least once during the ice-on period and, if possible, at the onset of at least one substantial run-off event (precipitation) per year (following a dry period).

Sediment Quality

It is recommended that sediment chemistry and toxicity be collected from Christal Creek (KV-6 and KV-7), Flat Creek (KV-9A and KV-9), the South McQuesten River (KV1, KV-4), Lightning Creek (KV-37 and KV-38), and from two reference stations (WILC and FIEC). This information can then be used to determine the relevance of elevated sediment concentrations to biota and the need for sediment monitoring within the LTAMP.

Chemical analyses of sediment should include percent moisture, particle size distribution (whole sediment), total organic carbon (TOC), TKN, and TP and metal content. In addition, to better understand the biological effects associated with the elevated sediment concentrations, sediment toxicity testing (for chronic effects) should be also conducted at the same stations selected for sediment chemistry monitoring using the amphipod *Hyallela azteca* over a 14-day exposure period.

Benthic Invertebrate Communities

Benthic invertebrate community monitoring will be an important component of the LTAMP. To determine the best long-term approach for benthic community monitoring, a comparative evaluation was conducted synoptic with Hess collections under the Water Licence in 2009. The study compares the effectiveness of two design options, RCA versus Control-Impact, as well as two sampling methods (kick and sweep versus Hess; Minnow 2011a). The LTAMP should be updated to incorporate the recommendations of this report.

Benthic macroinvertebrate surveys conducted as part of the LTAMP will be done in the mid to late summer; consistent with previous surveys and that these surveys will be repeated and reported at predetermined intervals.

Fish

Fish community composition and relative species abundances should be tracked at key near-field locations near the UKHM over time (Christal Creek, Flat Creek, and South McQuesten River) and compared to the communities at reference areas possessing similar habitat characteristics. The recommended methods for fish community characterization are similar to those used in previous surveys, including collection of fish by backpack electrofisher and minnow traps, although a standardized effort has been recommended for each area. Also, slimy sculpin populations should be assessed using indicators of population health such as mean length, mean weight, weight relative to length (condition), and length-frequency distributions (sample sizes permitting). Once the first survey is complete, the methodology and scope of the program should be reviewed to ensure the proposed approach is feasible in the long-term.

Sampling will be done in mid- to late summer, when stream and river flows are moderate to low, and less variable than during other seasons. Also this timing corresponds with collections of sediment and benthic invertebrate samples. Similar to sediment and benthic monitoring, fish surveys are to be repeated and reported at predetermined intervals.

Quality and Safety Management Plan

A number of formal procedures must be implemented to assure the quality and integrity of data produced by the monitoring programs at UKHM. This includes clearly defining and communicating responsibilities and reporting channels, as well as sample collection protocols. Standard operating procedures (SOPs) should be developed, implemented, and updated as appropriate for things such as sample collection methods, the cleaning of sampling equipment before and after use, calibration and maintenance of field instruments, proper sample labelling, laboratory sample submission procedures (including chains of custody), data handling, and data quality control. Quality control samples (e.g., blank samples, replicate samples, and matrix spike recoveries) need to be collected and evaluated relative to pre-defined data quality objectives and reported. Specific quality assurance-quality control (QA-QC) requirements have been outlined for each component of the LTAMP.

Schedule and Reporting

Monitoring of water quality at surface water stations will be on-going to provide regular assessment of conditions and adequate warning of any substantial changes. Such data will be formally reported in Annual Water Quality Reports. Annual Reports should present concentrations (and loadings where applicable) relative to previous years, and identify any issues encountered since the previous reporting period (e.g., missed samples, data quality problems, etc.). Data should be compared and assessed relative to Water Quality Goals and Objectives established for receiving environment stations (Minnow 2011b).

Biological data (e.g., sediment, benthic invertebrates and fish) will be assessed and reported at a lower frequency in Comprehensive Aquatic Ecosystem Study Reports. A three-year monitoring interval is recommended post-closure, consistent with the gradual change expected in water quality over time and an appropriate time interval over which measurable biological change may be detectable.

Triggers for Change

Future increases or decreases in the scope and/or frequency of aquatic ecosystem monitoring should be based on the findings of Annual Water Quality Monitoring Reports or Comprehensive Aquatic Ecosystem Study Reports. Formal acceptability criteria and mechanisms for change in scope and response to change (triggers) should be incorporated into the final LTAMP. These criteria and triggers should be developed by EDRC and INAC and UKHM stakeholders (i.e., YG and First Nations) such that all parties have agreed upon decision points and methods for modifying the program. Through the incorporation of triggers the monitoring program can be reduced over time as conditions improve or conversely a response can be implemented should unexpected (i.e. worse) conditions occur. This allows the program to be flexible and responsive to the study findings.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Background

United Keno Hill Mines Limited and UKH Minerals Ltd. were the previous owners of the properties located on and around Galena Hill, Keno Hill and Sourdough Hill, collectively known as the Keno Hill Mining Property. For the purposes of this report these mining areas are referred to as the United Keno Hill Mines (UKHM) complex. The UKHM complex is located in north-central Yukon Territory (Figure 1.1) and is comprised of approximately 827 mineral claims that cover an area of approximately 15,000 ha (about 29 km long and 8 km wide). Although the mine has not operated since 1989, abandoned adits (more than 44), buildings/structures, and waste dumps associated with the site represent sources of contaminants to the downstream watersheds. The most significant of these sources include the lime-treated discharge from the tailings pond system, Galkeno 900 Adit, Galkeno 300 Adit, Bellekeno 600 Adit, Silver King Adit and Valley Tailings (Figure 1.2; Burns 2008). The influence from these sources is largely limited to the tributaries that drain the properties (Christal, Flat and Lightning Creeks), although some influence on water and sediment quality can be measured further downstream in the South McQuesten River (Minnow 2008, 2009a). In addition to the historical mining activities, the area is currently host to a number of placer mining operations which cause extensive alteration of the watercourses and impacts to habitat and water quality downstream (Dan Cornett, Access Consulting pers. comm.; Pentz and Kostaschuk, 1999).

In June 2005, Alexco Resources Corp. was selected as the preferred purchaser of the UKHM assets. As required in the purchase agreement, Alexco formed a subsidiary company – Elsa Reclamation and Development Company Ltd. (ERDC), to own and manage the site. Another requirement of the purchase agreement is for ERDC to prepare and implement, to the satisfaction of the Governments, a Reclamation Plan to address historical mining liabilities on the UHKM claims. Funding for the development and implementation of the Closure Plan is primarily from the Government of Canada (represented by Indian and Northern Affairs Canada (INAC) with some cost sharing by ERDC.

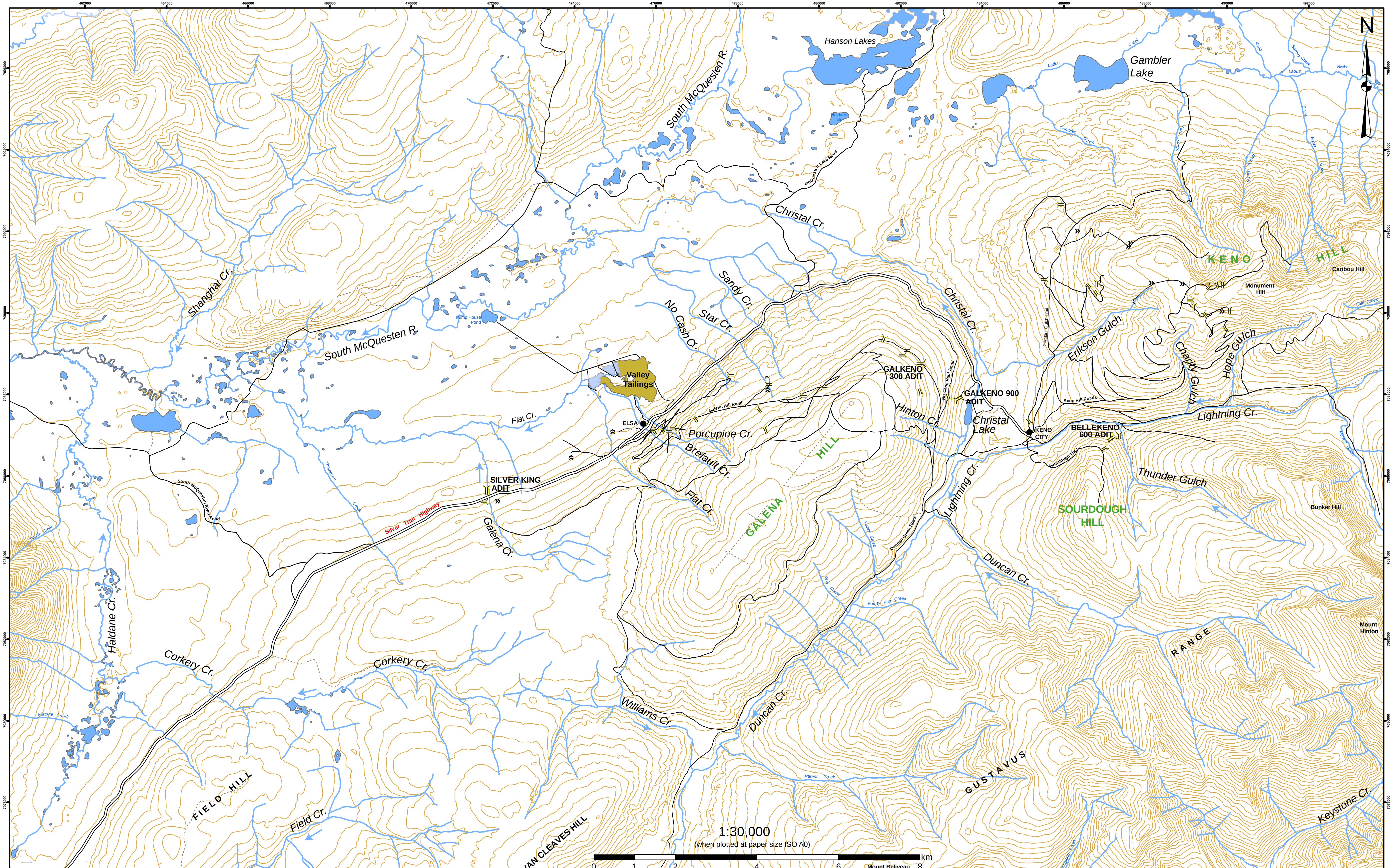
Under the purchase agreement, ERDC is allowed to resume production at a historic mine by declaring it as a Production Unit. The terrestrial liability associated with historical mine operations within the Production Unit remains with the Government of Canada, however, ERDC becomes responsible for water related liabilities in addition to any new terrestrial liabilities associated with the redevelopment of mine operations within the Production Unit.

Figure 1.1

Location of United Keno Hill Mines within the Yukon Territory.

Ref: 2274
Date: April 2011

Source: Access Consulting Group



Legend

Mine Working

- Adit
- Shaft (to surface - connection to underground not determined)
- Valley Tailings
- Pit

Topography

- Town
- Silver Trail
- Secondary and Limited-use roads
- Trail
- Watercourse
- Waterbody
- Flow Direction

ALEXCO ERDC

Figure 1.2

minnow environmental inc.

United Keno Hill Mines, Mine Workings and Surrounding Watercourses

Ref: 2274
Date: April 2011

Source: Access Consulting Group

Alexco Resources operates the Bellekeno Mine and is responsible for the BK625 treatment facility and new terrestrial liabilities associated with Bellekeno operations.

One of the mandates of ERDC is to develop a Reclamation Plan for the “Existing State of the Mine” such that historical mining liabilities may be address and future environmental conditions anticipated. ERDC is currently in the process of developing this reclamation plan.

Related to this, the ERDC has requested that Minnow Environmental Inc. assist in identifying the requirements of a comprehensive, site-wide long-term aquatic monitoring program (LTAMP). Such a program will need to support the environmental assessment, closure planning, and regulatory processes in the short-term and provide adequate information to evaluate environmental conditions relative to closure initiatives and redevelopment/ operations in the long-term.

Current environmental monitoring requirements at the site are stipulated in a site Water Licence in support of the closed mines (Appendix A). This Licence dictates the scope of monitoring (sample types, substances, sampling frequency and locations) as well as reporting requirements. The scope of the monitoring requirements under the licenses is generally inadequate to quantify mine related effects relative to background or over-time. Therefore, a more robust monitoring design is required that will allow for conditions downstream of UKHM to be quantifiably assessed. Through a more robust and rigorous program, the mine and its stakeholders will be able to confirm trends and determine when conditions have achieved set goals or acceptability criteria.

To date, monitoring data has been collected through a number of independent programs which have largely been guided by the requirements of the water license. As a result, there is paucity of continuous and/or consistent data available on which to develop a statistical and robust monitoring design. Therefore, this document represents an interim LTAMP that will need to be revised and updated as additional information is collected and evaluated. It is expected that the program will become more streamlined over-time as uncertainties are addressed through the provision of additional data.

1.2 Project Objectives, Scope and Approach

1.2.1 Project Objectives and Scope

The objective of this project was to develop an interim LTAMP for the UKHM complex. The goal of the LTAMP is to track conditions relative to the predicted closure conditions following mitigation and remediation measures and to be able to discern the additional influence of mine operations and discharges planned for the future. Thus, the program needs to incorporate areas of historical influence and areas of potential future effects. The design and scope of the program will need to be sufficiently robust to allow for these influences to be quantitatively defined.

Review of historical study information for the UKHM indicated that there are key information gaps that will need to be addressed in order to optimize the long-term monitoring program design. The costs associated with additional data collection over the short-term (e.g., two to three years) are expected to be greatly offset by savings realized through the implementation of a streamlined, scientifically defensible monitoring program over the longer term (e.g., decades). In recognition of limited data on which to base the design of a LTAMP, this interim program has been developed which will need to be updated when sufficient data has been collected to address uncertainties identified herein.

The most cost effective monitoring design for an LTAMP will identify the minimum sample types, sample locations, and sampling frequencies necessary to adequately evaluate chemical and biological conditions in surface water downstream of the historic UKHM complex and track changes in these over time. To identify the optimal design, sufficient data need to be available to show that collection of additional or different samples will not provide additional insight. Since the existing data are inadequate to answer key questions regarding current conditions, additional data will need to be collected and assessed (in the short-term) before the optimal long-term design can be finalized. Therefore, the scope of the Interim LTAMP is broader than would be expected for a LTAMP in order to address uncertainties which need to be resolved prior to finalizing the LTAMP.

In the future, ERDC the development of source and perimeter monitoring programs will complement the receiving environment components of the LTAMP and provide a more comprehensive site-wide monitoring network. However, the program described herein is focused solely on the aquatic receiving environment.

1.2.2 Approach

This document outlines the general framework for an Interim LTAMP at UKHM and identifies data gaps that will need to be addressed before details the LTAMP can be finalized. The program will integrate biological and chemical information for a weight-of-evidence approach, including the following components:

- water chemistry,
- hydrology (i.e., flow),

- sediment chemistry and toxicity,
- benthic invertebrate community monitoring, and
- fish community assessment.

These monitoring components are typical of those incorporated into closed mine monitoring in the Yukon and across Canada.

For the biological components, the proposed approach is similar to the EEM program that is applied to operating mines in Canada (Environment Canada 2002). While it is recognized that the UKHM is not subject to MMER or the ensuing EEM requirements, the use of a similar approach allows for national standards of scientific rigour to be incorporated in the LTAMP while allowing flexibility on the implementation and design aspects of the program. The general monitoring framework involving the components listed above is presented in subsequent sections of this report. However, before the details of the LTAMP can be fully developed, additional information on water and sediment quality and the benthic and fish communities is required to fill identified data gaps.

1.3 Report Organization

The approaches for monitoring of water and sediment quality are presented in Sections 2.0 and 3.0, respectively. Sections 4.0 and 5.0 outline the approaches for monitoring of benthic invertebrate and fish community health, respectively. The quality management plan and reporting requirements associated with the interim LTAMP are presented Sections 6.0 and 7.0, respectively. Section 8.0 provides a summary of the monitoring components outlined in previous sections, with a tentative implementation schedule. References cited throughout the report are listed in Section 9.0.

2.0 SURFACE WATER QUALITY MONITORING

2.1 Overview of Current Conditions

Historical mining activities at UKHM have affected the water quality in the headwater tributaries of the South McQuesten River and Duncan Creek (i.e., Christal Creek, Flat Creek and Lightning Creek), but have had a limited impact in the South McQuesten River (Minnow 2008). Cadmium and zinc were previously identified as contaminants of concern (COC) and a number of other substances could not be ruled out as possible COC's due to limitations associated with the data set (e.g. small sample sizes and/or poor method detection limits (MDLs); Minnow 2008).

2.2 Considerations for Future Monitoring

Water quality monitoring is central to an integrated, long-term environmental monitoring program for the UKHM complex since the ultimate fate of most mine-related contaminants will be discharge to downstream surface water bodies, either directly or via surface water runoff. Any future increases in metal loadings to surface waters will become apparent as increases in water concentrations prior to measurable impacts in biological communities. Therefore, the frequency of surface water monitoring should be greater than that of biological monitoring to serve as an early warning of changes that may affect biota.

A number of factors need to be considered and incorporated in the LTAMP study design:

1. Planned remediation measures and expected changes in source loading to the aquatic environment.

2. The scope of future mining in the UKHM area (e.g., placer mining, ERDC or other operators) and anticipated discharge/release locations.

3. Placer mining activities in the area and their potential confounding influence on downstream water quality. Placer operations tend to move along streams in response to yields. It will be important to ensure that there is flexibility within the LTAMP to move, add, or exclude stations in response to placer mine activities.

4. Adequate characterization of reference areas. To date, most surface water quality monitoring has been limited to two reference areas (KV-37 and KV-1). While KV-1 provides an adequate upstream reference area for the South McQuesten River, there are an insufficient number of reference areas that match the habitats found in the tributaries. Therefore, tributary reference areas in addition to KV-37 need to be

incorporated into the program to better define background conditions and provide a stronger basis for evaluation of conditions in mine-exposed areas.

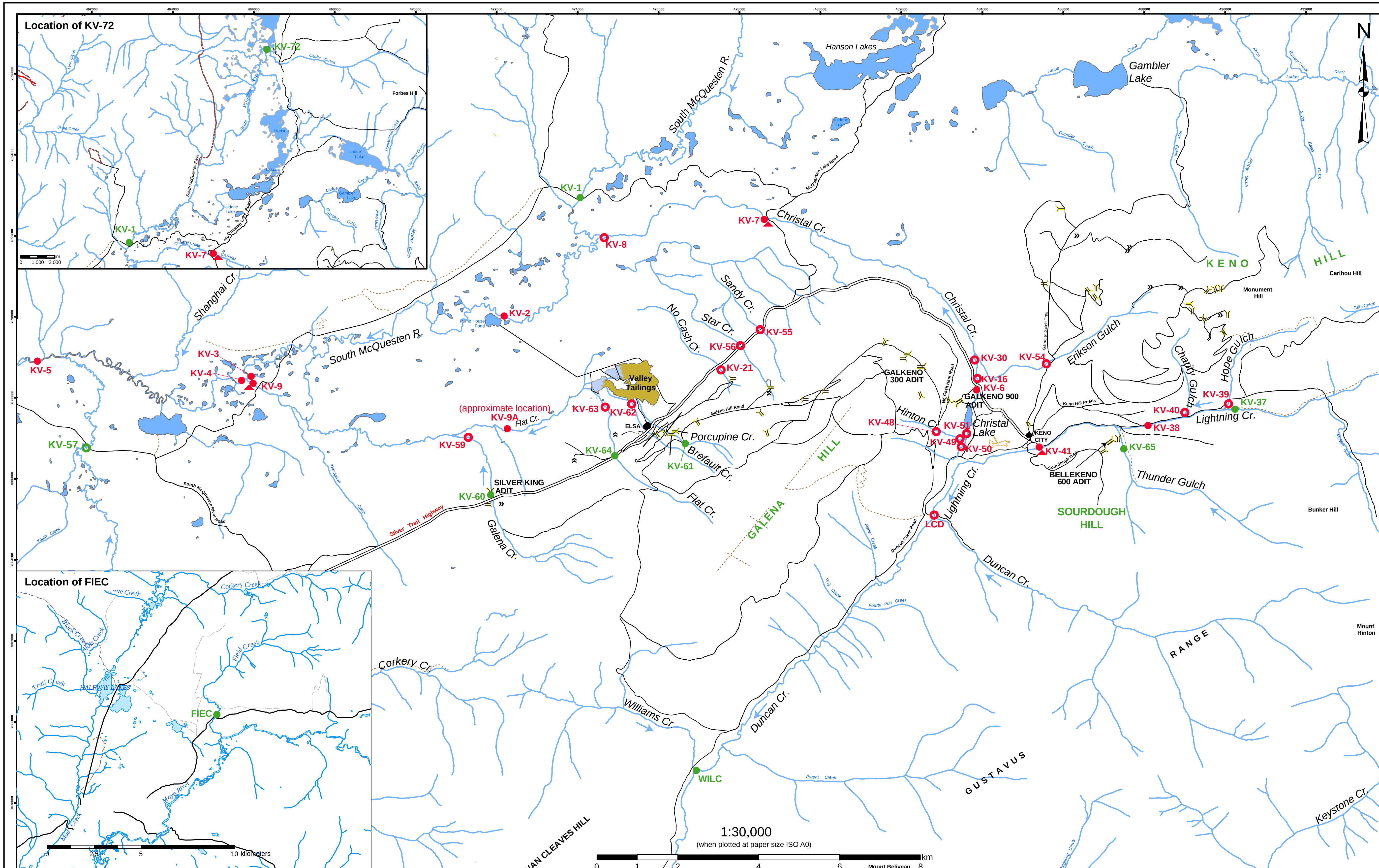
2.3 Proposed Monitoring Locations

In a regulatory framework, monitoring stations at an industrial site are often added over time in response to specific concerns, events (e.g., spills), or changing information needs. Therefore, it was appropriate to review all surface water stations that are currently required by the site's Water Licences (Appendix A), and those that are, or have been voluntarily monitored, to determine if each one is still relevant and should be included in the LTAMP. Each station was recommended for inclusion in the LTAMP if it:

- is located on a surface water body which does or could be expected to support fish;
- does not represent a source (e.g., seep) nor can it be considered a perimeter station (the point at which a contaminant enters the natural environment from the area of mine disturbance) since long-term monitoring programs for these types of stations should be developed separately;
- currently shows elevated concentrations of one or more mine-related substances or is a suitable reference station; and
- provides unique information relative to all other stations.

Stations were selected to capture the spatial extend of mine influence (headwater tributaries to downstream on the South McQuesten River) based on a previous review of water quality data (Minnow 2008). Where possible, stations with a historical record were included in the program to allow for temporal comparisons of water quality conditions within watersheds and sub-watersheds. A total of 19 stations, including nine reference stations (KV-1, KV-72[1], KV-37, KV-60, KV-61, KV-64, KV-65, WILC and FIEC), are recommended for inclusion in the LTAMP (Figure 2.1; Table 2.1). A number of the reference stations (KV-60, KV-61, KV-64, and KV-65) represent reference areas immediately upstream of mine sources and thus will be useful for assessing mine influence downstream. However, these station are situated on very small water courses (i.e., often near headwaters) and thus do not provide comparable habitat to downstream exposure stations and for this reason they will not be used for biological monitoring.

[1] KV-72 has been monitored by EDRC to provide a pristine reference area upstream of KV-1 which is influenced by an unknown source. However, KV-1 is the best reference area for the South McQuesten River downstream of UKHM as it represents the upstream condition prior to UKHM sources. KV-72 is not like the other exposure habitats which are small tributaries and so is likely not suitable as a reference for the other mine exposed stations. Once tributary reference stations are established, KV-72 could be removed from the program.



Legend

- Proposed reference water quality monitoring stations
- Proposed mine-exposed water quality monitoring stations
- Proposed mine-exposed flow monitoring stations
- Reference water quality monitoring stations excluded from LTAMP
- Mine-exposed water quality monitoring stations excluded from LTAMP

KV-15 not shown on map (excluded from LTAMP)

Mine Working: Adit; Shaft (to surface - connection to underground not determined); Valley Tailings; Pit

Topography: Town; Silver Trail; Secondary and Limited-use roads; Trail; Watercourse; Waterbody; Flow Direction

ALEXCO ERDC

Figure 2.1

minnow

Water Quality Monitoring Stations at United Keno Hill Mines

Ref: 2274
Date: April 2011
Source: Access Consulting Group

Table 2.1: Water quality stations monitored under the Water Licences and proposed for inclusion in the LTAMP.

