# Keno Hill Silver District
# QML-0009 Site Characterization Report

## Final Report

**Prepared for:**

## Alexco Keno Hill Mining Corp.

**Date:**

**February 28, 2023**

ENSERO solutions

# Table of Contents

# LIST OF TABLES

# LIST OF FIGURES

# 1 INTRODUCTION

The Site Characterization Report summarizes environmental conditions for the mining operations in the Keno Hill Silver District (KHSD) conducted by Alexco Keno Hill Mining Corp. (AKHM), a wholly owned subsidiary of Hecla Yukon. The AKHM Project areas within the KHSD include New Bermingham, Bellekeno, Flame & Moth, Onek 990, Lucky Queen, and the District Mill, and these areas are discussed in this report. This report provides an update to the previous QML-0009 Site Characterization Report issued March 31, 2020. All Project areas are in the Traditional Territory of the First Nation of Na-cho Nyak Dun (FNNND).

The KHSD has a long mining history and is a brownfields site. AKHM develops the mineral resources, operates the KHSD mines and undertakes receiving environmental monitoring and treatment of mine discharge waters. Hecla Yukon's wholly owned subsidiary Elsa Reclamation and Development Company Ltd. (ERDC) undertakes care and maintenance, environmental monitoring and water treatment of historic adit drainages, district-wide closure planning, studies, and remediation of the historic environmental liabilities.

## 1.1 PROJECT LOCATION

The KHSD is in central Yukon (63° 54' 32" N, 135° 19' 18" W; NTS 105M/14 & 105M/13), 354 km due north of Whitehorse. Access to the property is via the Alaska, Klondike, and Silver Trail Highways from Whitehorse to Mayo (407 km) and an all-weather gravel road northeast from Mayo to Elsa (45 km); a total distance of 452 km.

The KHSD Mining Operations are located on and around Galena Hill, Keno Hill, and Sourdough Hill (Figure 1-1). These three prominent hills lie to the south of the broad McQuesten River valley. The New Bermingham mine is located on Galena Hill. The Lucky Queen and Onek 990 mines are located on Keno Hill, while the Bellekeno mine is located on Sourdough Hill. The Flame & Moth mine and the District Mill are located at the base of the three hills.

## 1.2 PERMITTING CONDITIONS

Currently licenced mines under the Quart Mining License (QML-0009) include the Bellekeno deposit, Dry Stack Tailings Facility (DSTF) phase 1, and District Mill operation (Type A Water Licence QZ09-092), the Onek 990 and Lucky Queen mines (Water Licence amendment QZ12-053), the Flame & Moth mine and the DSTF expansion (phase 2) (Water Licence amendment QZ09-092-2) and the New Bermingham mine (Water Licence renewal QZ18-044) (Table 1-1). The Onek 990 and Lucky Queen mines are excluded from the current reporting Water Licence, QZ18-044. The Type B Water Licence (QZ17-076, renewal of QZ17-084) was issued for the purpose of care and maintenance activities for the Keno Hill Silver District. Monitoring locations under both the Type A and Type B Water Licence are included in this report.

**Table 1-1: Keno Hill Silver District Mining Operations Permitting Timeline**

| Mine | Date |
|---|---|
| Bellekeno | 2009 |
| District Mill and DSTF | 2009 |
| Onek | 2013 |
| Lucky Queen | 2013 |
| Flame & Moth | 2016 |
| New Bermingham | 2019 |

## 1.3 KENO HILL SILVER DISTRICT MINING OPERATIONS

A summary of KHSD mining operations is provided in Table 1-2.

**Table 1-2: Keno Hill Silver District Mining Operations Overview**

| | |
|---|---|
| **Mines / Ore Deposits** | Bellekeno (Production 2010 – 2013, suspended 2013 – 2020, production resumed in Q4 of 2020, temporary closure December 15 2021)<br>Flame & Moth (Development 2018, suspended 2018 – 2020, development and production 2020 - present)<br>New Bermingham (Advanced exploration 2017 – 2018, development and production 2020 - present)<br>Lucky Queen, Onek 990 (Advanced exploration 2013, not active) |
| **Mill** | District Mill location at Flame & Moth Mine area (Constructed 2010, operated 2010 – 2013, suspended 2013 – 2020, operated December 2020 – 2022, suspended 2022)<br>Tailings placed in Dry Stack Tailings Facility (Established 2010, no deposition of tails during suspension of mill operations) |

## 1.4 RECENT CHANGES TO MINE OPERATIONS

The following subsection summarizes the changes that have occurred to site operations and site infrastructure since the previous Site Characterization Report was issued.

### 1.4.1 MINE INFRASTRUCTURE

In 2022, the Flame & Moth ventilation raise was completed.

Surface construction activities at New Bermingham included the continued deposition of N-AML waste rock in the destinated disposal area adjacent the portal.

### 1.4.2 ROAD CONSTRUCTION

Christal Lake Road was resurfaced in 2022. No major upgrades occurred on the roads to New Bermingham, Lucky Queen, or the Lightning Creek Bypass, or the Bellekeno Haul Road in 2022. Standard maintenance occurred throughout the year.

### 1.4.3 MILL SITE CONSTRUCTION

In 2022, a tress and an earthen mound located between the District Mill, Mobile Maintenance Shop, and the Flame & Moth Portal was removed. The soil was utilized to resurface the Christal Lake Road and District Mill parking areas.

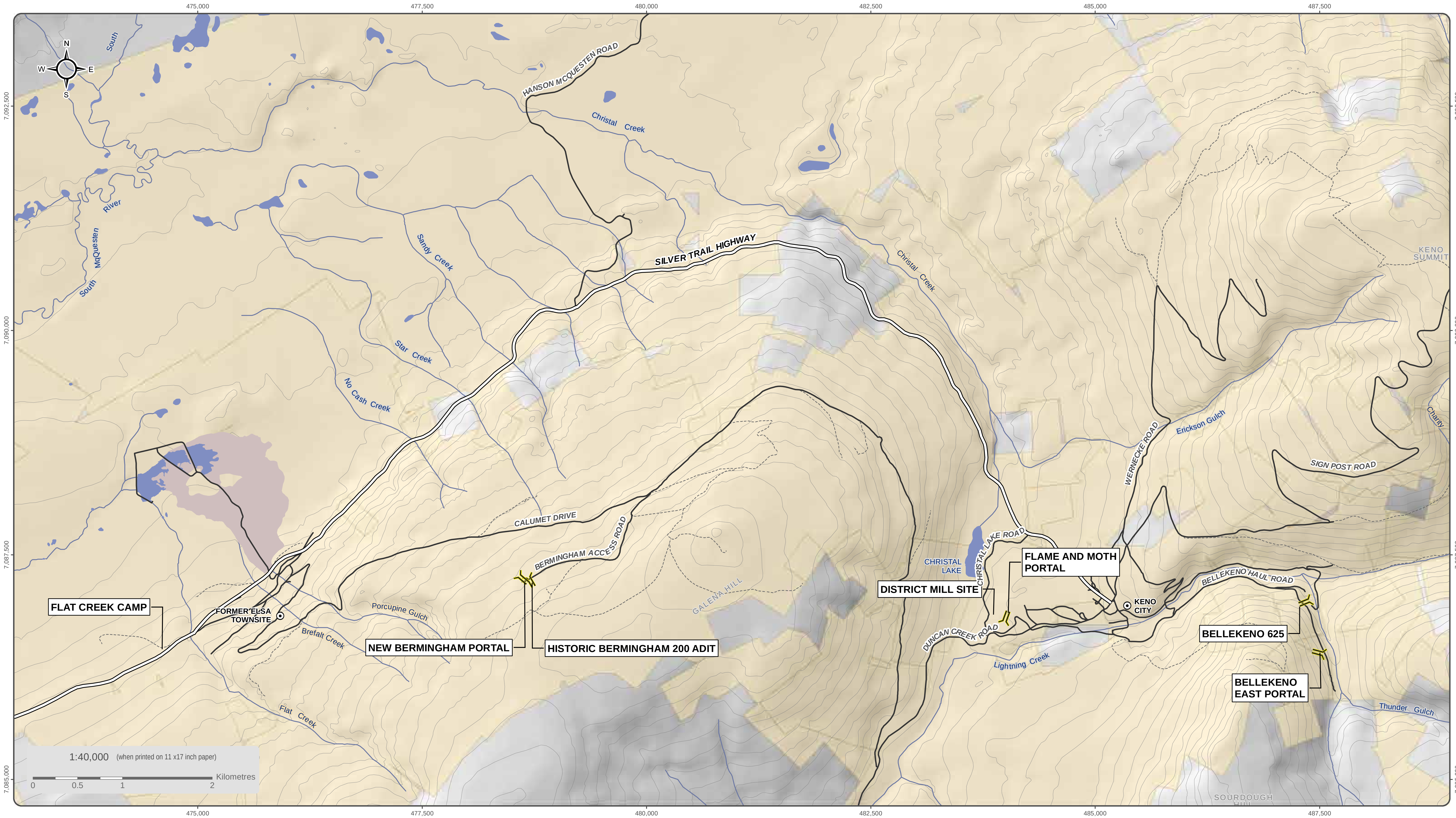
Ditches and culverts at the mill yard continued to be maintained to facilitate channeling melt water in the spring and storm events into to sediment basins. Organics from the removal of the earthen mound were used on the DSTF or stockpiled.

### 1.4.4 DRY STACK TAILINGS FACILITY

In 2022, the footprint for Phase 1 DSTF was expanded by removing trees and overburden. Liner was laid for additional tailings placement in accordance with the phase 1 DSTF design. Maintenance of the ditches and sumps were made. Additional maintenance activities were completed in response to recommendations from the annual geotechnical inspection.

### 1.4.5 FLAT CREEK (ELSA) CAMP UPGRADES

In 2022, upgrades included: the installation of additional boardwalks and the construction of a smoking shelter.






Datum: NAD 83; Map Projection: UTM Zone 8N



- Adit
- Alexco/ERDC Quartz Claims
- Silver Trail Highway
- Other Road
- Limited-Use Road
- Tailings Area
- Waterbody
- Watercourse
- Contours (100 ft intervals)

HECLA KENO HILL

**FIGURE 1-1**

**KENO HILL SILVER DISTRICT MINING OPERATIONS OVERVIEW**

**NOVEMBER 2022**

D:\Project\AllProjects\Keno_Area_Mines\ALL-SITES\02-Map\01_Overview\01-Property Overview\01-District_Wide\Overview_20221115.mxd
*(Last edited by: fsparling;11/22/2022/10:33 AM )*

# 2 GEOLOGY AND SOILS

The KHSD has been subject to numerous faulting and folding events that have shaped the district's geology and mineralogy, and therefore the surface and groundwater flow regime.

A complete description of the regional, district and surficial geology has been provided to add insight into structural controls (faults, permeable flowpaths, etc.) on groundwater flow in the alluvial material, bedrock zone, and the surface/groundwater interfaces. Hydrogeology studies and mine histories suggest that groundwater within the KHSD originates from infiltrated meteoric water, which migrates within unconsolidated glacial deposits and through fractures in metamorphic rocks (SRK, 2014).