Station ID	Station Description	Reference/ Exposed	Water Licences[a]	Include/ Exclude	Rational for Inclusion or Exclusion
KV-1	South McQuesten River upstream of Christal Creek	Exposed	✓	Include	Historical reference station recently determined to be impacted by an unknown upstream source. Include to characterize water quality on the South McQuesten River upstream of UKHM.
KV-2	South McQuesten River at Pumphouse downstream of Christal Creek	Exposed	✓	Include	Characterizes water quality in the South McQuesten River downstream of Christal Creek and upstream of Flat Creek.
KV-3	South McQuesten River upstream of Flat Creek	Exposed	✓	Include	Characterizes water quality in the South McQuesten River immediately upstream of Flat Creek and captures possible subsurface contributions between KV-2 and KV-3.
KV-4	South McQuesten River downstream of Flat Creek	Exposed	✓	Include	Characterizes water quality in the South McQuesten River immediately downstream of Flat Creek.
KV-5	South McQuesten River 9 km downstream of Flat Creek	Exposed	✓	Include	Delineates possible spatial extent of mine influence on water quality in the South McQuesten River.
KV-6	Christal Creek at Keno Highway	Exposed	✓	Include	Characterizes water quality on Christal Creek in a reach where concentrations of substances in water and sediment have been elevated in past surveys.
KV-7	Christal Creek at Hanson Road	Exposed	✓	Include	Characterizes water quality on Christal Creek downstream of all tributaries discharging into Christal Creek.
KV-8	Christal Creek at mouth	Exposed	✓	Exclude	Does not provide unique water quality information relative to KV-7.
KV-9A	Flat Creek between Valley Tailings and station KV-9 (exact location to be determined)	Exposed		Include	Characterizes water quality in Flat Creek closer to the source (Valley Tailings) than KV-9.
KV-9	Flat Creek upstream of South McQuesten River	Exposed	✓	Include	Past water quality monitoring report elevated concentrations of substances in sediment and water and it captures all source loading to Flat Creek.
KV-15	South McQuesten River at bridge below Haggart Creek	Exposed	✓	Exclude	Past water quality monitoring report concentrations typically near or at background levels indicating that this sation is outside of UKHM influence. No unique information relative to KV-5.
KV-16	Christal Creek 600 m downstream of Silver Trail Highway	Exposed	✓	Exclude	Located in close proximity to KV-6 and therefore does not provide unique water quality information.
KV-21	No Cash Creek at Keno Highway	Exposed	✓	Exclude	No Cash Creek is a minor tributary, does not discharge to any other watercourse and is not fish bearing. Any subsurface influence from this creek to the South McQuesten River is captured at KV-3.
KV-30	Christal Creek 825m downstream of Silver Trail Highway	Exposed	✓	Exclude	Located in close proximity to KV-6 and therefore does not provide unique water quality information.
KV-37	Lightning Creek upstream of Hope Gulch	Reference	✓	Include	Located upstream of mine influence on Lightning Creek and would therefore serve as a reference station
KV-38	Lightning Creek upstream of Thunder Gulch	Exposed	✓	Include	Characterizes water quality in Lightning Creek upstream of Bellekeno Mine discharge into Thunder Gulch.
KV-39	Hope Gulch upstream of Lightning Creek	Exposed	✓	Exclude	Hope Gulch is a minor tributary to the Duncan Creek watershed and any mine inputs are captured downstream at KV-38.
KV-40	Charity Gulch upstream of Lightning Creek	Exposed	✓	Exclude	Charity Gulch is a minor tributary to the Duncan Creek watershed and any mine inputs are captured downstream at KV-38.
KV-41	Lightning Creek upstream of bridge at Keno City	Exposed	✓	Include	Located within an area influenced by placer mining. Data collected from this station could be used to separate UKHM from placer mining influence on water quality.
LCD	Lightning Creek near confluence with Duncan Creek	Exposed	✓	Exclude	Provides no new information on mine influence relative to KV-41.
KV-48	Hinton Creek upstream of Calumet Drive	Exposed	✓	Exclude	Hinton Creek is a minor tributary of the South McQuesten River watershed.
KV-49	Hinton Creek upstream of Christal Creek	Exposed	✓	Exclude	Hinton Creek is a minor tributary of the South McQuesten River watershed.
KV-50	Christal Creek upstream of Hinton Creek	Exposed	✓	Exclude	This reach of Christal Creek is upstream of KV-6 and thus mine influence wil be captured at KV-6.
KV-51	Christal Creek downstream of Hinton Creek	Exposed	✓	Exclude	This reach of Christal Creek is upstream of KV-6 and thus mine influence wil be captured at KV-6.
KV-54	Erickson Gulch at Road to Lucky Queen	Exposed	✓	Exclude	Erickson Gulch is a minor tributary of the Christal Creek watershed and contributions from this area are captured at KV-7.
KV-55	Sandy Creek at Silver Trail Highway	Exposed	✓	Exclude	Sandy Creek is a minor tributary and does not discharge to any other watercourse (i.e., not fish bearing). Any influence from this creek (subsurface) to the South MCQuesten River will be captured at KV-3.
KV-56	Star Creek at Silver Trail Highway	Exposed	✓	Exclude	Star Creek is a minor tributary and does not discharge to any other watercourse (i.e., not fish bearing). Any influence from this creek (subsurface) to the South MCQuesten River will be captured at KV-3.
KV-57	Haldane Creek at South McQuesten Road	Reference	✓	Exclude	Habitat at this station does not adequately match habitat at exposure stations.
KV-59	Galena Creek upstream of Flat Creek	Exposed	✓	Exclude	Galena Creek is a minor tributary of the South McQuesten River watershed and its contribution is captured at KV-9.

[a] station included in one or both Water Licences

[b] Metal Mining Effluent Regulations

[c] These reference stations represent water quality upstream of mine sources but are generally located in headwater where habitat conditions are not comparable to near-field exposure conditions. Therefore, these stations will not be used as reference areas for biological monitoring.

[d] Once tributary reference areas are established, KV-72 could be removed from the program

Table 2.1: Water quality stations monitored under the Water Licences and proposed for inclusion in the LTAMP.

Station ID	Station Description	Reference/ Exposed	Water Licences[a]	Include/ Exclude	Rational for Inclusion or Exclusion
KV-60	Galena Creek upstream of Silver King adit	Reference	✓	Include	This station is upstream of Silver King adit and thus serves as an upstream reference area.
KV-61[c]	Porcupine Gulch at Calumet Road Crossing	Reference	✓	Include	This station is upstream of mine workings on Porcupine Creek and thus serves as an upstream reference area
KV-62	Brefault Creek upstream of Porcupine Diversion	Exposed	✓	Exclude	Brefalt Creek is a minor tributary of the South McQuesten River watershed and any influence for this creek will be captured at KV-9A.
KV-63	Flat Creek upstream of Porcupine Diversion	Exposed	✓	Exclude	This reach of Flat Creek is upstream of the Valley tailings but downstream of mine workings on Galena Hill. Any mine influence will be captured at KV-9A
KV-64[c]	Flat Creek at Silver Trail Highway	Reference	✓	Include	This reach of Flat Creek is upstream of mine influence on Flat Creek and therefore serves as a reference area.
KV-65[c]	Thunder Gulch upstream of Bellekeno	Reference	✓	Include	This station is upstream of Bellekeno influence and thus serves as an upstream reference area.
KV-72[d]	South McQuesten River upstream of Cache Creek	Reference	✓	Include	Located upstream of mine influence on the South McQuesten River and would therefore serve as a pristine reference area.
KV-76	Thunder Gulch downstream of Bellekeno 625 Adit	Exposed	✓	Exclude	Mine influence from Thunder Gulch will be captured downstream at station LCTG.
KV-77[c]	Thunder Gulch upstream of Bellekeno East	Reference	✓	Exclude	Water quality upstream of Bellekeno is captured by KV-65, thus this station is redundant.
WILC	Williams Creek downstream of Duncan Creek Road	Reference		Include	Williams Creek is outside of mine infuence and habitat at this station is an adequate match to habitat at exposure stations.
FIEC	Field Creek upstream of Duncan Creek Road	Reference		Include	Field Creek is outside of mine infuence and habitat at this station is an adequate match to habitat at exposure stations.

[a] station included in one or both Water Licences

[b] Metal Mining Effluent Regulations

[c] These reference stations represent water quality upstream of mine sources but are generally located in headwater where habitat conditions are not comparable to near-field exposure conditions. Therefore, these stations will not be used as reference areas for biological monitoring.

[d] once more suitable tributary reference areas are established, KV-72 should be excluded from the program.

For the most part, fewer exposure stations than are currently required by the licences are needed to characterize the influence of historical properties and future discharges due to redundancies in locations relative to mine sources. For example, KV-7 captures all mine sources to Christal Creek and there are no additional mine sources or sources of dilution further downstream at KV-8, thus KV-8 does not provide new/unique information and has not been recommended for inclusion in the LTAMP. While numerous stations were eliminated to remove redundancies, some stations were added to better delineate future influences or track near field recovery. For example, KV-9 situated immediately upstream of the mouth of Flat Creek, has been the only station monitored on Flat Creek. However, this station is located almost 10 km downstream of the Valley Tailings area (primary mine source). Therefore an additional station (KV-9A) is recommended on Flat Creek upstream of Galena Creek to better document near field conditions associated with the Valley Tailings.

The selected stations provide for the assessment of both near- and far-field water quality influences associated with the UKHM complex. It will be important for ERDC, INAC and regulatory reviewers of water quality data within Lightning Creek (KV-37, KV-38, and KV-41) to consider the influence of placer mining within this system relative to water quality concentrations and trends. Currently, the creek is being actively mined by a placer mining operation. These operations, which are highly disruptive to in-stream habitat and water quality (Pentz and Kostaschuk, 1999), are moved along the stream over time in response to yields, so they may encroach on UKHM LTAMP stations. This movement of placer mining activities may make it impossible to isolate historic UKHM influence on the water quality of Lightning Creek. Thus, stations designed to assess the influence of sources upstream of Bellekeno may need to be moved or may no longer be feasible should the placer mining activities encroach on this area.

As noted above, additional reference stations have been recommended to better characterize the natural range of background conditions relative to water quality guidelines particularly in support of biological monitoring[2]. The care and maintenance Water Licence (QZ06-074) includes two reference locations within the main surface waters in the vicinity of UKHM:

- KV-37 upstream of mine influence on Lightning Creek and
- KV-1 –upstream of UKHM on the South McQuesten River.

[2] While several reference locations are monitored upstream of mine influence on the tributaries (KV-60, KV-61, KV-64, KV-65, and KV-77) these station are located near the headwaters of the stream and do not provide comparable habitat to support biological monitoring.

Station KV-1 is being affected by an unknown source that enters the river upstream at Cache Creek and while it is an appropriate reference station for the South McQuesten River downstream of UKHM, it is not suitable as a reference station for the mine influenced areas within the tributaries where KV-1 does not represent the upstream condition. For these reasons KV-1 should be maintained as a reference area but only for the stations/areas located on the South McQuesten River downstream of UKHM. The mine has initiated sampling (starting in 2007) at a location further upstream of KV-1 on the South McQuesten River (KV-72) and this station represents pristine water quality on the South McQuesten River. However, KV-72 is not suitable as a reference area for the mine exposed tributary stations as it does not represent comparable habitat conditions and should be removed from the program once adequate tributary reference stations are established.

During the 2009 biological monitoring program, additional reference areas were sampled as part of a benthic invertebrate community assessment (Section 4.0). This assessment included the evaluation of twelve reference locations, ten of which were new. Five of these locations are readily road accessible and therefore represent possible reference locations for long-term water quality monitoring. Review of the water quality data for these stations indicates that most substances are generally below water quality guidelines with the exception of arsenic, iron and sulphate at selected stations (Table 2.2). Periodic elevations of iron and sulphate are consistent with previously reported reference concentrations for the area (Minnow 2008); however elevated arsenic concentrations found in Corkery, Mud and Haldane Creeks, are higher than previously reported reference concentrations. Thus, Williams Creek and Field Creek likely represent the best options as reference areas for future water quality monitoring. Also, field observations of substrate characteristics, creek size and water velocity suggest that these creeks provide comparable habitat to many tributary exposure locations.

2.4 Chemical and Physical Endpoints

Water quality substances selected for inclusion in the LTAMP were based on an extensive review of historical water quality conducted by Minnow (2008). Generally, substances were included if they had been shown to be indicators of historic mine influence (i.e., “mine indicators”) or if there was insufficient information to assess these substances (too few data or high method detection limits).

Cadmium, zinc and sulphate should be measured in all water samples because evaluation of previous water quality data showed these substances were clearly elevated above background concentrations in mine-exposure areas and were often at concentrations well

Table 2.2: Water quality results for reference areas accessible by road, United Keno Hill Mine, August 2009.

Variables	Units	MDL[n]	Guideline	Williams Creek (WILC)	Field Creek (FIEC)	Corkery Creek (CORC)	Mud Creek (MUDC)	Haldane Creek (KV-57)
Non-metals and nutrients								
Cyanide (WAD)	mg/L	0.0005	0.005[a,b]	< 0.0005	0.0005	< 0.0005	< 0.0005	< 0.0005
Hardness (as CaCO3)	mg/L	0.5	-	0.206	0.146	0.24	0.168	0.215
Nitrate (as N)	mg/L	0.02	13[a]	< 0.02	0.03	< 0.02	< 0.02	< 0.02
Nitrite (as N)	mg/L	0.005	0.06[a]	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Nitrate plus Nitrite (as N)	mg/L	0.02	-	< 0.02	0.03	< 0.02	< 0.02	< 0.02
Total Kjeldahl Nitrogen	mg/L	0.02	-	0.19	0.15	0.23	0.18	0.19
Phosphorus	mg/L	0.002	0.03[j,k]	0.005	0.008	0.007	0.006	0.009
Sulphate	mg/L	0.5, 5	50[c]	37	14	77	21	51
Total Suspended Solids	mg/L	1	6.6[a,d]	2	2	2	1	1
Dissolved Organic Carbon	mg/L	0.5	-	8.6	10.4	9.2	6.6	7.6
Total metals								
Aluminum	mg/L	0.0002	0.1[a,e]	0.0138	0.0329	0.0166	0.0074	0.0081
Arsenic	mg/L	0.00002	0.005[a]	0.00318	0.00157	0.0115	0.0074	0.0373
Cadmium	mg/L	0.000005	0.000033[a,f]	0.000009	0.000012	0.000006	0.000005	0.000012
Chromium	mg/L	0.0001	0.001[a,g]	< 0.0001	0.0001	< 0.0001	< 0.0001	< 0.0001
Copper	mg/L	0.00005	0.002[a,f]	0.00092	0.00114	0.00085	0.00034	0.00078
Iron	mg/L	0.001	0.3[a]	0.127	0.311	0.238	0.295	0.331
Lead	mg/L	0.000005	0.002[a,f]	0.00006	0.000162	0.00016	0.000039	0.000078
Magnesium	mg/L	0.05	-	14.2	11.4	16.9	11.2	16.9
Manganese	mg/L	0.00005	1.3[c,f]	0.0109	0.0595	0.0267	0.0524	0.0456
Mercury	mg/L	0.00001	0.000026[a,i]	< 0.00001	< 0.00001	< 0.00001	0.00001	< 0.00001
Nickel	mg/L	0.00002	0.065[a,f]	0.00078	0.00128	0.00124	0.00071	0.00083
Selenium	mg/L	0.00004	0.001[a]	0.00007	0.00017	0.00013	0.00017	0.00025
Silver	mg/L	0.000005	0.0001[a]	< 0.000005	< 0.000005	< 0.000005	< 0.000005	< 0.000005
Uranium	mg/L	0.000002	0.005[j,k]	0.00245	0.00151	0.00294	0.000814	0.00111
Zinc	mg/L	0.0001	0.03[a]	0.0007	0.0011	0.0005	0.0005	0.0008
In-Situ Measures								
Temperature	°C	-	-	6.43	6.20	12.35	9.58	12.6
Dissolved Oxygen	mg/L	-	6.5 - 9.5[a,l,m]	13.51	13.18	10.48	11.41	9.7
Dissolved Oxygen	%	-	54 - 63[j,l,m]	110	106.4	98	100.3	91.3
Conductivity	uS/cm	-	-	229	163	326	201	298
pH	pH units	-	6.5 - 9.0[a]	7.36	7.65	8.16	8.10	7.9

[shaded] value exceeds applicable guideline

[a] Canadian Water Quality Guidelines (CCME 1999)
[b] based on free cyanide
[c] British Columbia Water Quality Guidelines (BCMOE 2006)
[d] no more than 5,000 ug/L above background; mean of background (Williams, Field, Corkery, Mud and Haldane Creeks) TSS values was used in calculating guideline shown.
[e] 0.005 mg/L at pH<6.5; 0.1 mg/L at pH ≥ 6.5
[f] hardness dependent; hardness of 100 mg/L representing the lower range of hardness values in the near-field receiving environment
[g] hexavalent form
[i] inorganic mercury
[j] Ontario Water Quality Objectives (OMOE 1994)
[k] interim objective or guideline
[l] for cold water streams
[m] upper end of range is applicable for protecting early life-stages
[n] MDL - Method Detection Limit

above water quality guidelines (Minnow 2008). Other substances were identified as possible mine indicators but data limitations (e.g., insufficient data, poor MDLs) prevented definitive conclusions (i.e., aluminum, arsenic cyanide, chromium, copper, iron, lead, manganese, mercury, nitrite, phosphorus, selenium, silver and uranium) and these substances should continue to be monitored as part of the LTAMP[3]. In addition, nickel was found to be slightly elevated in sediment samples collected in the South McQuesten River and thus should be monitored and evaluated in water samples for the time being. Possible nutrient inputs from historical UKHM sources have not been considered in the past, therefore phosphorus, nitrate, nitrite and total Kjeldahl nitrogen (TKN) are recommended for inclusion in the interim program to determine if they should be included in the final LTAMP. Finally, several laboratory measures are included which will aid in the interpretation of the water quality data (hardness, dissolved organic carbon (DOC), total suspended solids (TSS)).

Changes to laboratory analyses for phosphorus and cyanide are also recommended. It is strongly suspected that previous phosphorus data reflect anomalies associated with the analytical method employed (e.g., potential interference with another element in ICP scans; Minnow 2008). In the future, the laboratory responsible for water quality analyses should be instructed to use a more reliable method for analysis of total phosphorus, the standard colorimetric method (e.g., procedure 4500 PBE, APHA 1998) with a low detection limit (<0.01 mg/L), and a reasonable number of samples should be split and sent to a second laboratory for confirmation of total phosphorus concentrations. Previous monitoring of cyanide has been based on total concentrations; however, the Canadian Water Quality Guideline (CWQG) is based on free cyanide (most toxic form). While it is difficult to measure free cyanide in water samples, it is possible to measure weak acid dissociable (WAD) cyanide which includes free cyanide as well as the cyanide associated with metals such as copper, cadmium, nickel, zinc and silver. If WAD cyanide concentrations are below the CWQG then free cyanide will be as well. Therefore, to obtain the most ecological relevant measure, WAD cyanide should be analyzed in place of total cyanide. Should concentrations of WAD cyanide be above the CWQG, then the need for alternative analytical methods should be evaluated.

In total, 24 metal and non-metal substances are recommended for laboratory analyses for the LTAMP (Table 2.3).

Once sufficient data have been collected (e.g., after 2 years), the list of water quality variables should be reassessed to determine which substances are definitively elevated in

[3] Once sufficient data has been collected (2 years), the substances listed in Table 2.3 should be re-evaluated to determine if they are mine indicators and then the list of COCs and substances for monitoring may be finalized.

Table 2.3: Water quality variables recommended for the LTAMP. Variables also monitored under the Water Licences indicated by "X".

Variables	Unit	Guideline	Target MDL[o]	Water Licences[p]	Sampling Freqency
Laboratory measures					Monthly during the ice-free period and once during the ice-on period. If possible, one additional sample per year should be collected after a run-off event (e.g., storm)[q]
Non-Metals and Nutrients					
Cyanide (free)	mg/L	0.005[a,b]	< 0.0025		
Hardness	mg/L	n/a	n/a	X	
Sulphate	mg/L	50[c]	< 25		
Total Suspended Solids	mg/L	6.6[a,d]	< 3.35	X	
Nitrate (as N)	mg/L	1.3[a]	< 6.5		
Nitrite (as N)	mg/L	0.06[a]	< 0.03		
Total Kjeldahl Nitrogen	mg/L	n/a	n/a		
Dissolved Organic Carbon	mg/L	n/a	n/a		
Phosphorus	mg/L	0.03[j,k]	< 0.015		
Total Metals					
Aluminum	mg/L	0.1[a,e]	< 0.05	X	
Arsenic	mg/L	0.005[a]	< 0.0025	X	
Cadmium[n]	mg/L	0.000033[a,f]	< 0.000025	X	
Chromium	mg/L	0.001[a,g]	< 0.0005	X	
Copper	mg/L	0.002[a,f]	< 0.0015	X	
Iron	mg/L	0.3[a]	< 0.15	X	
Lead	mg/L	0.002[a,f]	< 0.002	X	
Magnesium	mg/L	-	< 41	X	
Manganese	mg/L	1.3[c,f]	< 6.5	X	
Mercury	mg/L	0.000026[a,i]	< 0.000013		
Nickel	mg/L	0.065[a,f]	< 0.055	X	
Selenium	mg/L	0.001[a]	< 0.0005	X	
Silver	mg/L	0.0001[a]	< 0.00005	X	
Uranium	mg/L	0.005[j,k]	< 0.0025	X	
Zinc[n]	mg/L	0.03[a]	< 0.015	X	
Field Measures					
Temperature	˚C	n/a	n/a	X	
Dissolved Oxygen	mg/L	6.5 - 9.5[a,l,m]	3.3		
Dissolved Oxygen	%	n/a	n/a		
Conductivity	uS/cm	n/a	n/a	X	
pH	pH units	6.5 - 9.0[a]	3.3		
Flow	m/s	n/a	n/a	X	

n/a - not available

[a] Canadian Water Quality Guidelines (CCME 1999)

[b] based on free cyanide

[c] British Columbia Water Quality Guidelines (BCMOE 2006)

[d] no more than 5,000 ug/L above background; mean of background TSS values was used in calculating guideline shown.

[e] 5 ug/L at pH<6.5 or 100 ug/L at pH≥ 6.5; since pH measured at water quality stations in the vicinity of UKHM is typically ≥ 6.5, 100 ug/L was chosen as guideline.

[f] hardness dependent; hardness of 100 mg/L representing the lower range of hardness values in the near-field receiving environment. Guideline will be re-calculated using hardness of monitoring station at the time of each survey.

[g] hexavalent form

[i] inorganic mercury

[j] Ontario Water Quality Objectives (OMOE 1994)

[k] interim objective or guideline

[l] for cold water streams

[m] upper end of range is applicable for protecting early life-stages

[n] Should draft CWQG guidelines for Cd and Zn become finalized, then the target MDLs should be adjusted lower for Zn to 0.008 mg/L and the target MDL for Cd could be adjusted higher to 0.0001 mg/L

[o] Target method detection limit (MDL) calculated as one half the guideline however these are maximum limits and efforts should be made to achieve MDLs of ≤ 1/10 guideline. For parameters lacking a guideline, the target MDL should be the lowest MDL that can be reasonably achieved by a reputable analytical laboratory (e.g., Maxxam Analytics)

[p] see Appendix A

[q] samples should be collected within first 24 hours of run-off event

areas downstream of UKHM relative to reference areas (e.g., mine indicators) and these should be retained in the LTAMP.