## 2.1 REGIONAL DESCRIPTION

The KHSD is located within the northwestern part of the Selwyn Basin, in an area characterized by the Robert Service and Tombstone Thrust Sheets that are overlapping and trend northwest. This area is underlain by Upper Proterozoic to Mississippian sedimentary rocks deposited in a shelf environment during the formation of the northern Cordilleran continental margin. The KHSD geology is dominated by the Mississippian Keno Hill Quartzite comprising the Basal Quartzite Member and conformably overlying Sourdough Hill Member. The unit is overthrust in the south by the Upper Proterozoic Hyland Group Yusezyu Formation and is conformably underlain in the north by the Devonian Earn Group (McOnie and Read, 2009). The area underwent regional compressive tectonic stresses during the Jurassic and the Cretaceous, producing thrusts, folds and penetrative fabrics of various scales.

The Yusezyu Formation of the Precambrian Hyland Group comprises greenish quartz-rich chlorite-muscovite schist with locally clear and blue quartz-grain gritty schist and is separated from the Keno Hill sequence by the regionally extensive Robert Service Thrust Fault that occurs immediately south of the area. The Tombstone Thrust Sheet that lies to the north.

## 2.2 PROPERTY GEOLOGY

The Earn Group, formerly mapped as the "lower schist formation" (Boyle, 1965), is typically composed of recessive weathering grey graphitic schist and green chlorite-sericite schist with an upper siliceous graphitic schist found locally.

Within the Keno Hill Quartzite Formation, the Basal Quartzite Member that is the dominant host to the silver mineralization, comprises commonly calcareous, thick to thin-bedded quartzite and graphitic schist and may be up to approximately 1,100 m thick where structurally thickened. The overlying Sourdough Hill Member, formerly mapped as the "upper schist formation" (Boyle, 1965), is up to approximately 900 m in thickness and comprises predominantly graphitic and sericitic schist, chloritic quartz augen schist some of which may be of volcanogenic origin, and minor thin bedded limestone. The geology of the KHSD is shown in Figure 2-1.

The Earn Group and Keno Hill Quartzite are locally intruded by stratigraphically conformable, although lensoidal, Middle Triassic greenstone sills, for which any feeder dykes are unrecognizable. The sequence was metamorphosed to greenschist facies assemblages during Cretaceous regional deformation at about 100 My, and subsequently intruded by aplite sills or dikes considered to be related to the Tombstone intrusive suite.

Three phases of folding are identified with the two earliest phases consisting of isoclinal folding with subhorizontal, east or west trending fold axes, the axial plane forming the dominant regional foliation. The later fold phase displays subvertical axial planes and moderate southeast-trending and plunging fold axes. The first phases of folding formed structurally dismembered isoclinal folds of which the Basal Quartzite Member outlines synforms at Monument Hill where the Lucky Queen mine is located and at Caribou Hill, while between Galena Hill and Sourdough Hill the Bellekeno, Flame & Moth, and New Bermingham mines are located on the upper limb of a large-scale anticline that closes to the north.

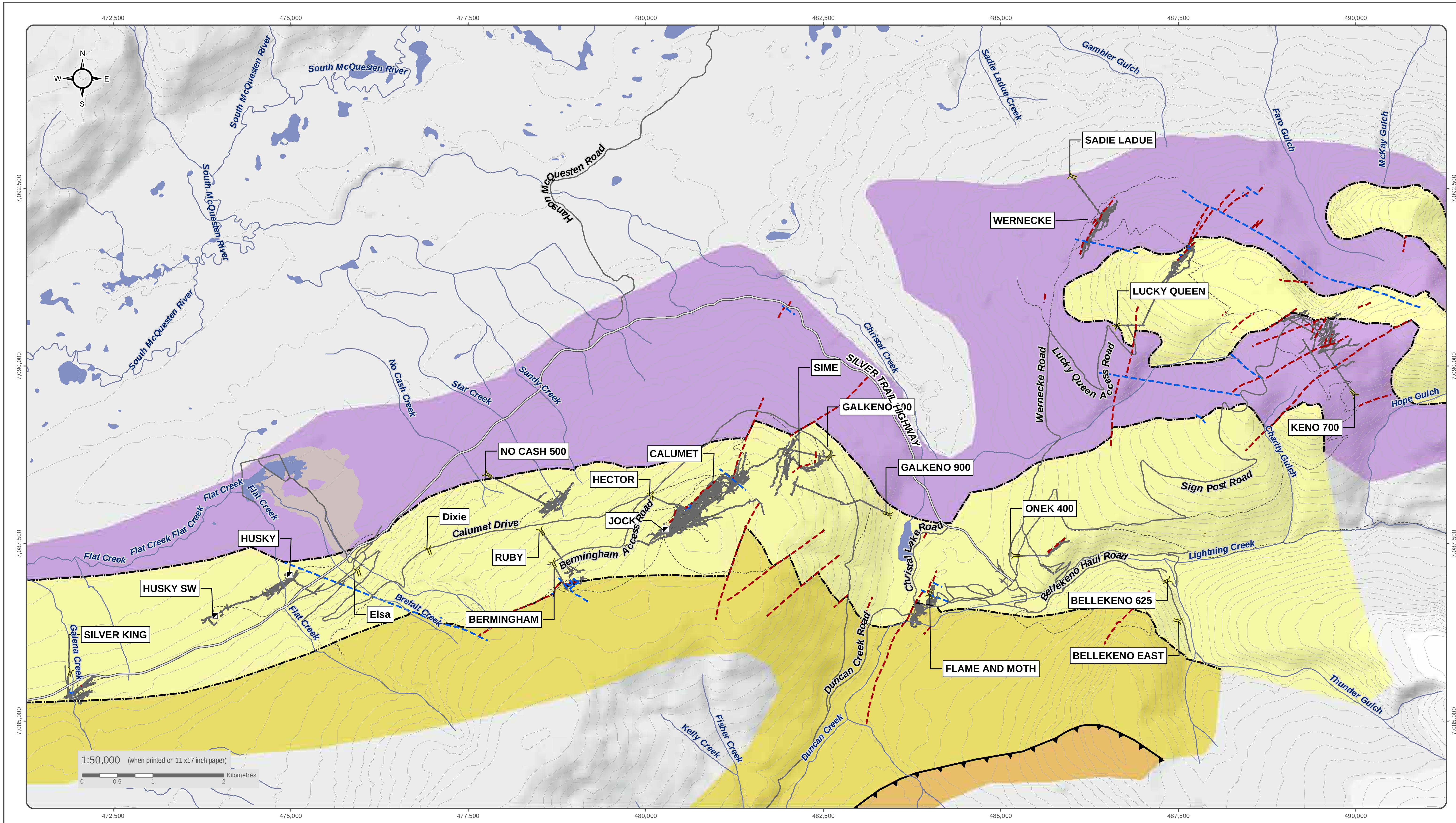
Up to four main periods of faulting are recognized with the oldest fault set consisting of south dipping foliation parallel structures that developed contemporaneously with the first phases of folding, sometimes shown as “low angle bedding faults”. The Robert Service Thrust Fault truncates the top of the Keno Hill Quartzite Formation and sets the Precambrian schist of the Yusezyu Formation above the Mississippian Sourdough Hill Member. The silver mineralization in the KHSD is hosted by a series of northeast oriented, southeasterly dipping veins formed in pre- and synmineral faults referred to as vein-faults (Boyle, 1965) that display left lateral normal oblique displacement. There are two related sets locally recognized as either a more easterly trending “longitudinal” vein set that, depending on the competency of the host rock, can form up to a 30 m wide zone of anastomosing subparallel veins, or a more northerly trending “transverse” vein set that can reach up to 5 m in thickness.