2.4.1 Total versus Filtered Metals

Water quality monitoring conducted at the UKHM site in recent years has included analysis of both total and filtered metal concentrations, where the latter is defined as the concentration of metal in a water sample that is passed through a 0.45 um filter. This practice increases the costs for sample collection and data management and doubles the cost of laboratory analyses. Also, differences in filtering methods, such as filter diameter, filter manufacturer, volume of sample processed, and amount of sediment in the sample, can result in significant variation in the concentrations of metals reported as being in the dissolved form (Horowitz et al. 1996). Although filtered metal concentrations are often considered a more relevant indicator of the metal concentrations present in a form that might be harmful to aquatic biota (i.e., bioavailable; Prothro 1993), the metal species passing through a 0.45 um filter are not necessarily truly dissolved (i.e., colloidal forms may also pass through; EVS 1997). Also, the metal species present in filtered samples can vary widely in toxicity (Campbell 1995, Deaver and Rodgers 1996, DiToro et al. 2005) and thus samples with the same concentration of filtered metal can have very different toxicities. Furthermore, Canadian water quality guidelines, to which site water quality data will be compared, are based on total, rather than filtered metal concentrations. Therefore, measurement of total metal concentrations will be adequate for routine surface water quality monitoring at the UKHM complex.

2.4.2 Flow

Seasonal and annual discharges (flows) vary widely in the creeks downstream of the UKHM in response to temperature (frozen versus flowing conditions) and precipitation events (Burns 2005). This affects the concentrations of mine-related contaminants released to surface waters, causing wide variation in concentrations of some substances at any given station within and among years. However, in aquatic receiving environments, concentrations are more relevant than loads in terms of evaluating potential effects on aquatic biota. Since surface water concentrations will be part of routine monitoring, there will be limited need for flow monitoring at surface water stations over the long-term. Flow monitoring is recommended at one station in each of the primary drainages, to track any changes in flow regimes that may occur over time as a result of climate change or mine-related remediation activities (e.g., groundwater recapture), since these factors could cause receiving environment concentrations to differ from predictions. Therefore, flow (discharge m^3/sec) should be measured at the following locations:

- Christal Creek (KV-7),
- Flat Creek (KV-9),
- Lightning Creek (KV-41), and
- South McQuesten River (KV-4).

To ensure the greatest accuracy of load estimates, it is important that both laboratory analyses of the concentrations of contaminants in water as well as flow measurements are accurate. Guidance for managing data quality of laboratory sample analyses is described in detail in Section 6.0. In terms of flow measurements, ERDC should consider retaining a flow measurement expert, if it has not already done so, to verify that flow monitoring systems and protocols are generating data of acceptable quality.

2.5 Sample Collection and Field Measurements

Water samples for laboratory analyses will be collected directly into appropriate sample bottles supplied by an accredited laboratory. Sample bottles will be rinsed three times with the surface water being sampled prior to final filling except if sampling container is pre-dosed with required preservatives. Care will be taken to ensure that no headspace is left in the collection bottles. All samples will be placed in coolers immediately following collection and then placed in a refrigerator at approximately 4°C until shipped, in coolers with ice packs, to the laboratory. At the laboratory, all samples will be analyzed for the specified suite of metal and non-metal substances (Table 2.3).

A number of environmental variables will be documented in the field to support the LTAMP. The location of each sample will be recorded using a Global Positioning System (GPS) with coordinates (UTMs) recorded using the North American Datum of 1983. Also, pH, temperature, dissolved oxygen and conductivity will be measured at the sediment-water interface at each benthic invertebrate station and at mid-column at each water quality monitoring station. All observations associated with the sampling station or the samples will be recorded in field notebooks and added to the water quality database.

ERDC should develop standard operating procedures to help ensure data quality and consistency over time (see Section 6.0)

2.6 Sampling Frequency

Water quality monitoring has been conducted at varying frequencies, ranging from monthly to once annually among surface water stations, and not always at a consistent frequency within stations. In order to determine the minimum frequency that would be adequate at each station for the LTAMP, key locations need to be sampled often enough to fully characterize the variability of conditions at that station within and among years. Therefore, it is strongly recommended that a monthly sampling frequency (during ice-free period) be employed for the surface water quality stations during the first two to three years of the LTAMP. In addition, one sample should be collected under ice cover and, if possible, one sample should be collected during at least one rain event following a dry period in the summer or fall. It is expected that contaminants from the old mines and adits are largely delivered to the watershed through surface runoff (as opposed to groundwater). Therefore, by sampling during the first 24 hours of a rain event it may be possible to capture peak loads and concentrations associated with flushing of these contaminants from sources (hydrometric response) within the watersheds. However, additional study may be required to characterize the hydrometric response of the downstream watersheds and the appropriate timing of sampling.

These data may then be used to characterize within and among-year water quality variance for key stations which can then be used to determine the minimum monitoring frequency necessary to adequately characterize conditions at each station (i.e., such that the resulting data will be adequate to capture the range identified by more frequent sampling). This information should be used to modify the water sampling frequencies of the LTAMP.

2.7 Data Analysis

The final list of substances and monitoring locations may be established once sufficient water quality data has been collected from tributary reference stations (i.e., two years). In order to do this a revised background benchmark for the tributaries must be established (95^{th} percentile) and then compared to downstream tributary concentrations in order to identify a final list of mine indicator substances to be included in the LTAMP. Once the mine indicators are established, the spatial extent of mine influence should be determined by comparing concentrations within the South McQuesten River to KV-1.

Once the parameters and locations are confirmed, water quality data should be consistently assessed. Concentrations from downstream monitoring stations should be compared to water quality guidelines (or background, if higher) to identify potential zones of biological effects. The LTAMP should refer to the Canadian Water Quality Guidelines (CWQG; CCME 1999) (Table 2.3) except in cases where a CWQG is lacking and then a British Columbia Water Quality Guideline (BCWQG; BCMOE 2006) should be used or alternatively a Provincial Water Quality Objective for Ontario (PWQO; OMOE 1994). Guidelines for certain substances (e.g., cadmium, lead, nickel) are hardness-dependent therefore, the hardness within the exposure areas should be evaluated and a value at the low end of the range (i.e., 10th percentile) should be used as conservative value on which to calculate guideline concentrations. The magnitude to which concentrations exceed guidelines should also be assessed by expressing the concentrations downstream as factors of the guideline. Water concentrations should be compared to previous concentrations at the same location in order to assess temporal trends. Receiving water quality performance for cadmium and zinc should be evaluated relative to water quality goals and objectives establish for Christal Creek, Flat Creek and the South McQuesten River.

The results of the data analysis should be presented in the Annual and Comprehensive Aquatic Ecosystem Study Reports (See Sections 7.1 and 7.2).

Should conditions improve over time in response to final closure of historical UKHM sources such that concentrations in some areas are equal to or less than background, then the spatial extent of the monitoring program stations should be retracted in response to the improved conditions[4].

2.8 Water Licence

In order to support activities relating to care and maintenance of the historic mine workings prior to closure, the Yukon Water Board has granted a “Type B” Water Licence (QZ06-074) to ERDC pursuant to the *Waters Act* (Appendix A). The Licence for care and maintenance activities includes requirements for water, sediment, and benthic invertebrate community monitoring of receiving environments and sampling is scheduled for various stations within the UKHM site watersheds.

The LTAMP should allow for the requirements stipulated within the licences to be harmonized and, ideally, the licences would refer to this monitoring framework or future updates, as applicable. This would provide flexibility to modify the program in response to findings without going through a formal licence amendment to address each change. Changes to the monitoring program would be proposed through the development of a study design well in advance of the implementation of periodic biological monitoring (Section 7.0) thereby providing regulators and other stakeholders an opportunity to comment prior to any modifications being made to the LTAMP.

[4] Changes to the program should be considered in light of any predicted changes in source terms over time (e.g. if concentrations are expected to increase in an area it may not be appropriate to retract the program).

2.9 Summary

Based on a review of existing surface water monitoring stations and available water quality data, 19 water quality stations are recommended (KV-1, KV-2, KV-3, KV-4, KV-5, KV-6, KV-7, KV9A, KV-9, KV-37, KV-38, KV-41, KV-60, KV-61, KV-64, KV-65, KV-72, WILC and FIEC). These stations include near-field, far-field and reference areas and encompass the current spatial extent of mine influence on surface water quality. The LTAMP will initially include 30 substances and *in situ* measures (Table 2.3) which represent either substances previously shown to be indicators of historic mine influence or substances for which there was insufficient information to fully assess them in the context of mine influence (too few data or high method detection limits). In order to determine what minimum frequency would be adequate at each station for the LTAMP, key locations need to be sampled often enough to fully characterize the variability of conditions at that station within and among years. Therefore, samples should be collected monthly during the ice-free period and once during the ice-on period. If possible, one additional sample per year should be collected after a run-off event (e.g., storm). This sampling frequency is strongly recommended for surface water quality stations during the first two to three years of the LTAMP. Once this information is compiled and analyzed, a lower frequency may be justifiable.

A final list of mine indicator substances should be established when sufficient water quality data is available (e.g., 2 years), and these should form the basis of the substances to be monitored for the LTAMP. Water concentrations from the tributaries should be compared to a background benchmark and water concentrations from the South McQuesten River should be compared to the upstream reference area, KV-1, to confirm the extent of mine influence downstream and thus the geographical extent of the monitoring program. Water concentrations should be compared to water quality guidelines on a routine basis to determine the zones of possible biological effects. The magnitude to which concentrations exceed guidelines should also be assessed by expressing the concentrations downstream as factors of the guideline. Water concentrations should be compared to previous concentrations at the same location in order to assess temporal trends.

Flow will be measured at KV-41, KV-7, KV-9 and KV-4 to assess contaminant loading within the main drainages associated with UKHM.

The results of the water quality monitoring will be reported in both Annual and Comprehensive Aquatic Ecosystem Study Reports (See Sections 7.1 and 7.2).

3.0 SEDIMENT QUALITY MONITORING

3.1 Current Conditions

Sediment quality has been evaluated at UKHM as part of numerous studies conducted over the past twenty years (1985, 1994, 2004 and 2007). Similar to water, sediment concentrations are generally highest closest to mine sources in the tributaries (e.g., Flat and Christal Creeks), decreasing somewhat further downstream in the South McQuesten River (Burns 1996, 2005, 2008, Davidge and Mackenzie-Grieve 1989).

Metals analyses were usually performed on the fraction of sediment samples that passed through a 100 mesh sieve (0.15 mm). Metal concentrations were elevated in the fine fraction of sediment samples collected downstream of mine sources, particularly arsenic, cadmium, lead, manganese and zinc, which were well above sediment quality guidelines (CCME 1999 or OMOE 1993) at several downstream locations (Minnow 2009a). However, bulk sediment concentrations, on which CSQG are based, were not measured until recently (2009). As part of a 2009 monitoring study (Minnow 2011a), sediment samples were collected and analyzed for both total and fine-fraction metal content at most locations specified within the Water Licences as well as at KV-7, which was included to further characterize conditions in Christal Creek. While concentrations of metals were generally less in bulk sediment samples than the fine sediment fraction, the concentrations of arsenic, cadmium, lead and zinc were still well above the CSQG Probable Effect Level (PEL; CCME 1999) at locations downstream of UKHM mine sources, with the exception of KV-41 on Lightning Creek where concentrations were below the PEL (Figure 3.1).

3.2 Considerations for Future Monitoring

Mine-related metals accumulate in bedload sediments when metals that are transported in the water column adsorb onto fine particulate materials and eventually settle to the bottom (Ongley 1996, McKay et al. 2001, DiToro et al. 2005). Accumulation is most apt to occur in slow-flowing or still aquatic environments, particularly those with substantial concentrations of suspended particles, than in fast-flowing environments. At UKHM, aquatic receiving environments are typically moderate to swiftly flowing with low concentrations of total suspended solids (<5 mg/L; Minnow 2008), except during high flow events (e.g., spring melt and/or heavy rain events) when flow conditions are particularly conducive to scour rather than deposition. Therefore, accumulation of fine particles (e.g., silt, clay) downstream of the UKHM is limited, with bottom substrates being primarily coarse materials (sand, gravel, rocks). Also, because fine sediment deposits are generally sparse in most areas, samples

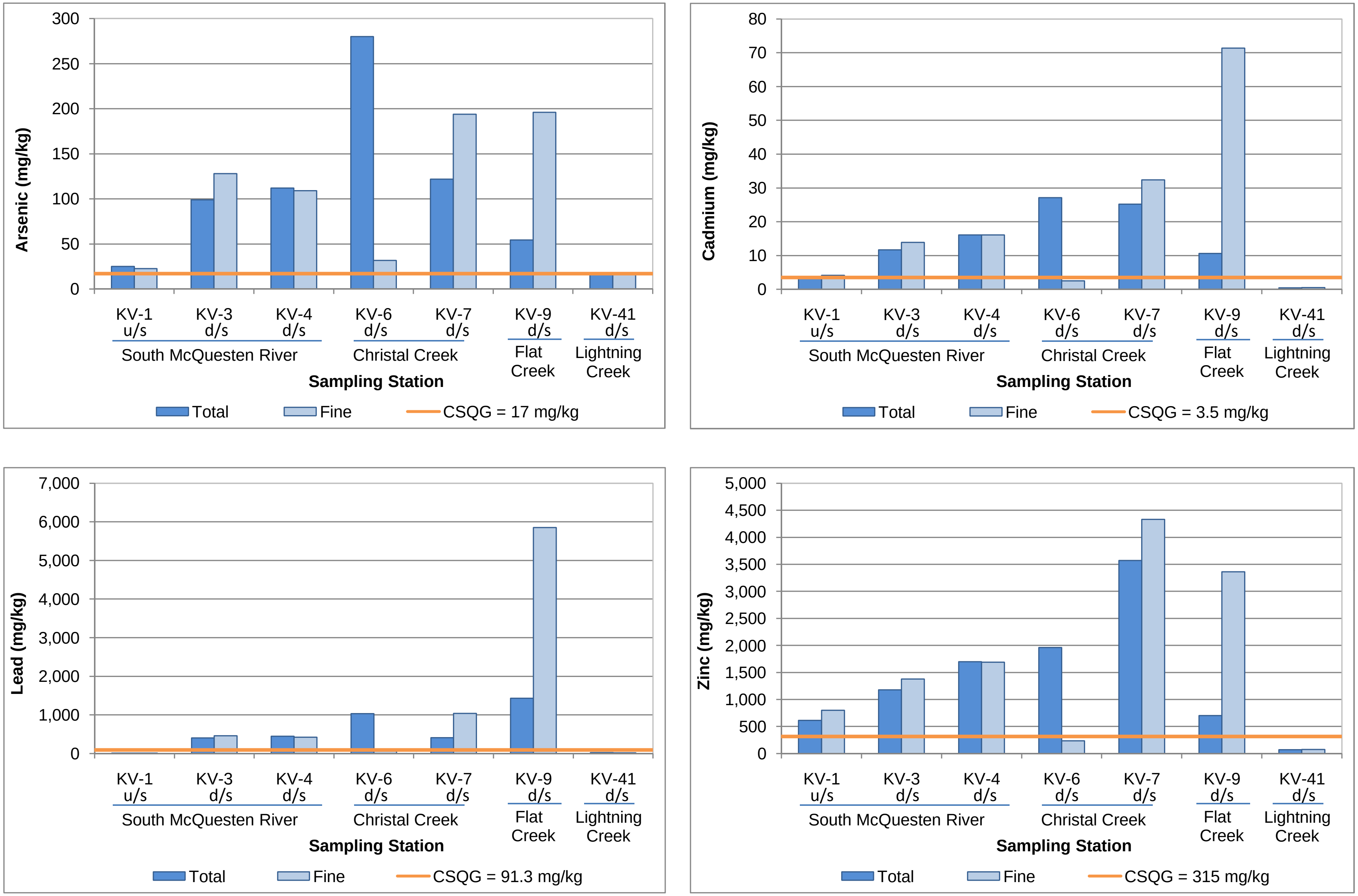


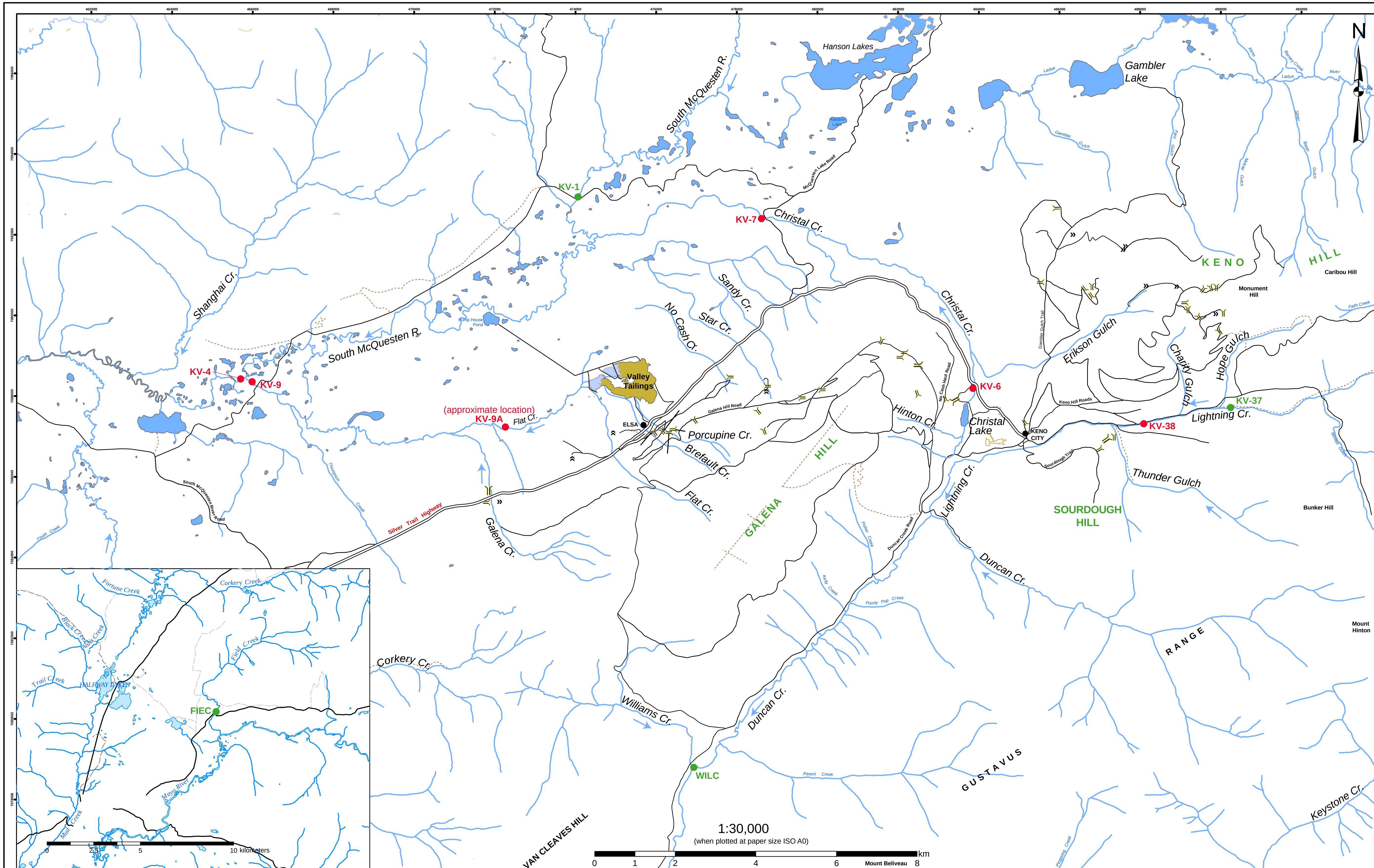
Figure 3.1: Concentrations of metals in whole (bulk) and fine fraction (<0.15mm) of sediments at United Keno Hill Mines, August 2009.

are sometimes collected from areas that are exposed (above the water line) at the time of sampling or had likely been exposed at other times of the year (i.e., not necessarily available to aquatic biota). Consequently, benthic invertebrate communities are probably primarily exposed to mine-related substances via water than sediment-detrital pathways. However, given that concentrations of several metals are substantially elevated in some areas, even limited exposure to these sediments may affect resident biota and as such sediment sampling should be incorporated into the interim LTAMP. In addition, to better understand the biological effects associated with the elevated sediment concentrations, sediment toxicity testing should be performed once as part of the first year of the monitoring program (see Section 3.5).

Once initial sediment sampling is complete (bulk and toxicity), the information will be used to determine whether sediment sampling should be retained in the program. For example, if concentrations in the sediment are elevated but no toxic, the impact of these elevated concentrations to resident biota is likely limited and therefore the value of continued sediment monitoring may not be justifiable. The sediment and toxicity data will be considered together to determine the need for on-going sediment monitoring to be incorporated into the final LTAMP.

3.3 Sampling Locations

As part of the LTAMP, it is recommended that sediment samples be collected from; Christal Creek (KV-6 and KV-7), Flat Creek (KV-9 and KV-9A), Lightning Creek (KV-37 and KV-38), and the South McQuesten River (KV-1, and KV-4; Figure 3.2). Sampling at KV-9A is subject to confirmation that adequate access can be achieved to permit establishment of a new sampling location closer to the Valley Tailings discharge on Flat Creek (otherwise sampling will only be done at KV-9). These mine-exposed areas represent those most relevant to biota and/or areas where highest concentrations have been observed in previous studies. KV-1 will be used as a reference to measure incremental effects of sediment deposits related to UKHM within the South McQuesten River (i.e., to account for the influences between KV-72 and KV1). KV-37 will be used as the upstream reference to assess the influence of Keno 700 and any other sources upstream of Bellekeno (i.e. Thunder Gulch). However, if placer mining in the area confounds an upstream to downstream comparison, then the stations on Lightning Creek should be eliminated. In addition, two other reference stations should be included in the program (WILC and FIEC) to characterize undisturbed background sediment chemistry and serve as a reference for the tributary streams.



Legend

- Proposed reference sampling station for sediment chemistry and toxicity testing
- Proposed mine-exposed sampling station for sediment chemistry and toxicity testing

Mine Working
- Adit
- Shaft (to surface - connection to underground not determined)
- Valley Tailings
- Pit

Topography
- Town
- Silver Trail
- Secondary and Limited-use roads
- Trail
- Watercourse
- Waterbody
- Flow Direction

ALEXCO ERDC

Figure 3.2 minnow environmental inc.

Proposed Locations for Collection of Sediments for Chemical and Toxicity Testing, United Keno Hill Mines

Ref: 2274
Date: April 2011
Source: Access Consulting Group

3.4 Sediment Collection and Analyses

Samples should be collected in the late summer when water flows are more likely to be low, enhancing accessibility to pools (i.e., by wading) where fine sediments may accumulate. This timing is consistent with the proposed collection of benthic invertebrate samples (Section 4.0). It is generally desirable to collect sediment samples from a standard depth, with analyses typically focussed on the top sediment layers (e.g., 1-3 cm) to reflect more recent conditions rather than historical deposits (ESG 1999). This usually necessitates the use of a corer or grab sampler (e.g., Ponar or Ekman; Environment Canada 1994). Such devices assist in preserving the natural integrity of the sample (and thus chemical composition), although some level of disruption is unavoidable (Environment Canada 1994). At UKHM, under the Water Licences and in previous studies, collection of sediment samples has typically involved a trowel or scoop shovel. As part of the Benthic Study Design Evaluation conducted in 2009, core sampling was attempted but the sediments were found to be too compact at most stations to allow for penetration of the core and proper retrieval (Minnow 2011a). Sediment sampling was successfully conducted using a petite Ponar. Since a Ponar (grab) sampler allows for a discrete and intact sample to be collected, it is preferable to using a trowel which is less quantitative and more susceptible to having sediment particles washed downstream. Therefore, a grab sampler should be used for sediment collection at all locations included in the LTAMP. Details pertaining to all samples (e.g., water depth, substrate characteristics, colour, and texture) will be recorded at the time of sampling along with GPS coordinates for each location sampled.

At each monitoring station, the top three centimetres of sediment should be collected from each of two Ponar grab samples and then homogenized. The homogenized sample should then be divided such that a portion is allocated for chemical analyses and the other portion is used to determine total organic carbon (TOC) and particle size distribution. Chemical analysis should be conducted on whole sediment samples.

Chemical analyses of sediment will include percent moisture, particle size distribution (whole sediment), TOC, total Kjeldahl nitrogen (TKN), total phosphorus (TP) and total metal content (Table 3.1). TOC and grain size will assist in characterizing sediment structure and composition and thereby provide insight as to habitat quality for benthic invertebrates.

3.5 Sediment Toxicity

Sediment toxicity samples should be collected from routine sediment monitoring stations: Christal Creek (KV-6 and KV7), Flat Creek (KV-9, KV-9A), the South McQuesten River (KV-1

Table 3.1: Sediment quality variables recommended for the LTAMP, UKHM.

Variables	Unit (dry weight)	Guideline	Target MDL[b]	Water Licences[f]	Whole (bulk)	Sampling Freqency
Total Metals						If sediment sampling is included in the final LTAMP then sampling should be conducted to coincide with benthic invertebrate sampling[h]
Aluminum	ug/g	n/a	n/a	X	X	
Arsenic	ug/g	17[a]	8.50	X	X	
Cadmium	ug/g	3.5[a]	1.8	X	X	
Chromium	ug/g	90[a]	45.0	X	X	
Copper	ug/g	197[a]	99	X	X	
Iron	ug/g	21,200[c,g]	10,600	X	X	
Lead	ug/g	91.3[a]	45.7	X	X	
Magnesium	ug/g	n/a	n/a	X	X	
Manganese	ug/g	460[d,e]	230	X	X	
Mercury	ug/g	0.486[a]	0.243		X	
Nickel	ug/g	16[c,g]	8	X	X	
Selenium	ug/g	2[c]	1	X	X	
Silver	ug/g	0.5[d,e]	0.25	X	X	
Uranium	ug/g	n/a	n/a	X	X	
Zinc	ug/g	315[a]	158	X	X	
Non-Metals and Nutrients						
Percent moisture	**%**	n/a	n/a		X	
Particle size	**%**	n/a	n/a	X	X	
Total nitrogen	ug/g	n/a	n/a		X	
Total Kjeldahl Nitrogen	ug/g	550[d,e]	275		X	
Total organic carbon	%	1[d,e]	0.5		X	
Total phosphrus	ug/g	600[d,e]	300		X	

n/a - not available
[a] Probable Effect Level Canadian Sediment Quality Guidelines (CCME 1999)
[b] Target method detection limit (MDL) calculated as one half the guideline. For parameters lacking a guideline, the target MDL should be commensurate with the lowest MDL that can be reasonably achieved by a reputable analytical laboratory (e.g., Maxxam Analytics)
[c] British Columbia Sediment Quality Guidelines (BCMOE 2006)
[d] Lowest effect level
[e] Provincial Sediment Quality Guidelines (OMOE 1993)
[f] see Appendix A
[g] Severe effect level
[h] Sediment sampling will only be conducted if sediment toxicity testing indicates potential for effects to biota.

and KV-4) and Lightning Creek (KV-37 and LCTG) as well as two reference locations (two of the tributary reference areas selected for biological monitoring; WILC and FIEC).

Sediment toxicity samples will require between 5 and 10 grab samples to be collected at each station in order to achieve the sample volume requirements. Similar to routine sediment monitoring (noted above), all grab samples should be composited and homogenized and then sub-sampled for toxicity, chemistry and TOC and particle size. A stainless steel spoon will be used to place a minimum of 3 L of homogenized sediment into pails with plastic liners. Immediately after collection, the samples will be kept at 4 °C then couriered to an accredited laboratory and tested for potential chronic effects on survival and growth of the amphipod *Hyallela azteca* over a 14-day exposure period (Environment Canada 1997).

Toxicity test data will show if metal concentrations observed in the whole sediment samples are toxic. If toxic, comparison of toxicity test results to sediment chemistry may suggest causal relationships. The results of the toxicity testing may then be used to guide the interpretation of the biological community data and possibly influence the locations of areas retained for sediment quality sampling.

3.6 Data Analysis

Sediment chemistry will be evaluated on whole (bulk) sediment samples. Observed concentrations in mine-exposed areas will be compared to the sediment quality guidelines and to background benchmarks to identify substances and locations having elevated concentrations. Guidelines for comparison, in order of preference, are the Probable Effect Level (PEL) Canadian Sediment Quality Guidelines (CCME 1998), British Columbia Sediment Quality Guidelines (Severe Effect Level [SEL] if available; BCMOE 2006) or SELs defined by the Ontario Ministry of Environment (OMOE 1993; Table 3.1). These guidelines are applicable to whole (bulk) sediment samples, which highlights the importance of analyzing whole sediments (Davidge and MacKenzie-Grieve 1989; Burns 1996, 2005, 2008).

Sediment chemistry and toxicity data should be considered together. Should sediment samples result in no significant impairment of biota relative to laboratory controls and/or reference areas, then sediment sampling should not be continued as part of the final LTAMP. However, should sediments indicate the potential to impair biota, then sediment sampling should be incorporated into the final LTAMP at all receiving environment stations and data should be presented in a Comprehensive Aquatic Ecosystem Study Report (Section 7.2).

3.7 Summary

The receiving environment downstream of UKHM is generally erosional with coarse substrate (sand, gravel, rock) with limited patchy deposits of fine particles along the margins or banks of the stream and interstitial areas. Sediment analysis conducted to date have shown levels of arsenic, cadmium, lead, manganese, and zinc above PEL (or LEL for manganese) in the fine sediment fraction (<0.15 mm) as well as in whole sediment samples. Since fine sediment deposits are sparse, exposure of biota to contaminant sediment deposits is likely limited. However, concentrations are sufficiently high that sediment monitoring should be conducted as part of the interim LTAMP for UKHM.

It is recommended that sediment samples be collected from Christal Creek (KV-6 and KV-7), Flat Creek (KV-9 and KV-9A), the South McQuesten River (KV1, KV-4), Lightning Creek (KV-37 and KV-38), and from two reference areas (WILC and FIEC). At each monitoring station, the top three centimetres of sediment should be collected from each of two Ponar grab samples and then homogenized and sub-sampled for chemical analyses and TOC and particle size distribution. Chemical analysis should be conducted on whole sediment samples.

Laboratory analyses of sediment should include percent moisture, particle size distribution, TOC, TKN and TP and total metal content (Table 3.1). Details pertaining to all samples (e.g., water depth, substrate characteristics, colour, and texture) will be recorded at the time of sampling along with GPS coordinates for each location sampled.

In addition, to better understand the biological effects associated with the elevated sediment concentrations, sediment toxicity testing should also be incorporated into the monitoring program the first time it is implemented. For this purpose, sediment will be collected from all routine sediment monitoring stations. Results of toxicity testing may be used to guide the interpretation of the biological community data and influence the need for sediment quality sampling as part of the LTAMP.

Concentrations in whole (bulk) sediment samples will be compared to sediment quality guidelines and background levels to identify substances and locations with elevated concentrations. Sediment results will be considered with biological benthic invertebrate community data to assess possible relationships. The results of the sediment quality monitoring under the LTAMP will be reported in the Comprehensive Aquatic Ecosystem Study Report with biological monitoring data (See Section 7.2).

4.0 BENTHIC INVERTEBRATE COMMUNITY MONITORING

4.1 Existing Conditions

Several benthic invertebrate surveys were previously conducted in the South McQuesten River and Duncan Creek watersheds during the past three decades (Minnow 2009a). Artificial substrates were used for studies conducted in 1985, 1994, and 2007, providing some consistency in data collection, although the mesh size used to sieve the samples varied between the first study (500 µm in 1985) and later studies (300 µm in 1994 and 2007).

These historical studies suggested that the UKHM has impacted benthic invertebrate communities in both Christal and Flat Creeks as far downstream as their confluence with the South McQuesten River (Minnow 2009a). Benthic communities within Christal Creek and Flat Creek have shown impairment through reduced abundances and number of taxa relative to the other watercourses sampled in the area. The benthic communities within the South McQuesten River and Lightning Creek had higher numbers of taxa and abundance suggesting limited impairment at these locations. The relationships between the number of taxa and water chemistry suggested the number of taxa decreased in response to increases mine related substances such as sulphate, cadmium, manganese, uranium, hardness, zinc and conductivity, consistent with elevated concentrations observed in Christal and Flat Creeks.

4.2 Considerations for Future Monitoring

Benthic invertebrates are excellent biomonitors for assessing potential effects of the chemical condition of water and sediment on the health of aquatic systems (Barbour et al. 1999, Feltmate and Fraser 1999) because they:

- are good indicators of localized conditions (they generally have limited migration patterns or a sessile mode of life);
- integrate the effects of short-term environmental variations over the longer-term;
- reflect the community level of organization, including a range of trophic levels and pollution tolerance, providing numerous useful assessment endpoints;
- are relatively easy to identify to family and many taxa can be identified to lower taxonomic levels with ease;
- are often abundant in areas where fish abundance may be low;

- are relatively easy to sample, with minimal detrimental effect on the resident community, and require few people and inexpensive gear; and
- serve as an important direct or indirect food source for fish.

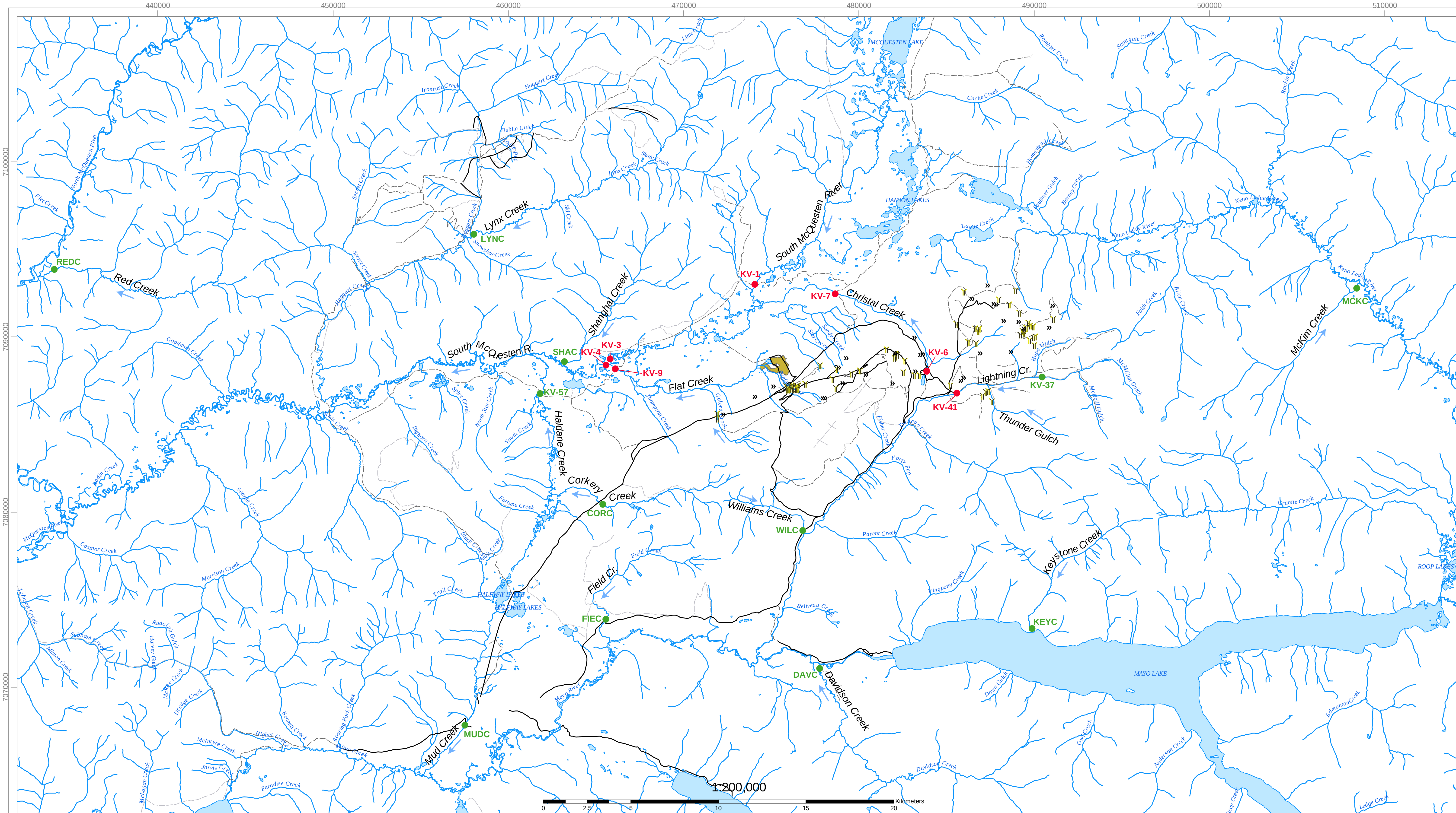
Consequently, benthic invertebrate community sampling allows for the tracking of potential effects or improvements among areas and over time through assessment of community characteristics. For these reasons, the assessment of benthic invertebrate community health downstream of the UKHM will be an important component of the LTAMP.

Under the current Water Licence for care and maintenance activities, a benthic invertebrate study is required every two years at selected areas (KV-1, KV-3, KV-4, KV-6 and KV-9; Figure 4.1; Table 4.1). These samples are to be collected by a Hess (0.0934 m^2; 250 um mesh) or Waters-Knapp sampler (0.089 m^2; 250 um mesh) with three samples collected per area[5]. The first of these benthic surveys was conducted in August 2009. At that time, a parallel study was undertaken by Minnow involving alternative sampling approaches to determine the most effective study design and sampling method for the LTAMP (Table 4.1; Minnow 2011a). The approach undertaken for this evaluation is described below. Once the report is finalized, the LTAMP described herein should be updated to incorporate the study findings and recommendations.

4.3 Sampling Design

The primary goal of each benthic invertebrate survey will be to assess the magnitude and spatial extent of any mine-related impacts as well as to indicate changes relative to previous surveys (trends). Spatial sampling designs that have been used in benthic invertebrate community surveys include Control-Impact (CI) designs, Reference Condition Approach (RCA) and gradient designs (Ellis and Schneider 1997; Taylor 1997; Taylor and Bailey 1997; Environment Canada 2002). Gradient and multiple gradient designs work best where environmental/habitat characteristics are relatively homogenous with the exception of a gradient of progressively decreasing concentrations with distance away from a point-source of contamination. However, at the UKHM, multiple mine sources drain into various streams with varied habitat characteristics such as size, elevation, gradient, and substrate type, so a gradient sampling design would not be preferred. Hence the two designs considered for long-term monitoring at UKHM included CI and RCA.

[5] For the 2009 Benthic Study Design Evaluation, the sample collection requirements were interpreted as the collection of three samples per area. Each sample was a composite of three individual Hess samples or grabs.



ALEXCO

ERDC

Reference benthic sampling stations
Mine-exposed benthic sampling stations

Mine Workings
- Adit
- Shaft

Topography
- Road
- Limited Use Road
- Trail
- Watercourse
- Waterbody

Flow Direction

Figure 4.1

minnow

2009 Benthic Invertebrate Community Sampling Locations, United Keno Hill Mines

Ref: 2274
Date: April 2011

Source: Access Consulting Group

Table 4.1: Sampling associated with the 2009 benthic invertebrate community study design evaluation.

Area Type	Water Body	Station	Water Licence	2009 Benthic Study Design Evaluation (Minnow, in preparation)		
			Hess sampler	Hess		Kick & Sweep
			Control Impact (CI) Design	Control Impact (CI) Design	Reference Condition Approach (RCA)	Reference Condition Approach (RCA)
Exposed	South McQuesten U/S Flat Creek	KV-3	3			1
	South McQuesten D/S Flat Creek	KV-4	3			1
	Christal Creek at Keno Hwy	KV-6	3			1
	Christal Creek at Hanson Road	KV-7		5	[a]	1
	Flat Creek U/S South McQuesten River	KV-9	3	2	[a]	1
	Lightning Creek	KV-41			1	1
Reference	South McQuesten River U/S Christal Creek	KV-1	3			3
	Lightning Creek U/S Hope Gulch	KV-37			1	1
	Shanghai Creek	SHAC			1	1
	Red Creek	REDC			1	1
	McKim Creek	MCKC			1	1
	Williams Creek	WILC		5	[a]	1
	Field Creek	FIEC			1	1
	Davidson Creek	DAVC			1	1
	Mud Creek	MUDC			1	1
	Corkery Creek	CORC			1	1
	Haldane Creek	KV-57			1	1
	Lynx Creek	LYNC			1	1
	Keystone Creek	KEYC			1	1
Total Samples			15	12	12	21

[a] one sample from the CI collections to be used for the RCA evaluation

A Before-After Control-Impact (BACI) design (Green 1979, Bernstein and Zalinski 1983, Smith et al. 1993, Stewart-Oaten et al. 1986, Underwood 1991, 1992, 1994, Underwood and Chapman 2003) is generally considered to be the optimal sampling design for situations where the location of a future disturbance is known but has yet to occur, and where one or more appropriate control areas can be found (Bowman and Somers 2005). In this design, the potentially impacted areas (I) are compared with unaffected control areas (C) both before (B) and after (A) the disturbance has occurred. If, as in the case of the UKHM, the area is already disturbed, a simple CI design is often applied and statistical differences in benthic community characteristics observed between control areas (mostly referred to as “reference” areas in this report) and impacted areas (more aptly called “exposed” or “influenced” areas until an impact is proven) are presumed to be due to the disturbance (e.g., presence of a mine). However, this inference is valid only if reference and exposure areas are comparable in all respects other than the disturbance, an assumption that cannot be tested, because the “before” measurement is missing (Osenberg and Schmitt 1996). While this issue is minimized in CI designs through selection of reference areas with habitat characteristics similar to the exposure area, it is impossible to exactly match all habitat characteristics among all areas (e.g., gradient, substrate type, distance to source, depth, flow and velocity). Consequently, a weakness of the CI design is that reference-exposure differences between areas for benthic invertebrate community characteristics may simply reflect subtle habitat differences rather than mine influences, and, the fewer the reference areas being tested, the greater the risk of this occurring. In other words, the inclusion of more reference areas takes into account the natural variability that occurs among areas with similar habitat.

RCA was specifically developed to take among-reference-area variability into account and thus improve the probability that an observed reference-exposure difference is truly due to the disturbance being tested (Rosenburg et al. 1998, Reynoldson et al. 2005). In RCA, samples are collected from one or more exposure areas and statistically compared to samples from multiple reference areas (e.g., 20-50 areas; Bowman and Somers 2005). There are currently several RCA programs in development across Canada (Rosenburg et al. 1998, Reynoldson et al. 1997, 2005; Sylvestre et al. 2005; Sarrazin-Delay et al. 2006), including the Yukon (Branton et al. 2006, Bailey et al. 2007), but most have been designed for broad-based assessment across wide geographic areas. Modifications to those approaches have been recommended for assessment of site-specific impacts within a regulatory framework (Minnow 2009b). For example, rather than randomly sampling a range of aquatic ecosystem types and sizes as is done for regional RCAs, site-specific impact assessments should involve sampling of only reference areas that closely resemble the habitat of the exposure area(s) of interest (e.g., stream order, gradient, bedrock geology etc.)

followed by formal tests to select the ones most appropriate for comparison to specific exposure areas.

Based on the above, both CI and RCA sampling designs were used to evaluate benthic invertebrate community health at the UKHM in 2009 (Minnow 2011a).

4.4 Sampling Methods

Historical benthic invertebrate community monitoring at UKHM has predominantly employed the use of artificial substrates. This method is often used in areas that are difficult to sample by other methods (e.g., bedrock, boulder, or shifting substrates; deep or high velocity water) and provides a standardized substrate type among areas, which may be helpful if natural substrate types vary among the areas of interest. However, such samples may not adequately represent the resident benthic assemblage, particularly because the samplers are typically deployed for relatively short periods (5-6 weeks) during which variation in water temperature and flow conditions relative to previous years may affect colonization patterns and confound temporal comparisons. Furthermore, artificial substrates require two site visits for sampling (one to set and one to retrieve) and are vulnerable to loss (e.g., from high flows or human or animal disturbances) or incomplete sampling (e.g., reductions in flow that leave samplers exposed). Studies conducted in the mid-1990s to evaluate the best approaches for assessing mine-related impacts on benthic invertebrate communities in Canada concluded that artificial substrates are generally unnecessary in shallow streams and rivers with cobble or gravel substrate where it is easy to sample communities inhabiting natural substrates (Golder 1995, ESG 1999). Current technical guidance for national monitoring programs at operating mines stipulates that artificial substrates should be used only in situations where it has been shown that suitable natural substrates are not present or other viable alternatives are unavailable (Environment Canada 2002). Furthermore, recent studies showed that community assessments at the Faro Mine complex based on artificial substrates were less sensitive than those that sampled resident benthic invertebrates (by Hess or kick and sweep methods) for detecting differences in mine-impacted benthic communities relative to those in reference areas (Minnow 2009b). Kilgour et al. (2004) also observed that artificial substrates were less sensitive in detecting reference-exposure area differences than samples of resident benthic communities (using Surber or Ponar grab samplers). Thus, it is recommended that sampling of resident benthic invertebrates, rather than artificial substrates, be used for early detection and verification of possible future aquatic resource impairments associated with the historic UKHM complex.

The Water Licence stipulates that Hess or Waters-Knapp samplers be used for collecting resident benthic invertebrates at UKHM. Kick sampling is an alternative method that is widely employed in studies following an RCA design. Therefore, the relative efficacy of Hess and kick-net sampling was tested as part of the Benthic Study Design Evaluation conducted at the UKHM in 2009. Like artificial substrates, these methods also offer different advantages and disadvantages. In Hess sampling, invertebrates are collected from a defined, enclosed area enabling relatively precise estimates of organism density per unit area whereas kick-net sampling usually involves collection within a standardized time period to estimate relative abundance. Also, motile organisms may be more able to avoid capture in a kick-net relative to a Hess sampler. Typically a smaller range in habitat type (e.g., velocity, depth, substrate type) is sampled using a Hess sampler, which can minimize the effects of natural habitat variables (potentially improving ability to detect impairments) but may also reduce taxa diversity or richness in a sample (potentially reducing ability to detect impacts). Also, Hess may be more difficult to use than kick sampling in some streams (e.g., high water levels, strong flows, large embedded cobble, and/or hard-packed substrate). The findings of the 2009 study will be used to identify the most appropriate sampling method for the UKHM final LTAMP.

At each benthic station, field measures of temperature, dissolved oxygen, conductivity and pH were collected to assist in the interpretation of benthic community data. In addition, habitat conditions including depth, velocity, wetted width and substrate type were recorded with GPS coordinates on field sheets.

4.5 Sampling Locations

As part of the 2009 study, seven exposure areas were sampled including near field areas (Christal Creek, Flat Creek and Lightning Creek) and far field areas in the South McQuesten River. Past studies included few reference areas and in order to evaluate the utility of an RCA design (Section 4.3) additional reference areas were sampled as part of the 2009 study. Reference areas were sought that have similar habitat characteristics to the exposure areas so that the variability associated with habitat conditions could be minimized and sensitivity to detect mine-related effects enhanced. In order to identify possible reference areas with similar habitat conditions, geographic information system (GIS) data was used to characterize exposure areas and a variety of candidate reference areas near UKHM (e.g., gradient, basin area, base geology etc.). Stream reaches of comparable size and in the vicinity of the UKHM were selected as candidate reference areas. These areas were further evaluated to ensure there are no current or historical human activities (e.g., placer mining) in the watersheds. Ease of site access and opportunity to data-share with the Faro mine complex (Minnow 2009b) was also considered in selecting reference areas to sample. The GIS data that was generated was used in formal habitat matching for the RCA versus CI 2009 data analysis and is presented in the Benthic Study Design Evaluation Report (Minnow 2011a).