The mineralized vein-faults are commonly offset by northwest striking, steeply southwest dipping, post-mineral cross faults, that display right lateral normal oblique displacement.

Mineralization is of the polymetallic silver-lead-zinc vein type that typically exhibits a succession of hydrothermally precipitated minerals from the vein wall towards the vein centre. However, in the KHSD, multiple pulses of hydrothermal fluids or fluid boiling, probably related to repeated reactivation and breccia formation along the host fault structures, have formed a series of vein stages with differing mineral assemblages and textures. Supergene alteration may have further changed the nature of the mineralogy in the veins. Much of the supergene zone may have been removed due to glacial erosion.

In general, common gangue minerals include (manganiferous) siderite and, to a lesser extent, quartz and calcite. Silver predominantly occurs in argentiferous galena and argentiferous tetrahedrite (freibergite). In some assemblages, silver is also found as native silver, in polybasite, stephanite, and pyrargyrite. Lead occurs in galena and zinc in sphalerite, which at the KHSD can be either an iron-rich or iron-poor variety. Other sulphides include pyrite, pyrrhotite, arsenopyrite, and chalcopyrite.

The Keno Hill mining camp has long been recognized as a polymetallic silver-lead-zinc vein district with characteristics possibly similar to other well-known mining districts in the world. The largest accumulation of minerals of economic interest occurs in areas of increased hydrothermal fluid flow in structurally prepared competent rocks such as the Basal Quartzite Member and Triassic Greenstone. Incompetent rocks like phyllites tend to produce fewer and smaller (if any) open spaces, limiting fluid flow and resulting mineral precipitation.

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Datum: NAD 83; Map Projection: UTM Zone 8N

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- Adit
- Shaft
- Post-Mineral Fault
- Pre-Mineral Fault
- Main Stratigraphic Break
- Robert Service Thrust Fault
- Underground_Workings_Dissolved
- Keno Hill Basal Quartzite Member
- Earn Group
- Keno Hill Sourdough Hill Member
- Hyland Group
- Silver Trail Highway
- Other Road
- Limited-Use Road

HECLA KENO HILL

FIGURE 2-1
KHSD GEOLOGICAL FORMATIONS AND FAULTS

FEBRUARY 2023

## 2.3 PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The KHSD lies within the northeastern part of the Yukon Plateau, and is characterised by mountainous terrain, with elevations that range from 610 masl (metres above sea level) (McQuesten River valley) to 1,848 masl (Summit of Keno Hill). The KHSD has been shaped by several glacial advances, notably the McConnell glaciation (approximately twenty thousand years ago (Ka)) and the Reid glaciation (approximately 200 Ka-300 Ka) (Lipovsky et al., 2001). The Reid glaciation almost completely covered the KHSD, with the exception of the peaks of Keno Hill, while the McConnell glaciation was not as extensive, with the peak extent of glaciation reaching an approximate elevation of 1,100 masl. There is less evidence of the Reid glaciation around the KHSD compared to the more recent McConnell glaciation. The McConnell glaciation advanced from east to west, flowing onto the McQuesten River valley, while a tongue of this glacier extended between Galena and Keno hills terminating near Keno City.

This extensive glaciation has defined the KHSD's surficial geology and surficial groundwater flow. The valleys are broad, glacially scoured and typically boggy with thick peat deposits. The lower slopes of Galena and Keno Hills have a variety of sand, gravel, and silt deposits, including kames and terraces, that were deposited off the sides of retreating glaciers and meltwater streams. These till deposits range from 10 m to 50 m thick, and are typically present up to 1,100 masl, the extent of the last glaciation. Till deposits through the KHSD are striated with lenses dominated by gravel or sand within a silt matrix. These were used during construction and mining as foundation and road material and are considered good borrow sources for covers and other reclamation activities. Keno City is underlain by 85 m of sand and gravel. At higher elevations, above the last glaciated extents, are thin layers of colluviated sediments and soils with exposed bedrock along ridge-tops, gulches, and cirques (LeBarge et al., 2002). Freeze-thaw cycles for over 300,000 years have created frost-shattered bedrock boulder fields running down the higher elevation hillsides of Keno and Galena hills. A map of the surficial geology of the KHSD is provided on Figure 2-2.

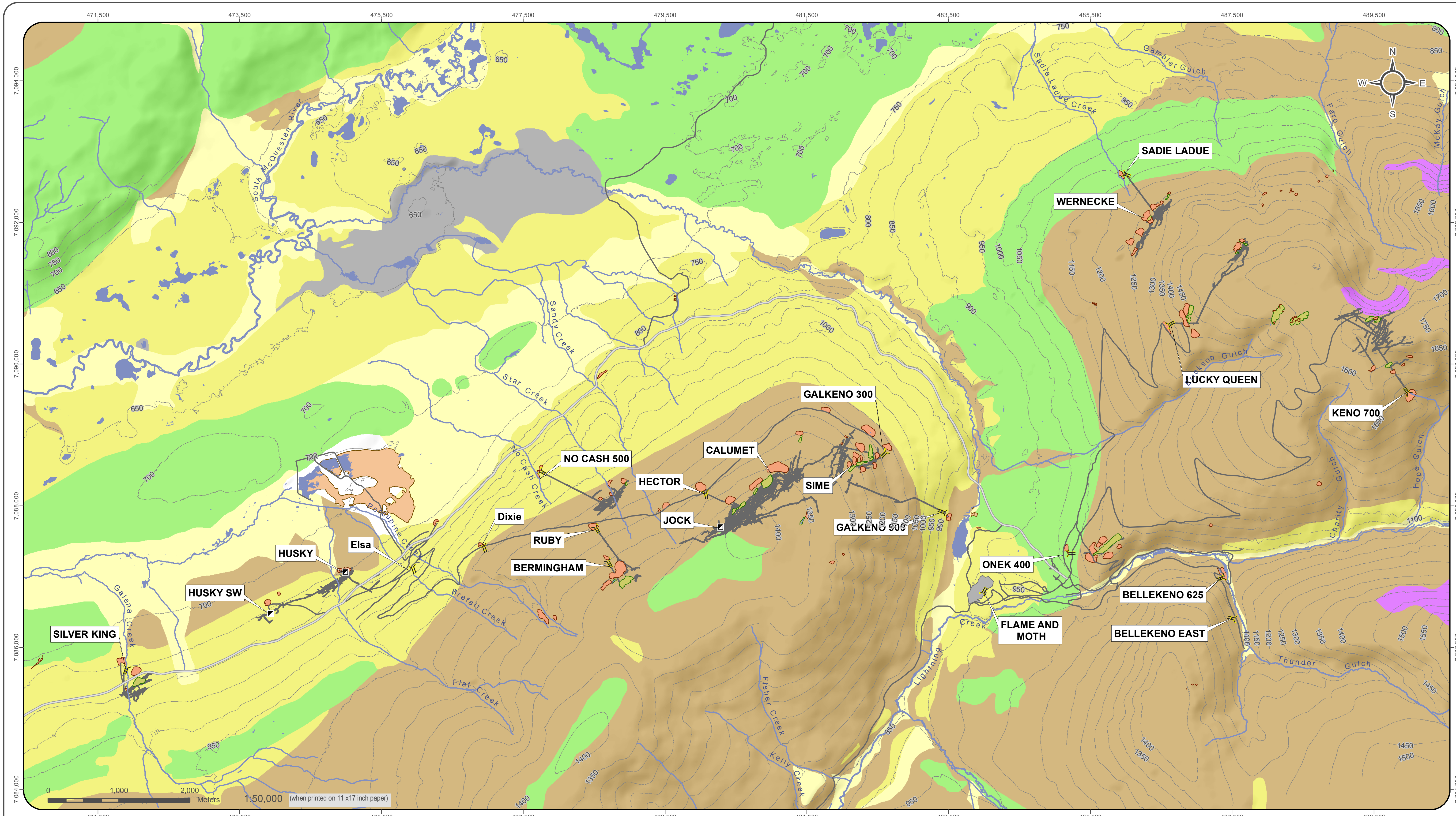
Galena Hill trends northeast between Duncan Creek and the McQuesten River valley. It has an elevation of 1444 masl, a moderately steep southwestern slope, and steeper north, northwestern, and southeastern slopes. The terrain above 1310 masl is relatively flat and rolling, and marked by several level grassy meadows. The north, northwestern, and southeastern slopes of the hill are crossed by several streams that have cut steep gulches into the rock strata. The principal streams responsible for these gulches are Galena, Flat, Brefalt, and Sandy Creeks and Porcupine Gulch on the northwestern slope and Hinton and Fisher Creeks on the eastern and southeastern slopes.

Keno Hill and Sourdough Hill are adjacent hills separated by Lightning Creek. Keno Hill trends northeast and lies between the Keno Ladue-McQuesten River valley and Allen, Faith, Lightning, and Christal Creeks. The hill has relatively gentle southern and southeastern slopes and a precipitous northern slope, marked by two cirques, Faro Gulch and Silver Basin Gulch. The terrain above 1372 masl is relatively flat and rolling with five prominent rocky knolls known as Keno, Minto, Monument (the highest point on Keno Hill, elevation 1848masl), Caribou, and Beauvette. On the slopes of the hill several streams follow steep gulches in the rock strata, the principal ones being Gambler, Faro, McKay, and Silver Basin on the northern slope, Faith, Hope, and Charity on the northeastern and southern slopes, and Erickson on the western slope.