For the CI component of the Benthic Study Design Evaluation, multiple stations were sampled within each area to measure within-area variability and allow for statistical comparisons to be made among areas. The areas used for the CI evaluation included two exposure areas (Christal Creek KV-7, Flat Creek KV-9) and one reference area (WILC). Five natural substrate sample stations were sampled with a Hess at exposure areas KV-7 and KV-9 and at reference WILC (Williams Creek) during the 2009 Benthic Study Design Evaluation to test the sensitivity of CI designs to determine mine-related effects (Figure 4.1; Table 4.1). Five stations were located in each area with three of the stations at the KV-9 area being used to also satisfy the conditions of the Water Licence. The stations/substrates were spaced sufficiently far apart (e.g., at least 3 bank full widths) to be considered stations within areas, rather than replicate samples within stations (Environment Canada 2002). In addition, three areas on the South McQuesten River (KV-1, KV-3 and KV-4) were sampled to achieve the conditions of the Water License and to provide for a limited CI comparison of downstream to upstream conditions (Table 4.1).

To evaluate the potential for using the RCA for the LTAMP, one Hess and at least one kick and sweep sample were collected at KV-37 and 11 other reference areas as well as at seven exposure areas (KV-1, KV-3, KV-4, KV-6, KV-7, KV-9, KV-41; Table 4.1). To the extent possible samples were collected from similar habitats (i.e., substrates, depth and velocity) between areas.

4.6 Sampling Time/ Schedule

The 2009 benthic invertebrate samples were collected in August to be consistent with the timing of previous surveys. Although the details regarding sampling design and methods for the LTAMP will not be decided until the conclusion of the 2009 Benthic Study Design Evaluation, it is presently expected that samples collected for the LTAMP will also be taken in late summer.

It is expected that the benthic monitoring component will be conducted on the same schedule with the sediment and fish monitoring requirements (Section 7.2).

4.7 Data Analysis and Reporting

4.7.1 Monitoring Endpoints

Ideally, the metrics selected to describe benthic invertebrate communities will be those that provide the most useful information and provide the greatest sensitivity with lowest cost (Taylor and Bailey 1997). While numerous endpoints have been considered and statistically compared as part of benthic community assessments, many of these endpoints are either redundant (i.e., diversity versus number of taxa) or are co-dependent (% taxa composition). Kilgour et al. (2004) conducted a review of the sensitivity and redundancy of various benthic indices for assessing pulp and paper, mining and urbanization. Based on this review it is recommended that taxon richness, density or abundance and correspondence analysis (CA) axes 1 and 2 be used to evaluate the benthic community. However, EEM[6] for operating mines in Canada also requires Bray-Curtis and Simpson's Evenness indices to be assessed. Since mine operations are expected to resume at UKHM in the future, these indices should be included in the LTAMP to ensure that data from the LTAMP can be compared to EEM data associated with operating mines[7]. Therefore, the final list of benthic indices recommended for the LTAMP are; taxon richness, abundance, CA-1 and CA-2, Bray-Curtis and Simpson's Evenness.

Organism density (or abundance if sampling methods do not allow for expression of abundance based on unit area or volume) and species richness should be determined and are among the metrics recommended for federal monitoring programs under the federal MMER based on a long history of use and the conclusion that they are reasonably descriptive (ESG 1999). However, these metrics alone are often inadequate to detect mine-related effects, since more tolerant taxa may replace sensitive taxa such that an impacted area may still support similar numbers of individuals and taxa (ESG 1999). Therefore, other community descriptors and/or key indicator taxa also need to be assessed.

Community structure can also be assessed by using a multivariate technique known as correspondence analysis (CA). CA is used to calculate synthetic axes, which can be thought of as new variables summarizing variation in the relative abundance of benthic taxa. When depicted in two-dimensional plots, taxa that tend to co-occur will have similar CA axis scores and will plot together, while those that rarely co-occur plot farther apart. Similarly, stations sharing many taxa plot closest to one another, while those with little in common plot farther

[6] The EEM program under MMER requires that taxon richness, abundance, Simpson's Evenness and Bray-Curtis indices be computed and statistically compared to reference areas.
[7] In the future it may be necessary to determine historical from operating effects and this will only be possible is programs are consistent.

apart. The greatest variation among either taxa or stations is explained by the first axis, with other axes accounting for progressively less variation. It is recommended that the first two CA axes be included among the benthic community characteristics reported for surveys conducted at the UKHM.

Simpson's evenness ("E") index is computed following the formulae presented by Environment Canada (2002) and takes into account both the relative abundance of taxa, and the number of taxa, or richness. A bray-Curtis index is also calculated according to Environment Canada (2002). This metric takes into account the abundance of each taxon at each station compared to the median abundance at the reference stations to compute an index of the relative "distance" of each station from a hypothetical reference median station. Larger Bray-Curtis index values indicate greater dissimilarity from reference.

Past studies at the UKHM have also reported proportions of dominant taxa (e.g., Burns 1996, 2008), an approach that is considered reliable for assessing metal-related effects on benthic invertebrate communities (Taylor and Bailey 1997). It is recommended that the proportions of dominant taxa (e.g., two or three dominant orders, families or genera) also be compared among areas in the LTAMP.

4.7.2 Data Analysis and Interpretation

Data interpretation will partly depend on the sampling design and methods recommended in the benthic study design evaluation (Minnow 2011a). Generally, raw data, summary statistics and the endpoints noted above will be reported along with the results of statistical comparisons among areas. Correlation analysis may be used to identify potential relationships between benthic community characteristics and habitat variables (e.g., water chemistry, velocity etc.).

All data should be presented in a Comprehensive Aquatic Ecosystem Study Report (Section 7.2) along with recommendations regarding potential future benthic community sampling in the LTAMP.

4.8 Summary

Benthic invertebrates are good, community-level integrators of localized conditions over time, they are important components of aquatic food webs and there are standardized methods for their collection and evaluation. Therefore, benthic invertebrate community monitoring will be an important component of the LTAMP. Earlier benthic community assessments at the UKHM relied on deployment of artificial substrates, which have the advantage of controlling for natural differences in substrate among exposed and reference areas, but may bias collections toward organisms that happen to drift from upstream and colonize on the substrates over the short (typically 6-week) period they are deployed. However, the recent Water Licence specifies that benthic sample (as of 2009) be collected using a Hess or Water-Knapp sampler.

To determine the best long-term approach for benthic community monitoring, a more intensive sampling of resident benthic communities was conducted at the same time that the first benthic study under the Water Licence was conducted. Control-impact (CI) and Reference Condition Approach (RCA) sampling designs were followed and Hess as well as kick sampling methods used. For the CI and RCA designs benthic community characteristics will be assessed based on metrics such as density/abundance, number of taxa, CA axes 1 and 2, Bray-Curtis, Simpson's Evenness and proportions of dominant taxa. Community characteristics at exposure areas will be statistically compared to those at reference areas to determine the optimal approach for the final LTAMP at UKHM.

5.0 FISH MONITORING

5.1 Existing Conditions

Past studies conducted at UKHM (Sparling 2006; Sparling and Connor 1996) have focussed on relative fish abundance and community composition. According to a recent fish survey (Sparling 2006), fish communities in the vicinity of the UKHM are comprised of slimy sculpin (*Cottus cognatus*), Arctic grayling (*Thymallus arcticus*), round whitefish (*Prosopium cylindraceum*), Chinook salmon (*Oncorhyncus tshawytsha*), northern pike (*Esox lucius*), burbot (*Lota lota*) and Arctic lamprey (*Lampetra japonica*). Slimy sculpin and Arctic grayling are generally the most widely encountered species, both spatially and in terms of relative abundance, although densities of these species are low in most areas (Minnow 2009a).

Fish community comparisons between mine-exposed areas and reference areas located upstream of mine influence on the South McQuesten River (Stations KV1 and KV72) have shown no clear differences in overall fish species diversity (Minnow 2009a). In addition, relative fish abundance (based on CPUE[8]) at all mine-exposed creeks and downstream areas of the South McQuesten River were similar to or higher than at reference areas. Spatially, no clear differences in either species diversity or relative abundance were observed with distance from mine sources in individual watercourses, with the exception of lower fish diversity in Christal Creek at areas closest to the historical UKHM sources (Sparling 2006). Currently, it is unclear whether decreased fish diversity throughout much of Christal Creek and Flat Creek compared to downstream reaches (stations KV8 and KV9, respectively) is related to physical habitat conditions (i.e., barrier/log jams) or source area exposure (Sparling 2006).

Generally, fish health data from previous studies is restricted to length and weight. While slimy sculpin collected from mine exposed areas appeared to have reduced condition (weight-at-length) relative to reference area fish (KV-72), the age of the fish was unknown and so it is not possible to determine if such differences in condition were related to size-at-age differences. Fish tissue analysis has been conducted over time to assess metal concentrations in whole body slimy sculpin and muscle of Arctic grayling. Whole body analysis of slimy sculpin showed elevated concentrations of arsenic and lead in samples collected from Christal and Flat Creeks relative to wildlife benchmarks[9] (Minnow 2009a). However, Arctic grayling, which is of most interest recreationally and in terms of

[8] CPUE is Catch per unit Effort as reported in Sparling 2006.
[9] Wildlife benchmarks were established for piscivorous (fish eating) wildlife based on the most conservative food metal concentrations resulting in a NOAEL (Sample et al. 1996).

consumption, had muscle tissue concentrations below the consumption benchmark in almost all samples.

5.2 Considerations for Future Sampling

Monitoring of fish is justifiable for numerous reasons (Barbour et al. 1999):

- Fish are good indicators of long-term (several years) effects and broad habitat conditions (Karr et al. 1986).
- Fish assemblages generally include a range of species that represent a variety of trophic levels (omnivores, herbivores, insectivores, planktivores, piscivores) and contaminant sensitivities.
- Fish are at the top of the aquatic food web and are consumed by humans, making them important for assessing contamination.
- Fish are relatively easy to collect and identify to the species level. Most specimens can be sorted and identified in the field by experienced fisheries professionals, and subsequently released unharmed.
- Environmental requirements of many fish are comparatively well known. Life history information is extensive for many species, and information on fish distributions may also be available.
- Aquatic life uses (water quality standards) are typically characterized in terms of fisheries (coldwater, coolwater, warmwater, sport, forage). Monitoring fish provides direct evaluation of "fishability" and "fish propagation", which emphasizes the importance of fish to sport, subsistence, and commercial fishermen.
- Fish account for a large proportion of endangered vertebrate species and subspecies (Warren and Burr 1994).

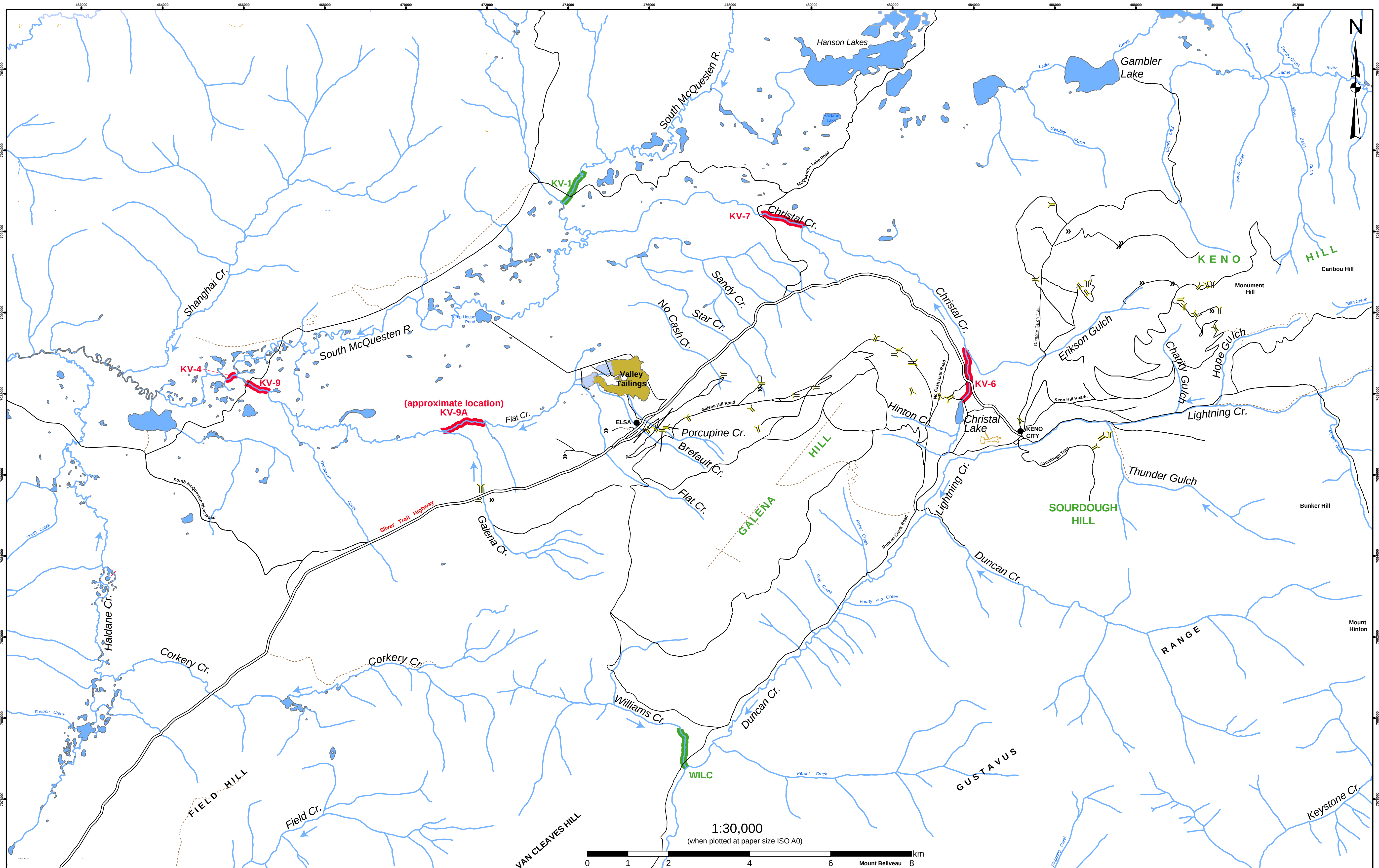
Monitoring of fish may include assessment of fish community composition, population health, tissue pathology, biochemical (biomarker) responses, and/or contaminant concentrations in tissues (EVS 1999). In the hierarchy of biological organization from the molecular to the ecosystem level, physiological processes affecting cellular and subcellular structure and function are generally the earliest responses to environmental stress (EVS 1999). However, sub-organism-level responses are more difficult to relate to community sustainability than direct measures or indicators of population or community health. Another consideration is that many measurements that are used to assess individual or population health necessitate that fish be sacrificed (e.g., to extract tissue samples, major organs, and/or bony ageing structures), which is undesirable in areas, such as those near the UKHM, where fish densities are naturally low.

As noted above (Section 5.1) previous monitoring of fish at UKHM has focussed on relative fish abundance and community composition among areas based on non-destructive sampling (catch-release). It can be technically challenging to implement community surveys quantitatively (e.g., Moran-Zippin population estimates) due to habitat conditions, such as those near the UKHM (e.g., stream size, depth, flow, and/or rocky substrate), that make it difficult to completely isolate fish within particular stream reaches by setting nets across the stream. Also, it is costly to achieve the level of station replication within areas that is necessary to make statistical comparisons of relative abundance among areas. Therefore, it is recommended that a semi-quantitative assessment of community composition be undertaken similar to those completed in previous years. Also, lengths and weights should be measured on all specimens caught to provide an indication of relative population health for each species in exposed versus reference areas. In particular, the recommended sampling effort may yield sufficient numbers of slimy sculpin to permit statistical comparisons among areas. More details are provided below.

5.3 Approach and Sampling Locations

As noted above, a traditional EEM fish survey will not be feasible for the UKHM. To date fish monitoring has been largely conducted using qualitative electrofishing and documenting the abundance and community structure. The recommended program has incorporated standardized fishing efforts to yield more comparable data between locations and over time.

Fishing should be conducted in mine-exposed areas in Christal Creek (KV-6 and KV-7), Flat Creek (KV-9 and KV9A) and in South McQuesten River (KV-1, KV-4; Figure 5.1). If reconnaissance of Flat Creek indicates that there are no fish in the reaches upstream of Galena Creek (KV-9A), then only KV-9 should be monitored instead. Selected mine-exposed areas represent key areas which are either: in close proximity to UKHM influence, of concern to First Nations people, and/or are located downstream of tributary inputs. Fishing within Lightning Creek has not been recommended because placer mining throughout the middle and lower reaches of the creek create turbid conditions which greatly hamper the ability to catch fish within these areas (i.e., the areas immediately downstream of Bellekeno discharge) and represent a substantial confounding influence. Fish communities should also be sampled in at least one reference area to provide the basis of comparison for mine-related exposed areas; consideration should be given to including a second reference area in



Proposed reference fish sampling areas

Proposed mine-exposed fish sampling areas

Legend

Mine Working		Topography	
Adit		Town	Trail
Shaft (to surface - connection to underground not determined)		Silver Trail	Watercourse
Valley Tailings		Secondary and Limited-use roads	Waterbody
Pit			Flow Direction

Figure 5.1

minnow environmental inc.

Proposed Fish Sampling Areas, United Keno Hill Mines

Ref: 2274
Date: April 2011

Source: Access Consulting Group

order to better understand the natural range of variability within the tributaries. Station KV-1 will serve as a reference area for KV-4 to allow for assessment of changes in fish community and abundance downstream of UKHM on the South McQuesten River.

Areas sampled should be as consistent as possible with respect to gradient, water velocity, depth, aquatic and riparian vegetation, and substrate type. In order to standardize the habitat between areas, sampling locations may need to be shifted up or downstream of the water quality station during the first survey of the LTAMP. Any such changes to locations should be documented with GPS coordinates recorded. Following the first survey, monitoring locations should be maintained in subsequent surveys.

5.4 Sample Schedule/Timing

Generally, the preferred sampling season for fish communities is late August/early September, when stream and river flows are moderate to low, and less variable than during other seasons. Although some fish species are capable of extensive migration, fish populations and individual fish tend to remain in the same area during summer (Funk 1957, Gerking 1959, Cairns and Kaesler 1971). Also, fish sampling will be most cost-effective in late summer, when it can be coordinated with benthic invertebrate sample collection.

5.5 Sampling Methods

Methods and fishing effort should be standardized among sampling areas so that valid comparisons between mine-exposed and reference areas can be made. Past surveys have shown that all habitats in the vicinity of UKHM are relatively unproductive (i.e., limited fish abundance), so every effort should be made to return fish unharmed to the areas in which they were caught. Fish should be collected using backpack electrofishing and Gee-type minnow traps. In each area, electrofishing should involve 900-1,000 seconds of shocking effort over a reach of approximately 100 m. Each area should be sampled by moving in an upstream direction and sweeping back and forth from shore to opposite shore (provided flow conditions permit crossing the channel). The electrofisher operator should be accompanied by another crew member who retrieves the fish with a dip net and holding bucket[10]. All fish collected should be held until the electrofishing has been completed to avoid recapturing the same fish. Also, ten minnow traps should be deployed overnight in each area but slightly upstream of the area being electrofished to avoid any disturbance caused by electrofishing and to avoid re-fishing the same area being electrofished. Minnow traps should be baited to

[10] Fish retrieval may be more efficient if there are two crew members with dip nets, but, if done, the same level of effort should be employed in all future surveys to ensure results can be compared among surveys over time.

attract a range of species. The same reaches should be fished in successive studies to make results comparable over time. The schedule and frequency of monitoring are discussed in Section 8.0.

5.6 Measurements, Endpoints, and Reporting

5.6.1 Fish Community

Conditions at the time of sampling must be recorded for each area (e.g., weather, water velocity, stream wetted width and mean depth, water clarity). Water temperature, conductivity, dissolved oxygen (concentration and percent saturation), and pH should also be recorded in each area. The upstream and downstream boundaries of each area (reach) that was electrofished should be determined using a GPS and recorded on field sheets, along with the duration of current deployment (total seconds of shocking time) and electrofisher settings. The GPS coordinates of each minnow trap should also be recorded on field sheets, along with set and lift times for each trap and the type of bait used. All fish caught should be identified and enumerated, and the lengths and weights of all specimens should be measured and recorded. Catch per unit effort (CPUE) will be calculated for each species and collection method based on the number caught per unit of time. For each area and fishing method, the total catch (all species), total number of each species, total and species biomasses (sum of body weights), and CPUE (each species) should be determined and reported. If sufficient numbers are available statistical comparisons of length and weight between reference and exposure locations should be conducted. Copies of field sheets that should note fish collections and conditions at the time of sampling (e.g., water velocities, stream width and depth and weather) should be provided in the report.

5.6.2 Slimy Sculpin Population Assessment

If sufficient numbers of slimy sculpin (*Cottus cognatus)* can be obtained in reference and exposure areas (e.g., minimum of 20 per area captured by electrofishing alone[11]), it is recommended that additional data analyses be completed to indicate relative population health among areas. Slimy sculpin is an appropriate species for a population survey because it:

- Is fairly widely distributed in the South McQuesten River and Duncan Creek watersheds, is more abundant than other fish species near UKHM (Minnow 2009a)

[11] Electrofishing is the most effective method for capture of slimy sculpin and it is desirable to base size-frequency distributions on fish captured by a single method to avoid gear selection bias in the results.

and it tends to have a small home range so it reflects localized conditions (Gray et al. 2004, Brasfield 2007).

- Reaches sexual maturity at approximately 3 years of age and has a life span of approximately 10 years (Coker et al. 2001, Scott and Crossman 1998) so it responds relatively quickly to changes in environmental conditions compared to populations of other longer-lived species.
- Feeds on immature aquatic insects such as mayflies (Ephemeroptera), caddisflies (Trichoptera), true flies (Diptera), stoneflies (Plecoptera) and dragonflies (Odonata; Scott and Crossman 1998, WMEC 2005). Sculpin is also preyed upon by large burbot and grayling (Scott and Crossman 1998, WMEC 2005). Therefore, this species is an integral component of the food web in surface waters near the UKHM.

Therefore, in addition to the endpoints identified in Section 5.6.1, weight relative to length (condition) should be reported for slimy sculpin caught by electrofishing. Fish age cannot be reliably determined without sacrificing the fish (e.g., using otoliths or other bony structures) so this will only be conducted on a subset (five fish) in each area which represents the various size ranges captured. In addition, length-frequency distributions should be plotted and ages determined applied to the various size ranges such that growth and condition may be compared between areas. Sample sizes permitting, area comparisons should be made using analysis of variance (ANOVA), analysis of co-variance (ANCOVA), or non-parametric equivalents, as appropriate. Young-of-the-year (YOY) should be evaluated separate from older fish. If enough YOY can be collected (i.e., 10 per area), it would be preferable to conduct size comparisons (statistical analysis) using only YOY so that these comparisons are not confounded by age differences. In addition, the data for each area should be compared to past studies results to assess potential changes over time.

5.6.3 Tissue Concentrations

Whole body concentrations should be measured on all slimy sculpin sacrificed from each area for age determination[12]. The suite of metals analyzed will be consistent with those measured in water and sediment (Tables 2.3 and 3.1). Since Arctic grayling muscle samples have shown concentrations below consumption benchmarks in almost all samples and the abundance of this species is low, it is not recommended that tissue sampling be continued for this species, unless water concentrations increase in the future.

[12] In order to obtain the aging structure (otolith) the head will need to be removed, thus whole body tissue concentration measures will be based on headless fish samples. However, it is unlikely that the head neither contributes significantly to the total concentration nor is the head generally consumed by people.

5.7 Summary

Fish tend to occupy the upper trophic levels of aquatic ecosystems and are often their most visible and valued components. Both population and community-level assessment can be used as indicators of longer-term exposure conditions (e.g., over years). Therefore, fish community composition and relative species abundances should be tracked at key near-field locations near the UKHM over time (Christal Creek, Flat Creek, and South McQuesten River) and compared to the communities at two areas possessing similar habitat characteristics (e.g., upper South McQuesten River [KV-1], and one smaller creek such as Williams Creek). The recommended methods for fish community characterization are similar to those used in previous surveys, including collection of fish by backpack electrofisher and minnow traps. Also, slimy sculpin populations will be assessed using indicators of population health such as mean length, mean weight, weight relative to length (condition), and length-frequency distributions (sample sizes permitting). If possible, the slimy sculpin survey will focus on YOY so that size comparisons are not confounded by age differences. The surveys will be conducted in late August/early September when water levels and velocity are most apt to be low to moderate and fish distributions relatively stable. Analysis of whole-body metal content in slimy sculpin will only be conducted on fish sacrificed for age determination (i.e., 5 per area). Once the first survey is complete, the methodology and scope of the program should be reviewed to ensure a feasible approach is implemented in the long-term.