Sourdough Hill lies southwest of Keno Hill and trends north between Thunder, Lightning, and Duncan Creeks. The part of the hill described in this report is on the northern and northwestern slopes, which are gentle up to 1280m and from there rise abruptly to a steep rocky hogsback that trends southwest for some 1828 masl.

Extensive rock outcrops are uncommon on Galena, Keno, and Sourdough hills, and with the exception of the gulches and cirques where relatively good geological sections are present, detailed mapping can only be done by observing float. Below an elevation of 1341 masl rock outcrops are sparse, and the slopes are covered with till, soil, rock debris, much, and muskeg, in which conifers, birch, aspen, Arctic black-birch, and other vegetation grow abundantly. Above this elevation the soil is thin, outcrops are more numerous, the ground is covered with local rock float, the terrain is treeless, and the vegetation is limited to alpine species and grassy meadows.

The lower slopes of the hills were severely glaciated during Pleistocene time by ice sheets that spread, from the east, over the entire area. Glacial till, gravel, and other debris lie in a series of benches on the slopes of the hills and floor the valleys. The deposits in the KHSD are generally 1.5 to 6m thick, but in some areas as on the southern slope of Keno Hill facing Lightning Creek and north of Christal Lake, they are 9 to 15 m thick or more.

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Datum: NAD 83; Map Projection: UTM Zone 8N

- Anthropogenic
- Colluvium
- Fluvial (Active)
- Fluvial (Glacial)
- Morainal
- Organic
- Bedrock
- Adit
- Shaft
- Underground Workings
- Silver Trail Highway
- Secondary Road
- Contours (50 meter)
- Watercourse
- Waterbody
- District Mill
- Open Pit
- Waste Rock Dump
- Tailings

* Only showing mine sites referenced in document

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KENO HILL SILVER DISTRICT
CHARACTERIZATION REPORT

**FIGURE 2-2**
**KHSD SURFICIAL GEOLOGY**

APRIL 2016

D:\Project\AllProjects\ALEX-05-01\gis\mxd\Overview_Maps\WQ\01-GROUNDWATER\Specific_Focus\Groundwater_Investigation\2015_GW_report\Fig_3_2_SurficialGeo20160421.mxd
(*Last edited by: amatlashevska; 4/25/2016/11:21 AM*)

## 2.4 PERMAFROST

The KHSD area is in the region of discontinuous permanently frozen ground. The permafrost is irregularly distributed, and its occurrence is dependent upon the elevation, hillside exposure, depth of overburden, amount of vegetative cover, and presence of flowing underground and surface water. At high elevations and on slopes with a northern exposure it is generally present.

On Keno Hill, the mine workings on the top of the hill and on the northern slope encountered permafrost some 120 m below the surface. On the northern slopes of Sourdough Hill and Galena Hill a similar situation prevails, and frost and ice lenses have been encountered at depths of 76 m or more in the mine workings. On the lower southern slope of Keno Hill, however, the workings of the Onek and Keno 700 mines show little evidence of permafrost. In places where surface and underground water are flowing the permafrost has been thawed out and frost-free windows and strips are present. These provide access and egress for waters that are oxidizing the lodes.

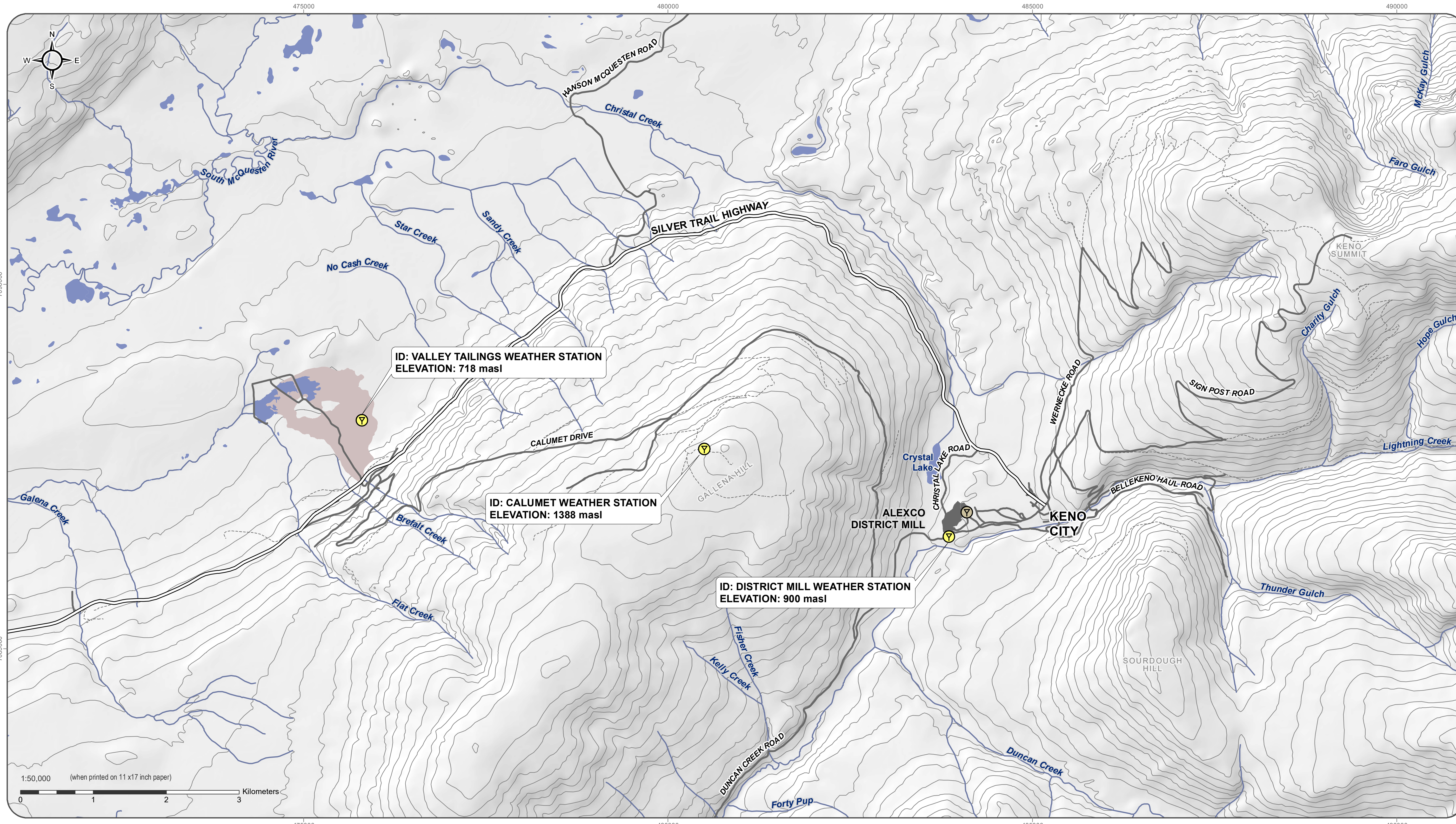
The effects of frost action, soil creep, and slope wash are marked on the hills, particularly at the higher elevations. Frost action is responsible for features such as stone rings and stripes, and produces a general 'boiling action' that brings rock float, mineralized float, and soil from deeper layers to the surface, thus facilitating the mapping of both the underlying bedrock and the tracing of vein faults. On steep slopes, however, frost action and land creep have transported float downhill places, 30m or more, making the accurate mapping of contacts and vein faults difficult.