6.0 QUALITY MANAGEMENT PLAN

A number of formal procedures, outlined herein, must be implemented to assure the quality of the LTAMP at UKHM. Such procedures include the establishment of organization and reporting channels, standard operating procedures (SOPs), requirements for training, data quality and quantity objectives, and a protocol for data quality assessment.

6.1 General Responsibilities, Controls and Reporting Channels

ERDC currently has responsibility for managing activities and monitoring at the UKHM complex. While responsibility for specific tasks may be delegated to other personnel or to contractors, someone within ERDC should be designated with overall responsible for the management and quality of the long-term monitoring, including routine water quality monitoring (on-going), comprehensive studies of aquatic ecosystem health (periodic), resources and support for training (as required), water quality database management (on-going), and data quality assurance (on-going). Responsibility for data quality includes managing and updating SOPs, monitoring and enforcing data quality control and assessment procedures, and periodic audits of field activities to ensure approved methods are being followed. To the extent such responsibilities are delegated, a reporting structure should be defined that clearly identifies names, contact information, and respective responsibilities and authorities. This structure should be clearly communicated to; individuals responsible for sample/data collection and management, INAC, YG, First Nations representatives and interested non-government organizations, updated as required, and included in annual water quality reports (Section 7.1) to ensure this information is broadly disseminated.

6.2 Training, Health and Safety Requirements

All staff and consultants involved in the LTAMP must be appropriately experienced and trained for their respective responsibilities (e.g., sample collection and handling; analyses; data entry; reporting etc.). If not already in place, a policy should be developed that clearly defines health and safety protocols and requirements for people conducting monitoring activities at the mine site, including any requirements for site safety induction.

6.3 Consistency (SOPs)

Consistency is an important component of a quality management program. To minimize field errors and to maintain quality and consistency in data handling for the LTAMP, SOPs should be developed, implemented, and updated as appropriate for such things as sample collection methods, the cleaning of sampling equipment before and after use, calibration and maintenance of field instruments, proper sample labelling, laboratory sample submissions (including chains of custody), data handling, and data quality control. In addition, a process and schedule for updating SOPs should also be developed. All current SOPs should be maintained in a centralized location accessible to all appropriate users. Any short-term changes to the specified methods should be documented in field notes, in the water quality database (water data only), and in reports in which the data are presented.

6.4 Overview and Definitions for Data Quality Assurance

Although the general intent and process for data quality assurance (DQA) has become increasingly standardized, the terminology and definitions used in controlling and describing the quality of environmental data varies among geographical locations, regulatory agencies, accreditation bodies, and practitioners. For the purpose of the monitoring conducted at the UKHM, the terminology and processes relating to data quality are defined below.

Quality assurance (QA) is a set of operating principles that, if strictly followed, will produce data with a quality that is defined and satisfies the intended use of the data. Included in QA are **quality control (QC)** and **data quality assessment (DQA).** Quality control involves special actions providing some measure of data quality. These measures provide a means to control the errors and variability associated with performance of sampling, analysis and reporting such that the data are appropriately accurate and precise to serve the purpose for which the data are being collected. Furthermore, it is desired that performance elements be controlled such that the variability observed in the data can be assumed to reflect real spatial or temporal variability. QC in an environmental monitoring program typically includes such elements as laboratory method detection limits for chemical analyses, collection and analysis of field and laboratory replicate samples, field and laboratory blank sample analysis, recovery of known additions (spikes), analysis of standard reference materials, etc.

Data quality objectives (DQOs) represent the performance expectations for QC elements. DQOs have been developed for the environmental monitoring program at UKHM (Section 6.5). These should be periodically reviewed and updated based on the results of data quality assessments conducted over time.

Data quality assessment (DQA) is the process of comparing actual field and laboratory performance to the DQOs to determine the overall quality of the data. The goal of data quality assessment is to identify any significant issues with the data (e.g., performance outside of accepted boundaries or data entry errors) and to take action in a timely and efficient manner to address errors and concerns. This will ensure that the data are associated with a defined level of quality and thus enhance the defensibility of the data in the context of its ultimate use.

Data validation is the additional process of applying preliminary statistical analyses to the data to identify any data points that fall outside expected limits (i.e., flagged data). Flagged data trigger additional assessment, and possibly re-sampling, to determine whether the result is valid or is the result of error or upset condition. All data must undergo data quality assessment and validation *prior* to use in statistical analysis and interpretation respecting the environmental conditions at the UKHM. This rigorous level of QA provides added confidence in the overall interpretation and conclusions of the program by ensuring that all data are defensible.

6.5 Laboratory Selection

Laboratories vary in their ability to consistently achieve specific DQOs, to follow up on any identified data issues, to produce clear and concise reports in formats that facilitate ready transfer of information to project databases, and in the costs charged for analyses. Therefore, it will be appropriate to do a thorough evaluation of candidate laboratories to select a preferred and back-up laboratory for each type of sample to be analyzed at the UKHM in the LTAMP. In all cases, candidate laboratories should be provided with relevant project DQOs, approximate annual sample quantities, requirements for data and QC reporting, and be invited to bid on the work. The laboratory should identify their capabilities with respect to relevant experience, available instrumentation, client service, QA/QC performance and reporting, and analytical costs. The laboratory should also identify if any of the requested analyses must be sub-contracted out to another location, whether it is a facility in the same or a different company.

Laboratory evaluation and selection should be done prior to the implementation of the LTAMP. Once selected, all site personnel and contractors should be required to submit all samples to the identified laboratories to ensure consistency in data quality and reporting and also minimize costs (i.e., to avail themselves of the negotiated pricing for UKHM).

Since personnel, equipment and pricing change over time, the selected laboratories should be periodically re-evaluated (e.g., approximately every 3 years prior to the implementation of periodic comprehensive biological surveys) by comparison to other laboratories following the process described above.

6.6 Data Quality Objectives and Quality Control

DQOs are statements of desired sensitivity, precision and accuracy in order to permit a defined level of confidence in drawing conclusions from the data of the entire monitoring program. DQOs established for the Faro complex serve as criteria for data acceptability and consider the intended use of the data and the technical feasibility of collecting data of such quality.

Assurance of adequate data quality is only possible when specific data uses and data quality objectives have been defined. Data quality objectives may pertain to factors such as sensitivity, precision, accuracy, comparability, compatibility, representativeness and completeness. Data quality objectives have been developed accordingly for chemical and biological measurements made as part of the LTAMP (Table 6.1). These data quality objectives include negligible contaminant levels in all blank samples, acceptable variability between field and laboratory duplicate samples, efficient recovery of laboratory matrix spike amounts and minimal bias in analytical estimates for certified reference materials. Each type of quality control sample is explained in more detail below.

6.6.1 Quality Control Sample Types

Quality control (QC) samples are taken in the field and in the laboratory. General guidelines for the type of quality control samples required to track and minimize the effects of bias and imprecision in the sampling effort are outlined below. The number of QC samples should correspond to a minimum of 10% of the total number of samples taken in the sampling period the QC samples are intended to represent. Quality control samples are integral to a quality assurance program, and recommendations for their use should be strictly adhered to. Types of QC samples that will be used in the LTAMP at UKHM are listed below.

Field (Bottle) Blanks: A field blank is a sample of distilled/de-ionized water that, at a randomly selected sampling location is placed in a container identical to those used for all environmental samples. Field blanks allow assessment of the potential contamination of the sample by the container itself, preservatives, dust, and sample handling. This type of sample is usually incorporated in water sampling programs, prepared by field personnel, and submitted to the laboratory with the other samples.

Field Duplicates: A field duplicate is a randomly selected sample that is taken at the same time and location as a regular field sample (i.e., side by side). The samples are prepared and analyzed in an identical manner. The data from field duplicate samples reflect the natural spatial variability, as well as the variability associated with sample collection and handling methods. These types of sample are applied in water, sediment, and tissue

Table 6.1: Data quality objectives for environmental samples, United Keno Hill Mines.

Quality Control Measure	Quality Control Sample Type/Check	Study Component			
		Water Quality	Sediment Quality	Benthic Invertebrate Community	Fish Tissue Quality
Method Detection Limits (MDL)	Comparison actual MDL versus target MDL	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	n/a	MDL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]
Blank Analysis	Field or Laboratory Blank	<two-times the laboratory MDL	two-times the laboratory MDL	n/a	n/a
Field Precision	Field Duplicates	25% RPD[b] between duplicates	40% RPD between duplicates	n/a	25% RPD between duplicates
Laboratory Precision	Laboratory Duplicates	25% RPD between duplicates	35% RPD between duplicates	n/a	20% RPD between duplicates
	Sub-Sampling Error	n/a	n/a	20% difference between sub-samples	n/a
Accuracy	Recovery of Certified Reference Material, QC Standards, Spiked Blanks	85-115%	75-125%	n/a	70-130%
	Matrix Spike	75-125%	75-125%	n/a	75-125%
	Organism Recovery	n/a	n/a	minimum 90% recovery	n/a
	Instrument Accuracy	n/a	n/a	n/a	n/a

[a] or below predictions, if applicable and no guideline exists for the substance.

[b] RPD - Relative Percent Difference

n/a - not applicable

chemistry sampling programs, and are collected by field personnel and submitted to the laboratory along with the other field samples.

Laboratory Blanks: A laboratory blank is a randomly selected laboratory analysis vial that is filled with distilled water and/or appropriate laboratory reagent(s) and then analyzed as a regular sample. The laboratory blank reflects any contamination associated with the analysis vial, laboratory reagents, or sample handling that may affect reported analyte concentrations. This type of QC sample may apply to water (common) or sediment (less common) sampling programs and is prepared, analyzed, and reported by the analytical laboratory.

Laboratory Duplicates: A laboratory duplicate is a sample that has been submitted for analysis and is randomly split in the laboratory into two sub samples that are analyzed independently. The laboratory duplicate sample results reflect the variability introduced during laboratory sample handling and analysis. This type of QC sample applies to water, sediment, and tissue chemistry sampling programs and is prepared, analyzed, and reported by the analytical laboratory.

Spike Recoveries: A spike involves the addition of a known quantity of chemical (e.g., metal) to an environmental sample (matrix spike) or blank sample (blank spike). The spiked sample is analyzed and the resulting chemical concentration is compared to the results for the unspiked sample to determine the percentage of the spike amount that was recovered in the analysis of the spiked sample. This type of QC sample applies to water, sediment, and tissue chemistry sampling programs. The samples are prepared, analyzed, and reported by the analytical laboratory.

Certified Reference Materials or QA Standards: Certified reference materials (CRM) or QA Standards have a known concentration of specified substance(s). The samples are prepared and analyzed in a manner identical to the field-collected samples. Analysis of these types of samples allows an assessment of analytical accuracy and allows for instrument calibration. This type of QC sample applies to water, sediment, and tissue chemistry sampling programs. The samples are prepared, analyzed, and reported by the analytical laboratory.

6.6.2 Quality Control for Chemical Analyses

Based on the above, DQOs for water samples have been established (Table 6.1), with further explanation provided below regarding how quality control is measured for comparison to DQOs.

Method detection limits (MDLs) are the smallest concentration of an analyte that can be measured with a defined certainty of being distinguishable from a blank sample. MDLs vary depending on the analyte, sample matrix, analytical method and instrumentation used. Analytical method detection limits for each analyte should be no higher than half the water quality guideline to which the data will be compared and preferably 1/10th that value or lower since analytical precision is reduced at concentrations approaching the MDL (McQuaker 1999). Target MDLs for UKHM samples should be periodically reviewed with the analytical laboratory responsible for the majority of sample analyses for the site and adjusted as appropriate to reflect any changes in laboratory methods or instrumentation, or the requirements of data users.

Blank samples should contain no quantifiable residue of any contaminants. To allow for a very small margin of error, the DQO for blank samples is sometimes set at twice the MDL routinely achieved for each analyte (also assuming MDL is sufficiently low, e.g., below relevant guidelines).

Precision is a measure of how closely replicate samples agree with one another. Precision can be expressed in various ways: as the standard deviation, relative standard deviation (RSD), or the relative percent difference (RPD) of replicate results. In the evaluation of environmental samples, the standard deviation (SD) alone is rarely used, because the magnitude of analyte concentration in samples usually influences the magnitude of standard deviation among samples and thus precludes setting a single SD as a data quality objective (DQO). Therefore, either the RSD or RPD method is preferred, because each expresses the variability among replicates relative to the arithmetic mean of replicate sample results (either field or laboratory replicate samples). In the case of two replicate samples (duplicates), RPD seems to be most frequently applied, and is used to estimate precision as follows:

Relative Percent Difference (RPD) of Duplicate Analyses

%RPD = 100 x ABS(A-B)/MEAN(A,B) (1) after Csuros (1997)

where: A is the result of the first analysis of a sample,

B is the result of the second analysis of a sample,

ABS (A-B) is the absolute value of the difference between duplicate results,

MEAN (A,B) is the arithmetic mean of duplicates A and B.

If, in the future, three or more replicate analyses become routinely incorporated in the LTAMP, all results should be expressed as RSD, according to the following:

Relative Standard Deviation (RSD) of Multiple Replicates

%RSD = 100 x s/ MEAN (replicates) (2) after Csuros (1997)

where: s is the standard deviation, and

MEAN (replicates) is the arithmetic mean of all replicate results.

It should be recognized that replicate analyses conducted on samples containing concentrations of substances approaching the MDL will tend to show less precision than samples containing concentrations more than five or ten times the MDL.

Accuracy is the degree to which a measured value agrees with the “true” (expected) value. Accuracy is generally expressed as percentage recovery (%R) of a known amount. For certified reference materials, the total analyte concentration in a sample matrix is known and therefore the percent recovery is calculated as shown in formula 3, below. For spiked samples, the spike amount is known and compared to the difference in total analyte concentration measured in spiked and unspiked samples (formula 4).

%R = 100 x measured value /known value (3) after Csuros (1997)

%R = $100(X_s – X_u)/K$ (4) after USEPA (in Patnaik, 1997)

where X_s = measured amount in the spiked sample,

X_u = measured amount in the unspiked sample, and

K = known spike amount.

The measured amount in an unspiked sample may be the result of a single analysis or the average of duplicate analyses.

6.6.3 Quality Control for Biological Samples

Requirements for **benthic invertebrate** data quality assurance include:

- documentation of study design and objectives;
- documented standard operating procedures for field and laboratory work;
- use of appropriately qualified and trained personnel for sample collection;

- use of a qualified laboratory for benthic invertebrate sorting and taxonomic identifications;
- documentation of data quality objectives and performance;
- an average of 95% recovery of invertebrates from samples with no samples having less than 90% recovery;
- calculation of the error associated with any subsampling techniques by examining a minimum of 10% of samples to verify that sub-sampling accuracy and precision are within 20%;
- archiving of sorted invertebrates and bench sheets until the study report has been completed and undergone any external technical review; and
- compilation of a voucher (reference) collection.

Minimum requirements for assurance of **fish data** quality are:

- documentation of study design and objectives;
- documented standard operating procedures for field and laboratory work;
- use of appropriately qualified and trained personnel for sample collection;
- use of instruments that allow for measurement of length and weight (whole body or tissues) with an accuracy of 10% or less;
- use of a qualified laboratory for analysis of fish ages; and
- submission of approximately 10% of age structures to a separate laboratory for third-party verification.

6.7 Data Quality Assessment

In order to assess whether the overall quality of the LTAMP is assured, formal data quality assessment (DQA) procedures must be utilized. The overall objective of a quality assurance program is to control measurement errors to acceptable levels and to ensure, therefore, that the data are useful and of known quality. DQA will involve evaluation of the requirements discussed in Section 6.6, with guidance on how to do so presented below.

6.7.1 Water Quality Data

For water monitoring, DQA should be undertaken monthly on an informal basis and annually on a more formal basis. The informal monthly assessment will be geared to pinpointing and correcting errors, while the Annual Water Quality Report will involve formal quality assurance reporting (see Section 7.1). The detailed processes for detecting data quality anomalies will depend on the capabilities of the database utilized for long-term information storage and management. Formal reporting will be based on a direct comparison of QC sample results with the objectives specified in Table 6.1. Data quality assessment reports prepared during this formal assessment will include the QC data (including the results of blanks and the precision and accuracy achieved) and an Annual Water Quality Report summarizing the significant findings. Formal quality assurance reporting will also include an assessment of the implications of not having met specific data quality objectives, if applicable, and recommendations for improvement. Formal quality assurance reports must be reviewed by the person responsible for managing/coordinating the environmental monitoring program, then filed as part of the long-term quality assurance record of the monitoring program and included with the Annual Water Quality Reports (Section 7.1). This will provide data users with a consistent record of data quality and can be used to determine the cause of any inconsistencies. It would be unrealistic to expect that the DQA processes for water samples described above can be implemented immediately. A schedule should be developed to allow for the coordination and phasing in of the various requirements.

6.7.2 Sediment

The DQA for sediment should follow a similar process to that described for water data, including evaluation of the MDLs, field precision, and analytical precision and accuracy relative to the DQOs established for the program (Table 6.1). The information should be documented in all Comprehensive Aquatic Ecosystem Study Reports that include sediment quality monitoring.

6.7.3 Fish Tissue

The DQA for fish tissue should follow a similar process to that described for water and data, including evaluation of the MDLs, field precision, and analytical precision and accuracy relative to the DQOs established for the program (Table 6.1). The information should be documented in all Comprehensive Aquatic Ecosystem Study Reports that include fish quality monitoring.

6.7.4 Biological Data

The quality of the biological data will be evaluated on the basis of the information listed in Section 6.6.3. The information should be documented in all Comprehensive Aquatic Ecosystem Study Reports that include the corresponding biological components (e.g., benthic invertebrates and fish data).

7.0 REPORTING

It is expected that two types of reports will be prepared for documenting the results of the LTAMP. These include Annual Water Quality Reports and Comprehensive Aquatic Ecosystem Study Reports related to aquatic ecosystem monitoring. Annual Reports (Section 7.1) should report concentrations (and loadings where applicable) relative to water quality guidelines and previous years, as well as any issues encountered (e.g., missed samples, data quality problems, etc., as outlined in Section 6.0). Surface water data should also be summarized in a five-year comprehensive report, where interpretation can be integrated with the results of biological surveys (Section 7.2). If the first few cycles of monitoring (e.g., 9-12 years of monitoring on a 3-year cycle) confirm that historical mine-related impacts are minor and that conditions continue to be relatively stable (e.g., after closure) it would be appropriate to reduce the frequency of comprehensive monitoring, with a trigger in place (Section 8.0) to increase the frequency based on specific increases in the loadings of key mine-related substances or any biological surveys that clearly show degradation relative to previous surveys.

The contents of each type of report are described in the following sections.

7.1 Annual Water Quality Reports

The objective of Annual Water Quality Reports is to regularly assess and report current water quality conditions relative to water quality criteria and past results (e.g., any trends or step changes), so that any step-changes in condition are detected promptly, and to demonstrate to stakeholders that the ecological monitoring is being implemented competently and conditions at the site are being adequately managed. The report will present the surface water quality monitoring results obtained over the previous year and will include the following information:

- locations and dates monitored;
- samples collected at each station and methods employed;
- data quality assessment methods and results;
- explanation of outliers found through data validation and action taken as a result;
- results for surface water monitoring including;
    - tables that compare measured concentrations against applicable benchmarks (e.g., CWQG or background concentrations);

  - o graphs to show changes in the concentrations of key endpoints over time at each station;

- description(s) of any additional water quality monitoring planned or implemented; and,
- recommendations for potential changes to the program and associated rationale.

Should subsequent source area and perimeter monitoring programs be developed for UKHM as part of a larger long-term monitoring network, then the results of these programs should also be included in the Annual Water Quality Report. The report should present the data in a clear and concise manner, with detailed data presented in appendices as required. Statistical analysis, if any, and data interpretation should be brief and limited to key observations; more detailed assessment will be done in periodic comprehensive study reports. A template should be developed in the first year of preparation to establish the format to be followed for subsequent annual reports. The potential need for an alternate format for reporting to First Nations should also be determined at that time and developed, if required.

7.2 Comprehensive Aquatic Ecosystem Study Reports

The Comprehensive Aquatic Ecosystem Study Reports will summarize the water quality data collected since the previous study was completed highlighting any significant issues or finding reported in the Annual Water Quality Reports completed during that time. The comprehensive study of the LTAMP (biota, sediment and water) should be implemented every three years unless the findings from the previous survey indicate a change to the schedule is warranted[13]. In addition, the results of sediment and biological surveys (benthic invertebrate and fish) will be presented with an integrated interpretation, conclusions, and recommendations. Specifically, the reports will include the following information:

- descriptions of the methods used in each component of the program;
- review of quality control procedures and data quality assessment;

[13] If the first few cycles of post-closure monitoring (e.g., 12 years of monitoring on a 3-year cycle) indicate that mine-related impacts associated with the closed properties of UKHM have declined or that conditions are stable, it would be appropriate to reduce the frequency of comprehensive monitoring (e.g., once every 6 years), with a trigger identified in the Final LTAMP to increase the frequency based on specific increases in the loadings/concentrations of key mine-related substances or any biological surveys that clearly show degradation relative to previous surveys and associated with historical UKHM sources.

- presentation of the results of all monitoring components including summary information (main body of the report) and raw data (appendices);
- integration of the results of water and sediment chemistry with the biological community (fish and benthos) to identify and evaluate relationships;
- assessment of spatial and temporal changes in the receiving environment since the previous study;
- assessment of the conditions in the receiving environment relative to predicted changes; and
- recommendations for any changes to subsequent monitoring cycles.

8.0 SUMMARY AND IMPLEMENTATION SCHEDULE

8.1 Overall Framework

The goal of the Long-Term Aquatic Monitoring Program (LTAMP) is to track conditions relative to the predicted closure conditions following mitigation and remediation measures and to be able to discern the additional influence of mine operations and discharges planned for the future. The design and scope of the program will need to be sufficiently robust to allow for these influences to be quantitatively defined.

The initial scope of the LTAMP should reflect the current magnitude and spatial extent of mine-related effects (Minnow 2008, 2009a). The frequency of monitoring must be sufficient to provide early warning of changes, particularly degradation, so that appropriate responses can be made (e.g., changes to monitoring, mitigation, or remediation). Similarly, reductions in the scope or frequency of monitoring should be considered in response to improving conditions.

The approach and framework for the aquatic ecosystem monitoring program presented in this document can be a template for developing the approach and framework for other monitoring programs at UKHM such as source area monitoring and perimeter monitoring.

8.2 Interim Long-Term Aquatic Monitoring Program

The Interim LTAMP will integrate biological and chemical information for a weight-of-evidence approach, including the following components:

- water chemistry,
- hydrology (flow),
- sediment chemistry[14],
- benthic invertebrate community monitoring, and
- fish community and population assessment.

However, before the details of a final LTAMP can be fully developed for all of the components, additional information on the benthic and fish communities and water and sediment quality is required in order to provide a robust design that achieves the programs objectives. The benthic study design alternatives evaluation (draft completed in June 2011)

[14] Sediment toxicity testing will be included in the first comprehensive survey at the same stations where sediment chemistry is monitored to determine the need for retaining sediment sampling within the final LTAMP.

can be used to update the benthic study design presented herein. Additional water quality monitoring data using recommended parameter lists, stations and method detection limits (MDLs) will need to be collected over at least two years of regular sampling to produce a robust enough dataset for further evaluation and program rationalizations. In addition, sediment chemistry and toxicity will need to be conducted at selected stations before it can be determined whether sediment monitoring should be included or excluded from the LTAMP. Finally, it is recommended that the fish study recommended herein be conducted at least once to determine whether methods proposed can be successfully implemented at UKHM.

Once the additional information has been compiled (i.e. after two years of monitoring), it may be used to finalize the LTAMP.