# 3 CLIMATE, AIR QUALITY, AND NOISE

The KHSD falls within the subarctic clime of the Koppen climate classification. The closest current long term climate record is that at the Mayo Airport at 504 masl. The 1981-2010 Canadian Climate Normals for Mayo give an average daily temperature of -2.4 °C and average annual precipitation of 313.5 mm with 203.8 mm falling as rain. The wet season occurs in summer/fall with dryer winters. The District Mill sits at 913 masl and typically gets more precipitation than Mayo. The 1991-2020 Canadian Climate Normals had not been published at the time of the report.

## 3.1 METEOROLOGICAL STATIONS

This section describes the meteorological data collected for the KHSD area since 2007 at the Calumet meteorological station on Galena Hill, since 2011 at the District Mill meteorological station, and since 2012 at the Valley Tailings meteorological station. The location for the District Mill weather was changed in 2022 and it is now located adjacent the Duncan Creek Road at the Flame & Moth mine vent raise. The District Mill meteorological station was previously located within the DSTF phase 1 footprint. The locations of the three weather stations are shown on Figure 3-1. A summary of the climate information available is presented in the following sections.

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Datum: NAD 83; Map Projection: UTM Zone 8N



- Weather Station
- Weather Station, Discontinued
- Tailings Area
- Waterbody
- Watercourse
- Mill Site Footprint
- Silver Trail Highway
- Road
- Limited-Use Road
- Contours (100 ft)

Hecla KENO HILL

ELSA RECLAMATION AND DEVELOPMENT COMPANY

**FIGURE 3-1**

**KENO METEOROLOGICAL STATIONS**

FEBRUARY 2023

### 3.1.1 CALUMET WEATHER STATION

This station is an automated Onset HOBO meteorological station installed on Galena Hill at 1380 masl in June 2007 (UTM coordinates: 08 V 480377 7087790). Table 3-1 provides a list of the station's complete component list.

**Table 3-1: Calumet HOBO Meteorological Station**

| Component | Model | Serial Number |
|---|---|---|
| Datalogger | HOBO Weather Logger | 1153440 |
| Temp & RH Sensor | S-THB-XXXX | 10064003 |
| Soil Temp Sensor | S-TMB-XXXX | 985390 |
| Pyranometer | S-LIB-XXXX | 1048627 |
| Rain Gauge | S-RGB-M002 | 1017667 |
| Wind Speed & Direction Sensor | S-WCA-XXXX<br>Installed April 19, 2019: S-WCF-M003 | 1254995<br>20584743 |
| BP Sensor | S-BPA-XXXX | 1037089 |
| Solar Panel | SOLAR-6W<br>Installed August 3, 2019: SOLAR-15W | |

Monthly averages were calculated from 15-minute values recorded by the datalogger (averaged values from a 1-minute sampling interval). Average temperature and total rainfall are presented in Table 3-2 and Table 3-3, respectively below.