8.2.1 Surface Water Quality and Flow

Water quality monitoring is important as water is the main vector for off-site transport of contaminants and can be monitored frequently to serve as an early warning indicator of changing conditions. Based on a review of existing surface water monitoring stations and available water quality data, 19 water quality stations are recommended (KV-1, KV-2, KV-3, KV-4, KV-5, KV-6, KV-7, KV9A, KV-9, KV-37, KV-38, KV-41, KV-60, KV-61, KV-64, KV-65, KV-72, WILC and FIEC; Table 8.1). These stations include near-field, far-field and reference areas and encompass the current spatial extent of mine influence on surface water quality. The interim LTAMP will include measurement of 30 substances and *in situ* variables which represent either substances which have been shown to be indicators of mine influence or substances for which there was insufficient information to fully evaluate their relevance for future monitoring (too few data or high method detection limits). Measurements will be made on total (not filtered) samples since water quality guidelines are based on total concentrations. In addition it is recommended that flow (discharge m^3/sec) be measured at Christal Creek (KV-7), Flat Creek (KV-9), Lightning Creek (KV-41) and in the South McQuesten River (KV-4).

Water samples will be collected once per month during the ice-free period, at least once during the ice-on period and, if possible, at the onset of at least one substantial run-off event (precipitation) per year (following a dry period).

8.2.2 Sediment Quality

The receiving environment downstream of UKHM is generally erosional and deposits of fine sediments are typically sparse and patchy. Therefore, exposure to sediments by biota is likely quite limited. However, concentrations of several metals (arsenic, cadmium, lead,

Table 8.1: Summary of recommended LTAMP monitoring locations.

Watershed	Location	Water Quality	Flow (m^3/sec)	Sediment[h]	Benthos[j]	Fish
Lightning Creek[a]	KV-37	X		X	X	
	KV-38	X		X	X	
	KV-65[e]	X				
	KV-41	X	X			
Christal Creek	KV-6	X		X	X	X
	KV-7	X	X	X	X	X
Flat Creek	KV-61[g]	X				
	KV-64	X				
	KV-60[f]	X				
	KV-9A[b]	X		X	X	X
	KV-9	X	X	X	X	X
South McQuesten River	KV-72[i]	X				
	KV-1	X		X	X	X
	KV-2	X				
	KV-3	X			X	
	KV-4	X	X	X	X	X
	KV-5	X				
Williams Creek	WILC	X		X	X[c]	X[d]
Field Creek	FIEC	X		X	X[c]	
Additional Reference Areas	to be determined				X[c]	

[a] Extensive placer mining along Lightning Creek confounds evaluation of the relative influence of UKHM and associated turbidity makes fish capture difficult. Therefore, limited ecological sampling is proposed.
[b] a reconnaissance survey from the Valley Tailings Area to KV-9 will determine the location of a possible water quality, benthos, and/or fish monitoring station upstream of the confluence with Galena Creek.
[c] selection of benthic reference areas is pending completion of the 2009 Benthic Study Design Evaluation.
[d] one tributary reference area should be selected and included in the LTAMP. Consideration should be given to adding a second reference area in order to better capture the natural range of variability.
[e] station on Thunder Gulch, a tributary of Lightning Creek
[f] station on Galena Creek, a tributary of Flat Creek
[g] station on Porcupine Creek, a tributary of Flat Creek
[h] sediment toxicity testing should be conducted at sediment monitoring station during the first comprehensive survey.
[i] once tributary reference stations are established, KV-72 could be removed from the LTAMP.
[j] recommended benthic monitoring stations will be confirmed in the final LTAMP following the incorporation of the findings of the Benthic Study Design Evaluation (Minnow in prep.)

manganese, and zinc) have been substantially elevated relative to background levels and sediment quality guidelines downstream of UKHM such that even limited exposure to these sediments may affect resident biota. Therefore, sediment monitoring should be incorporated into the Interim LTAMP. It is recommended that sediment chemistry and toxicity be collected from Christal Creek (KV-6 and KV-7), Flat Creek (KV-9A and KV-9), the South McQuesten River (KV1, KV-4), Lightning Creek (KV-37 and KV-38), and from two reference stations (WILC and FIEC) (Table 8.1). This information can then be used to determine the relevance of elevated sediment concentrations to biota and then the need for sediment monitoring within the LTAMP.

Chemical analyses of sediment will include percent moisture, particle size distribution (whole sediment), total organic carbon (TOC), TKN, and TP and metal content. Metals selected for analysis were either elevated in sediment samples in earlier studies or have been elevated in water samples (Minnow 2008, 2009a). In addition, sediment toxicity testing will also be conducted at the same stations selected for sediment chemistry monitoring. These sediments will be tested for chronic effects on survival and growth using the amphipod *Hyallela azteca* over a 14-day exposure period (Environment Canada 1997).

Should sediment be incorporated into the final LTAMP then sediment surveys are to be repeated and reported at predetermined intervals as described in Section 8.2.6.

8.2.3 Benthic Invertebrate Communities

Benthic invertebrates are good, community-level integrators of localized conditions over time, they are important components of aquatic food webs and there are standardized methods for their collection and evaluation. Therefore, benthic invertebrate community monitoring will be an important component of the LTAMP. In the past, benthic community assessments at the UKHM have relied on deployment of artificial substrates, which have the advantage of controlling for natural differences in substrate among exposed and reference areas, but may bias collections toward organisms that happen to drift from upstream and colonize on the substrates over the short (typically 6-week) period they are deployed. The recent Water Licence specifies the use of a Hess sampler for benthic community assessment and the first study under the licence was conducted in August 2009.

To determine the best long-term approach for benthic community monitoring, a comparative evaluation was conducted synoptic with Hess collections under the Water Licence in 2009. The study compared the effectiveness of two design options, RCA versus Control-Impact, as well as two sampling methods (kick and sweep versus Hess; Minnow 2011a). The LTAMP should be updated to incorporate the recommendations of this report.

It is expected that future benthic macroinvertebrate surveys will be done in the mid to late summer, consistent with previous surveys and that these surveys will be repeated and reported at predetermined intervals as described in Section 8.2.6.

8.2.4 Fish

Fish tend to occupy the upper trophic levels of aquatic ecosystems and are often their most visible and valued components. Both population and community-level assessment can be used as indicators of longer-term exposure conditions (e.g., over years). Therefore, fish community composition and relative species abundances should be tracked at key near-field locations near the UKHM over time (Christal Creek, Flat Creek, and South McQuesten River) and compared to the communities at reference areas possessing similar habitat characteristics (e.g., KV-1 for comparison of the downstream areas of the South McQuesten River, as well as Williams Creek and/or Field Creek for evaluation of tributary fish communities; Table 8.1). The recommended methods for fish community characterization are similar to those used in previous surveys, including collection of fish by backpack electrofisher and minnow traps, although a standardized effort has been recommended for each area. Also, slimy sculpin populations should be assessed using indicators of population health such as mean length, mean weight, weight relative to length (condition), and length-frequency distributions (sample sizes permitting). If possible, the slimy sculpin survey will focus on YOY so that size comparisons are not confounded by age differences. Analysis of whole-bodied metal content in slimy sculpin will be conducted on all fish sacrificed for age determination (i.e., five per area). Once the first survey is complete, the methodology and scope of the program should be reviewed to ensure a feasible approach is implemented in the long-term.

Sampling will be done in mid- to late summer, when stream and river flows are moderate to low, and less variable than during other seasons. Also this timing corresponds with collections of sediment and benthic invertebrate samples. Similar to sediment and benthic monitoring, fish surveys are to be repeated and reported at predetermined intervals as described in Section 8.2.6.

8.2.5 Quality and Safety Management Plan

A number of formal procedures must be implemented to assure the quality and integrity of data produced by the monitoring programs at UKHM. This includes clearly defining and communicating responsibilities and reporting channels, as well as sample collection protocols. Standard operating procedures (SOPs) should be developed, implemented, and updated as appropriate for such things as sample collection methods, the cleaning of sampling equipment before and after use, calibration and maintenance of field instruments, proper sample labelling, laboratory sample submission procedures (including chains of custody), data handling, and data quality control. Quality control samples (e.g., blank samples, replicate samples, and matrix spike recoveries) need to be collected and evaluated relative to pre-defined data quality objectives and reported. Specific quality assurance-quality control (QA-QC) requirements have been outlined for each component of the LTAMP.

8.2.6 Schedule and Reporting

Monitoring of water quality at surface water stations will be on-going to provide regular assessment of conditions and adequate warning of any substantial changes. Such data will be formally reported in Annual Water Quality Reports. Annual Reports should present concentrations (and loadings where applicable) relative to previous years, and identify any issues encountered since the previous reporting period (e.g., missed samples, data quality problems, etc.).

Biological data (e.g., benthic invertebrates and fish) will be assessed and reported at a lower frequency in Comprehensive Aquatic Ecosystem Study Reports. A three-year monitoring interval is recommended post-closure, consistent with the gradual change expected in water quality over time and an appropriate time interval over which measurable biological change may be detectable. Surface water data reported in Annual Reports should also be summarized in the Comprehensive Reports, where interpretation can be integrated with the results of biological surveys. If the first few cycles of post-closure monitoring (e.g., 12 years of monitoring on a 3-year cycle) indicate that mine-related impacts have declined or that conditions are stable, it would be appropriate to reduce the frequency of comprehensive monitoring (e.g., once every 6 years), with a trigger identified in the final LTAMP to increase the frequency again based on specific increases in the loadings or concentrations of key mine-related substances or any biological surveys that clearly show degradation relative to previous surveys.

8.2.7 Triggers for Change

Future increases or decreases in the scope and/or frequency of aquatic ecosystem monitoring should be based on the findings of Annual Water Quality Monitoring Reports or Comprehensive Aquatic Ecosystem Study Reports. Formal acceptability criteria and mechanisms for change in scope and response to change (triggers) should be incorporated into the final LTAMP. These criteria and triggers should be developed by UKHM and its stakeholders (i.e., regulators and First Nations) such that all parties have agreed upon decision points and methods for modifying the program. Through the incorporation of triggers, the monitoring program can be reduced over time as conditions improve or conversely a response can be implemented should unexpected (i.e. worse) conditions occur. This allows the program to be flexible and responsive to the study findings. For example, a trigger to expand the spatial extent or frequency of monitoring (i.e., add a downstream station or conduct another study sooner than formerly scheduled) might be predicated on directly observing biological effects or a step-change increase in contaminant concentrations that could be expected to adversely affect biota downstream. Similarly, triggers should be developed to discontinue monitoring either for specific substances or at locations based on conditions achieving predefined acceptability criteria (i.e. water quality criteria or natural range of background). This approach will ensure the LTAMP is appropriately scoped relative to current conditions and can be modified in response to any future improvements or degradation.

9.0 REFERENCES

APHA (American Public Health Association). 1998. Standard Methods for the Examination of Water and Wastewater, Twentieth Edition. Clesceri, L.S., Greenberg, A.E., Eaton, A.D. (Editors). Prepared and published jointly by American Public Health Association, American Water Works Association and Water Environment Federation. Washington, D.C., USA.

Bailey, J.C., T,B. Reynoldson and R.C. Bailey. 2007. Reference Condition Approach Bioassessment of Yukon River Basin Placer Mining Streams Sampled in 2006. Prepared for the Mining and Petroleum Environment Research Group. MPERG Report 2007-2. March 2007.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

BCMOE (British Columbia Ministry of Environment). 2006. British Columbia Approved Water Quality Guidelines (Criteria), 2006 Edition. Updated August 2006.

Bernstein B. B. and Zalinski J. 1983. An optimum sampling design and power tests for environmental biologists. J. Environ. Manag. 16: 335-343.

Bowman, M.F. and K.M. Somers. 2005. Considerations when Using the Reference Condition Approach for Bioassessment of Freshwater Ecosystems. Water Qual. Res. J. Canada 40(3): 347-360.

Branton, M.A., Manson, M.M., and Galbraith, R.V. 2006. Application of the Canadian Aquatic Biomonitoring Network and reference condition approach to Canada's Pacific Wild Salmon Policy. Can. Manuscr. Rep. Fish. Aquat. Sci. 2770: v + 29p.

Brasfield, S. 2007. Investigating and interpreting reduced reproductive performance in fish inhabiting streams adjacent to agricultural operations. PhD Thesis, University of New Brunswick, Saint John, NB.

Burns, B., 1996. Biological Monitoring Survey at United Keno Hill Mine Area, 1994. Laberge Environmental Services, Whitehorse, YT, 1996.

Burns, B., 2005. Keno Valley Receiving Water Monitoring Program, 2004/2005. Laberge Environmental Services, Whitehorse, YT, March 2005.

Burns, B., 2008. Keno Valley Stream Sediment and Benthic Invertebrate Monitoring Programs, 2007. Laberge Environmental Services, Whitehorse, YT. March 2008.

Cairns, J., Jr. and R.L. Kaesler. 1971. Cluster analysis of fish in a portion of the Upper Potomac River. *Transactions of the American Fisheries Society* 100:750-756.

Campbell, P.G. 1995. Interactions between trace metals and aquatic organisms: A critique of the free-ion activity model. In Tessier A, Turner DR, eds, *Metal Speciation and Bioavailability in Aquatic Systems.* John Wiley, New York, NY, USA, pp 42–102.

CCME (Canadian Council of Ministers of the Environment). 1998. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment, Winnipeg.

CCME (Canadian Council of Ministers of the Environment). 1999. Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg

Coker, G.A., C.B. Portt, and C.K. Minns. 2001. Morphological and Ecological Characteristics of Canadian Freshwater Fishes. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2554. Fisheries and Oceans Canada.

Csuros, M. 1997. Environmental Sampling and Analysis: Lab Manual. Lewis Publishers, Boca Raton.

Davidge, D. and G. Mackenzie-Grieve, 1989. Environmental Quality of Receiving Waters at United Keno Hill Mines Ltd., Elsa Yukon. Regional Program Report No. 89-04. Department of Environment, Environmental Protection, Pacific Region, Yukon Branch. September 1989.

Deaver, E. and J.H. Rodgers. 1996. Measuring bioavailable copper using anodic stripping voltammetry. Environ. Toxicol. Chem. 15:1925-1930.

DiToro, D.M., J.A. McGrath, D.J. Hansen, W.J. Berry, P.R. Paquin, R. Mathew, K.B. Wu, and R. Santore. 2005. Predicting sediment metal toxicity using a sediment biotic ligand model: methodology and initial application. Environ. Toxicol. Chem. 24:2410-2427.

Ellis, J.I. and D.C. Schneider. 1997. Evaluation of a gradient sampling design for environmental impact assessment. Environmental Monitoring and Assessment 48:157-172.

Environment Canada. 1994. Guidance Document on Collection and Preparation of Sediments for Physicochemical Characterization and Biological Testing. Report EPS 1/RM/29. December 1994.

Environment Canada. 1997. Biological Test Method: Test for Survival and Growth in Sediment Using the Freshwater Amphipod *Hyallel azteca*. EPS 1/RM/33. December 1997.

Environment Canada. 2002. Metal Mining Guidance Document for Aquatic Environmental Effects Monitoring. Environment Canada Report EEM/2002/1. June 2002.

ESG International Inc. 1999. Aquatic Effects Technology Evaluation (AETE) Program Synthesis Report of Selected Technologies for Cost-Effective Environmental Monitoring of Mine Effluent Impacts in Canada (AETE Synthesis Report). Prepared for Canada Centre for Mining and Energy Technology, Ottawa, Ontario. March, 1999.

EVS Environmental Consultants. 1997. Technical Evaluation: Water Quality and Biological Effects. Prepared for Canada Centre for Mining and Energy Technology (CANMET) and Mining Association of Canada (MAC) for the Aquatic Effects Technology Evaluation (AETE) Program. May, 1997.

EVS Environmental Consultants. 1999. Technical Evaluation of Fish Methods in Environmental Monitoring for the Mining Industry in Canada: Final. Prepared for Aquatic Effects Technology Evaluation (AETE) Program, Canada Centre for Mining and Energy Technology (CANMET), Ottawa, Ontario. February 1999.

Feltmate, B.W., and B.G. Fraser. 1999. Determining Metal Related Impacts Utilizing Benthic Macroinvertebrate Population Level Fitness Endpoints: Discussion Paper. Prepared for Canada Centre for Mining and Energy Technology (CANMET) and Mining Association of Canada (MAC) for the Aquatic Effects Technology Evaluation (AETE) Program. February 1999.

Funk, J.L. 1957. Movement of stream fishes in Missouri. *Transactions of the American Fisheries Society* 85:39-57.

Gerking, S.D. 1959. The restricted movement of fish populations. *Biological Review* 34:221-242.

Golder Associates Ltd. 1995. Review of Artificial Substrates for Benthos Sample Collection. Sponsored by the Canada Centre for Mineral Technology (CANMET) and the Mining Association of Canada on Behalf of the Aquatic Effects Technology Evaluation (AETE) Program. Project 2.1.1. June 1005.

Gray, M.A., R.A. Cunjak, and K.R. Munkittrick. 2004. Site fidelity of slimy sculpin (Cottus cognatus): insights from stable carbon and nitrogen analysis. Can. J. Fish. Aquat. Sci. 61:1717-1722.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. Wiley, New York.

Horowitz, A.J., K.R. Lum, J.R. Garbarino, G.E.M. Hall, C. Lemieux, and C.R. Demas. 1996. Problems associated with using filtration to define dissolved trace element concentrations in natural water samples. Environ. Sci. Technol. 30:954-963.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. *Assessing biological integrity in running waters: A method and its rationale.* Special publication 5. Illinois Natural History Survey.

Kilgour, B.W., K.M. Somers, and D. R. Barton. 2004. A comparison of the sensitivity of stream benthic community indices to effects associated with mines, pulp and paper mills, and urbanization. Environ. Toxicol. Chem. 23:212-221.

McKay, D., S. Sharpe, T. Cahill, T. Gouin, I. Cousins, and L. Toose. 2001. Assessing the Environmental Persistence of a Variety of Chemical Substances Including Metals. Prepared for Environment Canada. November 2001. CEMC Report No. 200104.

McQuaker, N.R. 1999. Technical Evaluation on Sample Collection, Handling, Analysis and Interpretation for Trace Level Contamination in Water. Edited by C. Dumaresq, Environment Canada. Prepared for Natural Resources Canada, Canada Centre for Mineral and Energy Technology, Ottawa, Ontario. January 1999.

Minnow Environmental Inc. 2008. Water Quality Assessment Report for United Keno Hill Mines. Prepared for Elsa Reclamation and Development Company, Whitehorse, YT, July 2008.

Minnow Environmental Inc. 2009a. Aquatic Resource Assessment Report for United Keno Hill Mines. Prepared for Elsa Reclamation and Development Company, Whitehorse, YT, March 2009.

Minnow Environmental Inc. 2009b. Interim Environmental Monitoring Program: Vangorda Creek (2007) and Rose Creek (2008). Prepared for Assessment and Abandoned Mines Branch, Energy Mines and Resources, Whitehorse Yukon. June 2009.

Minnow Environmental Inc. 2011a. Evaluation of Study Design Alternatives for Benthic Community Assessment at United Keno Hill Mines. Prepared for Elsa Reclamation and Development Company, Whitehorse, YT, June 2011.

Minnow Environmental Inc. 2011b. Approach for Developing Water Quality Goals for United Keno Hill Mines. Prepared for Elsa Reclamation and Development Company, Whitehorse, YT, June 2011.

OMOE (Ontario Ministry of the Environment), 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario, 1993.

OMOE (Ontario Ministry of Environment and Energy). 1994. Policies, Guidelines, Provincial Water Quality Objectives of the Ministry of the Environment and Energy (Ontario), July 1994.

Ongley, E.D. 1996. Control of water pollution from agriculture - FAO irrigation and drainage paper 55. Chapter 2: Pollution by Sediments. Food and Agriculture Organization of the United Nations, Rome, 1996.

Osenberg, C. W., and R. J. Schmitt. 1996. Detecting ecological impacts caused by human activities. Pages 3-16 in C. W. Osenberg and R. J. Schmitt, editors. Detecting ecological impacts; concepts and applications in coastal habitats. Academic Press, San Diego, California, USA.Patnaik, P. 1997. Handbook of Environmental Analysis: Chemical Pollutants in Air, Water, Soil, and Solid Wastes. Lewis Publishers, Boca Raton.

Patnaik, P. 1997. Handbook of Environmental Analysis: Chemical Pollutants in Air, Water, Soil, and Solid Wastes. Lewis Publishers, Boca Raton.

Pentz, S.B. and Kostaschuk, R.A. 1999. Effect of placer mining on suspended sediments in reaches of sensitive fish habitat. Environmental Geology, 37:78-89.

Prothro, M. 1993. Technical Memorandum Regarding Office of Water Policy and Technical Guidance on Interpretation and Implementation of Aquatic Life Metals Criteria. U.S. Environmental Protection Agency. October 1, 1993. 40CFRS131.36(b)(1). Available at: http://www.epa.gov/waterscience/library/wqcriteria/metalsinterpret.pdf

Reynoldson, T. B., Norris, R.H., Resh, V.H., Day, K.E. and Rosenberg, D.M. 1997. The reference condition approach: a comparison of multimetric and multivariate approaches to assess water-quality impairment using benthic macroinvertebrate. J. North Am. Benthol. Soc. 16:833-852.

Reynoldson, T.B., C.I. Brereton, W. Keller, and C. Sarrazin-Delay. 2005. Development of a Northern Ontario Benthic Invertebrate Reference Condition Approach (RCA) Biomonitoring Network to Meet Metal Mining Environmental Effects Monitoring Requirements (DRAFT). January 2005.

Rosenburg, D.M., T.B. Reynoldson, P.F. Reece, and V.H. Resh. 1998. Design of a Regional Biomonitoring Program for the Fraser River Basin. FRAP Report No. DOE FRAP 1998-32.

Sarrazin-Delay, C.L., M.F. Bowman, W. Keller, and K.M. Somers. 2006. Summary of the Model-Building Results for the Northern Ontario Benthic Invertebrate RCA Biomonitoring Initiative: 2003-2006.

Scott, W.B. and E.J. Crossman. 1998. Freshwater Fishes of Canada. Galt House Publications, Oakville, Ontario.

Smith, E.P., D.R. Orvos, and J. Cairns, Jr. 1993. Impact assessment using the before-afterontrol-impact (BACI) model: concerns and comments. Canadian Journal of Fisheries and Aquatic Sciences 50:627-637.

Sparling, P.and M. Connor, 1996. Fish and Fish Habitat Assessment Conducted Near Elsa, Yukon for United Keno Hill Mines August 1994 – September 1995. White Mountain Environmental Consulting, Whitehorse, YT, December 1995.

Sparling, P., 2006. Fisheries Assessments Conducted in the Keno Hill Mining Area, Including Metals Analysis of Fish Tissue Samples, 2006. White Mountain Environmental Consulting, Whitehorse, YT. January 2006.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: "psuedoreplication" in time? Ecology 67:929-940.

Sylvestre. S., Fluegel M. and Tuominen T. 2005. Benthic invertebrate assessment of streams in the Georgia Basin using the Reference Condition Approach: Expansion of the Fraser River invertebrate monitoring program 1998-2002. Environment Canada, Vancouver, B.C., 194 p.

Taylor, B.R. 1997. Optimization of Field and Laboratory Methods for Benthic Invertebrate Monitoring: Final Report. Prepared for Canada Centre for Mineral and Energy Technology, Ottawa, Ontario. January 1997.

Taylor, B.R., and R.C. Bailey. 1997. Technical Evaluation for Benthic Invertebrate Data Analysis and Interpretation: Final Report. Prepared for Canada Centre for Mineral and Energy Technology, Ottawa, Ontario. June 1997.

Underwood, A. J. 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research 42:569-587.

Underwood, A. J. 1992. Beyond BACI: The detection of environmental impacts on populations in the real, but variable, world. Journal of Experimental Marine Biology and Ecology 161:145-178.

Underwood, A. J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications 4:3-15.

Underwood, A. J., and M. G. Chapman. 2003. Power, precaution, Type II error and sampling design in assessment of environmental impacts. Journal of Experimental Marine Biology and Ecology 296:49-70.

Warren, M.L., Jr., and B.M. Burr. 1994. Status of freshwater fishes of the US: Overview of an imperiled fauna. Fisheries 19(1):6-18.

WMEC (White Mountain Environmental Consulting). 2005. Aquatic Life Sampling and Testing Program for the Anvil Range Mine Site, Rose and Vangorda Creek Watersheds, Faro, Yukon. Prepared for Deloitte and Touche Inc. December 2005.

APPENDIX A

YUKON WATER BOARD WATER LICENCES

YUKON WATER BOARD

Pursuant to the *Waters Act* and *Waters Regulation*, the Yukon Water Board hereby grants a Type B water licence for a quartz mining undertaking to:

Elsa Reclamation and Development Company Ltd.
Suite 1920-200 Granville Street
Vancouver, BC V6C 1S4

LICENCE NUMBER: QZ06-074

LICENCE TYPE: B **UNDERTAKING:** QUARTZ MINING

LOCATION: Keno Hill Mines Property

MAP CO-ORDINATES:

Minimum Northing: 7082468	Maximum Northing: 7094292
Minimum Easting: 493897	Maximum Easting: 464710
Centre Northing: 7088380	Centre Easting: 479303

PURPOSE: To obtain water, divert water, store water and to deposit a waste for the purpose of care and maintenance activities for the Keno Hill Mines Property.

EFFECTIVE DATE: The effective date of this Licence shall be the date on which the signature of the Chairperson of the Yukon Water Board is affixed.

EXPIRY DATE: November 30, 2012

This Licence shall be subject to the restrictions and conditions contained herein and to the restrictions and conditions contained in the *Waters Act* and the *Waters Regulation* made thereunder.

Dated this 14 day of

November, 2007.

Witness

Approved by:

Chairperson
YUKON WATER BOARD

PART A - DEFINITIONS

"Act" means *Waters Act* and any amendments thereto.

"Adaptive Management Plan" means the Adaptive Management Plan submitted as part of the Application and included in the Water Use Register QZ06-074 as part of exhibit 1.4.3, and any subsequent revisions.

"Application" means Water Use Application QZ06-074, including any additional submissions and/or revisions submitted to the Yukon Water Board by the Licensee, up to the date of the Board's decision.

"Board" means the Yukon Water Board.

"Dam Safety Guidelines" means the Dam Safety Guidelines issued by the Canadian Dam Association (1999), and any subsequent revisions.

"Inspector" means any person designated as an Inspector under the Act.

"Natural Boundary" means the visible high water mark of any lake, river, stream or other body of water where the presence and action of water is so common and usual and so long continued as to mark upon the soil of the bed of the lake, river, stream or other body of water a character distinct from that of the banks thereof, both in respect to vegetation and in respect to the nature of the soil itself. In addition, the best estimates of the edge of dormant or old side channels and marsh areas are considered to be Natural Boundaries.

"Regulation" means the *Waters Regulation* made under the Act.

"Spill Contingency Plan" means the Emergency Response Guide that was submitted as part of the Application and included in Water Use Register QZ06-074 as exhibit 1.2.9, and any subsequent revisions.

"Waste" means any substance as defined in the Act.

"Watercourse" means any stream, lake, pond, river, creek, spring, ravine or swamp whether ordinarily containing water or not.

"Wetted Perimeter" means the horizontal extent of the present water level while the work is taking place.

PART B - GENERAL CONDITIONS

Representations, Warranties and Undertakings

1. In this licence, the Board has relied on the representations, warranties and undertakings provided by the Licensee in the material filed in the Application.

2. Where there is a discrepancy between the Application and this licence, the conditions of this licence shall prevail.

Other Laws

3. No condition of this licence limits the application of any other federal, territorial, first nation or municipal legislation.

4. All construction or installation of works authorized by this licence shall occur on property that the Licensee has the right to enter upon and use for that purpose.

Correspondence

5. Where any direction, notice, order or report under this licence is required to be in writing, it shall be given:

   a) To the Licensee, if delivered, faxed or mailed by registered mail to the following address:

      Elsa Reclamation and Development Company Ltd.
      Suite 1920-200 Granville Street
      Vancouver, BC V6C 1S4
      Fax: 604 633 4887

      and shall be deemed to have been given to the Licensee on the day it was delivered or faxed, or 7 days after the day it was mailed, as the case may be.

   b) To the Board, if delivered, faxed or mailed by registered mail to the following address:

      Yukon Water Board
      Suite 106, 419 Range Road
      Whitehorse, YT Y1A 3V1
      Fax: 867 456 3890

      and shall be deemed to have been given to the Board on the day it was delivered or faxed, or 7 days after the day it was mailed, as the case may be.

c) The Board or the Licensee may, by notice in writing, change its address for delivery.

Non-Compliance

6. In the event that the Licensee fails to comply with any provision or condition of this licence, the Board may, subject to the Act, cancel the licence.

Other Uses

7. If, subsequent to the issuing of this licence, the Licensee uses water and/or deposits Waste in one or more ways not authorized in this licence, and the combined effect of those uses and/or deposits of Wastes, as determined by an Inspector:

a) has no potential for significant adverse environmental effects; and
b) does not interfere with existing rights of other water users or Waste depositors; and
c) satisfies the criteria set out in column 2 of Schedule 7 of the Regulation,

no amendment to this licence will be required for that use of water and/or deposit of Waste.

Spills and Unauthorized Discharges

8. The Licensee shall immediately contact the 24-hour Yukon Spill Report number, 867 667 7244, and implement the Spill Contingency Plan should a spill or an unauthorized discharge occur. A detailed written report on any such event including, but not limited to, dates, quantities, parameters, causes and other relevant details and explanations, shall be submitted to the Board not later than 10 days after the occurrence.

9. All personnel shall be trained in procedures to be followed and the equipment to be used in the containment of a spill.

10. Ten days prior to construction, the Licensee shall submit material safety data sheets to the Board for all petroleum products and/or hazardous materials that are to be present during this undertaking.

11. The spill contingency plan shall be posted on site for the term of the licence.

Fuel Storage and Transfer

12. Fuel, lubricants, hydraulic fluids, coolants and similar substances shall be stored and/or transferred a minimum of 30 metres from the Natural Boundary of any Watercourse, in such a way that said substances are not deposited in or allowed to be deposited in waters.

Waste Substances

13. Waste substances shall be used, transported, stored or disposed of in such a manner that they are not deposited, or allowed to be deposited, into any Watercourse or on any surrounding land.

Annual Reports

14. Annual reports shall be submitted to the Board by the Licensee. The first report shall be for the period from the effective date of the licence to December 31, 2008. Subsequent reports shall be for each calendar year. Annual reports will be submitted to the Board on or before February 28 of the following year.

15. Annual reports shall include the information required by the Regulation, including, but not necessarily limited to:

a) a description of the water use operations carried out during the year reported; and
b) the quantity of water used each day; and
c) a detailed record of any major maintenance work carried out or planned to be carried out that could have an impact on water; and
d) summaries of all data generated as a result of the monitoring requirements of this licence, including analysis and interpretation by a qualified individual or firm and a discussion of any variances from baseline conditions or from previous years' data; and
e) details of any work carried out or planned to be carried out under the Adaptive Management Plan.

Monthly Reports

16. Unless otherwise specified in this licence, the Licensee shall forward to the Board a copy of all data collected as part of the monitoring programs of this licence no more than 30 days after the conclusion of the month in which that data was collected.

Reports

17. Unless otherwise specified in this licence, all monitoring data, reports, plans studies, study results, designs or manuals shall be submitted to the Board in an unbound form that is reproducible by standard photocopier and shall be accompanied by 5 copies.

18. All monitoring data, reports, plans studies, study results, designs or manuals shall be submitted in digital form on computer diskette using an IBM compatible format that is readable using commonly available software.

Term of Licence

19. The term of this licence is for the period from the effective date to November 30, 2012.

PART C - OPERATING CONDITIONS

Description of Water Use and Deposit of Waste

20. The Licensee is hereby authorized to:

a) obtain a maximum combined quantity of 90 cubic metres of water per day from Flat Creek and Bellekeno 600 adit, Silver King 100 adit, Galkeno 300 adit, Galkeno 900 adit and the Valley Tailings Area for the purpose of water treatment; and
b) construct a sludge treatment pond and store water in settling ponds at the Galkeno 300 adit; and
c) operate existing wastewater treatment systems and store water in settling ponds at the Bellekeno 600 adit, Silver King 100 adit, Galkeno 900 adit and the Valley Tailings Area; and
d) use existing diversions of Porcupine Creek and lower Flat Creek; and
e) deposit Waste to Flat Creek drainage, Christal Creek drainage and Lightening Creek, in the form of wastewater that has been treated to meet the discharge standards required by this licence from settling ponds located at Bellekeno 600, Silver King 100, Galkeno 300, Galkeno 900 and the Valley Tailings Area; and
f) deposit Waste in the form of sludge; and
g) construct earthworks and erosion protection,

as described in the Application, and subject to the conditions of this licence.

Untreated Wastewater

21. The Licensee is hereby authorized to discharge untreated wastewater from the adits at locations KV-17, KV-18, KV-19, KV-20, KV-33, KV-34, KV-35, KV-36, KV-45 and KV-53, as described in the Adaptive Management Plan, so long as all discharges are to ground or to drainages that report to ground.

PART D – PLANS

22. The Licensee shall submit an updated Adaptive Management Plan for the Keno Hill Mines Property to the Board within 120 days of the effective date of this licence. A summary of activities carried out under the plan shall be submitted to the Board as part of the annual report.

23. The Licensee shall develop and submit a sludge management plan to the Board 90 days prior to the implementation of the plan.

24. Subject to any required assessments, authorizations or approvals, the Licensee shall implement all plans required by this section of this licence.

PART E – EFFLUENT QUALITY STANDARDS

25. No Waste discharged from the wastewater treatment systems at Bellekeno 600 adit, Silver King 100 adit, Galkeno 300 Adit, Galkeno 900 adit and the Valley Tailings Area shall exceed the following limits:

Parameter	**Maximum Concentration in a Grab Sample Measured in mg/L**
pH	6.5 to 9.5 pH Units
Suspended Solids	25.0 mg/L
Arsenic (total)	0.50 mg/L
Cadmium (total)	0.05 mg/L
Copper (total)	0.30 mg/L
Lead (total)	0.20 mg/L
Nickel (total)	0.50 mg/L
Silver	0.10 mg/L
Zinc (total)	0.50 mg/L

26. Any discharge to a Watercourse must meet a bioassay standard of a 96-hour at 100% LT_{50} bioassay using rainbow trout, pH non-adjusted.

27. The points of compliance at the Bellekeno 600 adit, Silver King 100 adit, Galkeno 300 adit, Galkeno 900 adit and the Valley Tailings Area for the effluent quality standards included in this licence shall be the final point of control prior to discharging effluent to the environment.

PART F – MONITORING AND SURVEILLANCE

28. The Licensee shall comply with the water quality monitoring program and surveillance network program contained in Schedule A of this licence.

29. The Licensee shall compile data relating to the surveillance network program into a monthly report. The report shall be submitted to the Board within 30 days of the end of each month for which the report is compiled.

30. Monitoring and sampling shall be carried out in accordance with the procedures and standards described in:

a) Guidance Document for the Sampling and Analysis of Metal Mining Effluents, April 2001, (Report: EPS 2/MM/5), Minerals and Metals Division, Environment Canada;

b) Guidance Document for Flow Measurement of Metal Mining Effluents, April 2001, (Report: EPS 2/MM/4), Minerals and Metals Division, Environment Canada;

c) Standard Guide for Sampling Ground-Water Monitoring Wells, ASTM D4448-01, ASTM International, PA, USA.

Sediment and Benthic Invertebrate Monitoring

31. Bi-annually, during the term of the licence, the Licensee shall carry out a sediment monitoring program and a benthic invertebrate monitoring program, with sampling and analysis conducted as described below at sampling stations KV-1, KV-3, KV-4, KV-6 and KV-9 for each program. The studies will be carried out by persons qualified to do so by education and/or experience. The results of the studies will be included in the next annual report.

a) Sediment sampling shall be carried out as follows:

i) sediment samples shall be collected in replicates of three from the active channel, directly into high density plastic sample jars, using an aluminum or Teflon scoop.
ii) samples shall be dried and screened, using sieves at ASTM mesh numbers 10, 20, 40, 60, 100, 140 and 270 (ASTM-E11-61) and the fraction weights shall be recorded.
iii) a sub-sample composed of material passing through the 100 mesh number sieve shall be analyzed for metals by a 33 element ICP scan. Loss on ignition shall also be determined by heating the sample to 600 degrees C.

b) Benthic invertebrate sampling shall be carried out as follows:

i) three replicate samples shall be taken by a circular Hess sampler (0.0934 m^2) or Waters and Knapp sampler (0.089 m^2) equipped with a 250 μm mesh net.
ii) samples shall be preserved with 10% formalin solution, and identified to the lowest possible taxon (usually genus) and counted.
iii) stream information collected at the time of the benthos collection shall include velocity, depth, temperature, substrate conditions and riparian conditions.

Physical Inspections and Monitoring

32. An annual inspection of the Valley Tailings Area dams shall be carried out in accordance with the Dam Safety Guidelines by a Professional Engineer licenced to practice in Yukon. A report on the inspection, prepared by the Professional Engineer, shall be submitted as part of the annual report. The report shall document the inspection locations and methodologies, the results of the inspection, all problems identified, and remedial measures recommended. The status of any remedial measures recommended in the previous year's report shall be appended to the report together with an explanation regarding any recommendation not implemented.

33. Details of any maintenance, inspection and/or surveillance activities undertaken in the previous year in relation to dam safety shall be included in the annual report.

PART G – DESIGN AND CONSTRUCTION

Design

34. The sludge treatment pond and associated structures shall be constructed at the Galkeno 300 adit location in accordance with the design drawings which were submitted as part of the Application in exhibit 1.4.2.

35. Where site conditions require minor modifications to the designs submitted to the Board, the Licensee shall notify the Board, a minimum of 10 days in advance, of the details of the modifications or variations from final detailed design, specifications and quality assurance/quality control procedures previously submitted to the Board, provide a detailed construction schedule and the name and contact number(s) of the construction superintendent. The notice shall be in writing and must include an explanation of the reasons for the change and an assessment of the potential impact on the performance of the works. The notice shall be sealed by a Professional Engineer licensed to practice in Yukon.

36. As-constructed (record) drawings of the sludge treatment pond and associated structures, sealed by a Professional Engineer licensed to practice in Yukon, shall be submitted to the Board within 60 days of completion of construction.

Settling Ponds

37. The settling ponds at the Silver King 100, Galkeno 300, Galkeno 900 and Bellekeno 600 adit locations shall be lined with an impermeable membrane, as described in the Application.

38. A minimum freeboard of 0.4 metres shall be maintained in all settling ponds.

39. No heavy equipment shall be operated within the Wetted Perimeter of any Watercourse.

40. Granular bedding and backfill material shall consist of non-frozen material.

41. All disturbed ground surfaces shall be stabilized in such a manner so as to prevent erosion and surface runoff from carrying sediment into any Watercourse.

42. Construction and/or maintenance equipment shall be mechanically sound and free of leaks.

PART H - SITE DECOMMISSIONING AND RECLAMATION

43. The Licensee shall develop a decommissioning and reclamation plan for the closure of the Keno Hill Mines Property and submit the plan to the Board by December 31, 2008. The plan shall include, but not necessarily be limited to a schedule and cost for completion of decommissioning and reclamation activities. As part of each annual report, the Licensee shall report on the status of the decommissioning and reclamation plan.

44. Subject to any required assessments, authorizations or approvals, the Licensee shall implement the plan required by this section of this licence.

QZ06-074 SCHEDULE A

SCHEDULE A, PART I
MONITORING STATIONS

Monitoring Station	Description	Northing	Easting
KV-1	South McQuesten River u/s Christal Creek	7092956	474078
KV-2	South McQuesten River at Pumphouse	7090031	472153
KV-3	South McQuesten River u/s Flat Creek	7088534	465846
KV-4	South McQuesten River 350 m d/s Flat Creek	7088336	465620
KV-5	South McQuesten River 9 km downstream Flat Creek	7088870	460686
KV-6	Christal Creek at Keno Highway	7088204	483882
KV-7	Christal Creek at Hanson Road	7092443	478790
KV-8	Christal Creek at mouth	7091955	474615
KV-9	Flat Creek u/s South McQuesten River	7088406	465871
KV-10	Valley Tailings Pond #1 Decant	7088571	475015
KV-11	Valley Tailings Pond #2 Decant	7088486	474856
KV-12	Valley Tailings Pond #3 Decant	7088227	474341
KV-13	Silver King Adit	7085617	471850
KV-14	Silver King Treatment Pond #2 Decant	7085706	471838
KV-15	South McQuesten River at Bridge below Haggart Creek	7085805	449758
KV-16	Christal Creek 600 m d/s Silver Trail	7088634	483861
KV-17	Husky South West Adit	7086580	473854
KV-18	Bermingham Adit	7087294	478755
KV-19	Ruby Adit	7087765	478549
KV-20	No Cash 500 Adit	7088485	477689
KV-21	No Cash Creek at Keno Highway	7088750	477500
KV-27	Galkeno 300 Adit	7088797	482636
KV-28	Galkeno 300 Treatment Pond Decant	7088902	482703
KV-29	Silver Trail Culvert #4	7088713	483757
KV-30	Christal Creek 825m d/s Silver Trail	7089007	483811
KV-31	Galkeno 900 Adit	7087809	483454
KV-32	Galkeno 900 Treatment Pond Decant	7087719	483512
KV-33	Keno 700 Adit	7089621	490095
KV-34	Lucky Queen Adit	7090614	486562
KV-35	Sadie Ladue Adit	7092805	485895
KV-36	Flame and Moth	7086963	484352
KV-37	Lightning Creek u/s Hope Gulch	7087765	490343
KV-38	Lightning Creek u/s Thunder Gulch	7087345	488188
KV-39	Hope Gulch u/s Lightning Creek	7087840	490068
KV-40	Charity Gulch u/s Lightning Creek	7087624	489017
KV-41	Lightning Creek u/s bridge at Keno City	7086748	485382
KV-42	Bellekeno 600 Adit	7086944	487428
KV-43	Bellekeno 600 Treatment Pond Decant	7087052	487419
KV-44	Bellekeno 600 Seep	7087151	487464
KV-45	Onek Adit	7087288	485101
KV-47	Porcupine Diversion Ditch	7088008	474853
KV-48	Hinton Creek u/s Calumet Drive	7087199	482820
KV-49	Hinton Creek u/s Christal Creek	7086954	483445

Monitoring Station	Description	Northing	Easting
KV-50	Christal Creek u/s Hinton Creek	7086897	483575
KV-51	Christal Creek d/s Hinton Creek	7087058	483601
KV-52	Natural spring to Christal Lake at Old Mackeno pump house	7087870	483756
KV-53	UN Adit	7089322	481595
KV-54	Erickson Gulch at Road to Lucky Queen	7088954	485774
KV-55	Sandy Creek at Silver Trail Highway	7089667.8	478539
KV-56	Star Creek at Silver Trail Highway	7089284	478031
KV-57	Haldane Creek at South McQuesten Road	7086794	461921
KV-58	Seepage at toe of #3 dam	7088296	474317
KV-59	Galena Creek at mouth (just upstream of Flat Creek)	7087018	471127
KV-60	Galena Creek upstream of Silver King adit	7085532	471913
KV-61	Porcupine Gulch at Calumet Road Crossing	7086895	476607
KV-62	Brefalt Creek upstream of Porcupine Diversion	7087917	475249
KV-63	Flat Creek upstream of Porcupine Diversion	7087815	474644
KV-64	Flat Creek at Silver Trail Highway	7086551	474910
KV-65	Thunder Gulch upstream of Bellekeno	7086803	487466
KV-66	Klondike Keno Adit	7090929	485593
KV-67	Keno 200 Adit	7090037	489379
KV-68	Brewis Red Lake Adit	7090379	486570

SCHEDULE A, PART II
MONITORING SCHEDULE FREQUENCY LEGEND

Symbol	**Frequency**
BA	Every Second Year
D	Daily
A	Annually
Q	Quarterly May/July/October/February
M	Monthly

SCHEDULE A, PART III
MONITORING SCHEDULES

Monitoring Stations	Parameters								
	Total ICP Metals	Dissolved ICP Metals	Hardness	pH	Cond.	TSS	LT50	Sediment Program	Benthic Program
Treatment Sites:									
KV-12	M	M	M	M	M	M	M		
KV-13	M	M	M	M	M	M			
KV-14	M	M	M	M	M	M	M		
KV-31	M	M	M	M	M	M			
KV-32	M	M	M	M	M	M	M		
KV-27	M	M	M	M	M	M			
KV-28	M	M	M	M	M	M	M		
KV-42	M	M	M	M	M	M			
KV-43	M	M	M	M	M	M	M		
Receiving Water Stations:									
KV-1	M	M	M	M	M	M		BA	BA
KV-2	Q	Q	Q	Q	Q	Q			
KV-3	Q	Q	Q	Q	Q	Q		BA	BA
KV-4	Q	Q	Q	Q	Q	Q		BA	BA
KV-5	Q	Q	Q	Q	Q	Q			
KV-15	Q	Q	Q	Q	Q	Q			
KV-6	M	M	M	M	M	M		BA	BA
KV-7	M	M	M	M	M	M			
KV-8	M	M	M	M	M	M			
KV-9	Q	Q	Q	Q	Q	Q		BA	BA
KV-21	Q	Q	Q	Q	Q	Q			
KV-29	M	M	M	M	M	M	M		
KV-39	Q	Q	Q	Q	Q	Q			
KV-47	Q	Q	Q	Q	Q	Q			
KV-37	Q	Q	Q	Q	Q	Q			
KV-38	Q	Q	Q	Q	Q	Q			
KV-41	Q	Q	Q	Q	Q	Q			
KV-48	Q	Q	Q	Q	Q	Q			
KV-49	Q	Q	Q	Q	Q	Q			
KV-50	Q	Q	Q	Q	Q	Q			
KV-51	Q	Q	Q	Q	Q	Q			
KV-52	Q	Q	Q	Q	Q	Q			
KV-53	Q	Q	Q	Q	Q	Q			
KV-54	Q	Q	Q	Q	Q	Q			
KV-55	Q	Q	Q	Q	Q	Q			
KV-56	Q	Q	Q	Q	Q	Q			
KV-57	Q	Q	Q	Q	Q	Q			

Monitoring Stations	Parameters								
	Total ICP Metals	Dissolved ICP Metals	Hardness	pH	Cond.	TSS	LT50	Sediment Program	Benthic Program
KV-58	Q	Q	Q	Q	Q	Q			
KV-59	Q	Q	Q	Q	Q	Q			
KV-60	Q	Q	Q	Q	Q	Q			
KV-61	Q	Q	Q	Q	Q	Q			
KV-62	Q	Q	Q	Q	Q	Q			
KV-63	Q	Q	Q	Q	Q	Q			
KV-64	Q	Q	Q	Q	Q	Q			
KV-65	Q	Q	Q	Q	Q	Q			
Adit Discharge:									
KV-17	Q	Q	Q	Q	Q	Q			
KV-18	Q	Q	Q	Q	Q	Q			
KV-19	Q	Q	Q	Q	Q	Q			
KV-20	Q	Q	Q	Q	Q	Q			
KV-33	Q	Q	Q	Q	Q	Q			
KV-34	Q	Q	Q	Q	Q	Q			
KV-35	Q	Q	Q	Q	Q	Q			
KV-36	Q	Q	Q	Q	Q	Q			
KV-45	Q	Q	Q	Q	Q	Q			
KV-53	Q	Q	Q	Q	Q	Q			
KV-66	Q	Q	Q	Q	Q	Q			
KV-67	Q	Q	Q	Q	Q	Q			
KV-68	Q	Q	Q	Q	Q	Q			

* ICP Metals include: Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Sulfur, Thallium, Tin, Titanium, Uranium, Vanadium, Zinc and Zirconium

Physical Inspection	**Frequency**
KV-10 Tailing Dam No. 1	D
KV-11 Tailing Dam No. 2	D
KV-12 Tailing Dam No. 3	D
Tailings Dam Crest Survey	A
KV-47 Porcupine Diversion Ditch	Q
Treatment Site Settling Ponds	D