## Table 3-2: Monthly Values for Average Temperature Collected at the Calumet Station (2007-2012)

| Month | Average Temperature (°C) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
| January | - | -17.18 | -18.84 | -14.08 | -16.78[3] | -18.71[4] | -16.9 | [6] | -13.22 | *-8.34*[8] | *-13.06*[9] | -13.8 | [12] | [14] | [15] | *16.52*[16] |
| February | - | -16.99 | -16.95 | -9.09 | -15.88[3] | -9.94[4] | -10.81 | -15.69 | -13.42 | -9.32 | [9] | -16.86 | [12] | [14] | [15] | -15.23 |
| March | - | -11.04 | -16.39 | -9.21 | -12.92[3] | -12.92[4] | -14.45 | -11.95 | -10.69 | -5.84 | *-16.43*[9] | -11.99 | [12] | *16.06*[14] | [15] | -10.68 |
| April | - | -4.93 | -4.75 | -2.01 | -3.77[3] | -1.88[4] | -12.32 | -4.39 | -3.33 | -0.43 | *-3.62*[10] | -6.33 | *-4.21*[12] | -5.99 | *-2.14*[15] | -7.27 |
| May | - | 3.31 | 3.66 | 5.35 | 4.41[3] | 1.61[4] | - | 4.17 | 7.85 | 5.55 | [10] | 2.84 | *-2.50*[13] | 3.38 | 2.34 | 1.44 |
| June | *11.25*[1] | 8.7 | 9.58 | 8.68 | 8.82[3] | 7.76[4] | 11.59 | *7.31*[7] | 8.42 | 10.07 | [10] | 8.68 | [13] | 7.5 | 10.61 | 10.76 |
| July | 11.8 | 8.17 | 12.45 | 10.5 | 3.80[3] | 7.84[4] | 11.11 | [7] | 9.67 | 10.6 | *11.81*[10] | 11.93 | [13] | 8.59 | 11.73 | 11.06 |
| August | 9.63 | 5.54 | 7.47 | 9.61 | [2] | 8.34[5] | 10.58 | 7.95 | 6.71 | 9.25 | 10.03 | 7.14 | *6.02*[13] | 8.19 | 8.22 | 8.80 |
| September | 1.12 | 2.27 | 3.58 | 2.4 | [2] | 3.39 | 3.33 | 1.86 | *2.17*[8] | 2.95 | 4.74 | 1.55 | 7.22 | *5.51*[15] | 1.38 | 3.61 |
| October | -6.53 | -7.2 | -4.73 | -4.86 | [2] | -8.16 | -2.52 | -5.02 | [8] | -6.23 | -4.94 | -2.64 | [14] | [15] | -4.1[16] | -1.21 |
| November | -9.41 | -10.17 | -11.94 | -11.19 | -17.39[4] | -18.44 | -15.5 | -9.87 | [8] | -8.87 | -17.31 | -9.29 | [14] | [15] | [16] | - 12.63 |
| December | -16.19 | -18.34 | -11.16 | -17.72 | -11.78[4] | -18.83 | -14.56[6] | -10.43 | [8] | -15.27 | -5.31[11] | -10.67[12] | [14] | [15] | [16] | -17.17 |

***Notes:***

*Values in grey italics indicate a partial month.*

*[1] Station commissioned June 15, 2007.*

*[2] Temperature probe malfunction – no proxy data available.*

*[3] Calculated from Mayo A data.*

*[4] Sensor occasionally offline but most data complete*

*[5] Sensor replaced August 7, 2012*

*[6] The station was down from December 12, 2013 to January 31, 2014.*

*[7] Station was down between June 26 and July 31, 2014.*

*[8] Data missing from September 17, 2015 to January 5, 2016.*

*[9] Temperature data missing between January 14, 2017 and March 4, 2017.*

*[10] Data missing between April 7, 2017 and July 17, 2017.*

*[11] Last data download on December 15, 2017.*

*[12] Data missing between December 26, 2018 and April 19, 2019. Battery depletion and windspeed sensor failure.*

*[13] Data missing between May 8, 2019 and August 3, 2019. Solar panel issues.*

*[14] Data missing as battery depleted due to solar panels being covered by snow.*

*[15] Data missing due to a power issue September 4, 2020 to April 13, 2021.*

*[16] Station down between October 16, 2022 to January 26, 2022 due to a depleted battery.*

## Table 3-3: Monthly Values for Total Rainfall Collected at the Calumet Station (2007-2022)

| Month | Total Rainfall (mm) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
| January | - | - | - | - | - | - | - | [7] | 0 | *0.01*[9] | *0.02*[11] | 5.1 | [13] | [15] | [16] | *0.0*[17] |
| February | - | - | - | - | 1.8[4] | [5] | - | - | 0.2 | 0.3 | [11] | 0.3 | [13] | [15] | [16] | 1.0 |
| March | - | - | - | - | 0.5[4] | [5] | 0.6 | - | 2.8 | 2.8 | *0.8*[11] | 1.3 | [13] | *0*[15] | [16] | 2.2 |
| April | - | 1.0 | - | 1.3[4] | 2.8[4] | [5] | 0.2 | 6.2 | 8.6 | 7.8 | *4.3*[12] | 0.8 | *1.0*[13] | 5.8 | *0*[16] | 0.6 |
| May | - | 25.4 | 21.8 | 32.3[4] | 15.5[4] | [5] | n/a | 17.2 | 4.0 | 23.0 | [12] | 82.8 | *0.5*[14] | 23.8 | 54.26 | 12.4 |
| June | *55.2*[1] | 44.6 | *11.9*[2] | 56.7[4] | 121.8[4] | [5] | 45.2 | *69.8*[8] | 45.2 | *43.0*[10] | [12] | 116.3 | [14] | 135.5 | 19.43 | 28.4 |
| July | 108.8 | 108.4 | *22.9*[3] | 137.7[4] | 135.9[4] | *27.8*[6] | 39.2 | [8] | 135.5 | [10] | *71.3*[12] | 31.6 | [14] | 149.4 | 75.02 | 60.6 |
| August | 54.8 | 110.2 | 89.4 | 140.0[4] | [5] | 45.0 | 35.6 | 112.0 | 97.0 | [10] | 44.5 | 164.3 | *21.2*[14] | *31.3*[16] | 120.73 | 54.4 |
| September | 57.6 | 61.4 | 50.4 | 78.0[4] | [5] | 17.4 | 64.6 | 43.8 | *46.4*[9] | [10] | 115.2 | 15.9 | 41.5 | [16] | 27.31 | 50.8 |
| October | - | 12.6 | - | 16.0[4] | [5] | 1.6 | 14.6 | 15.2 | [9] | *0.01*[10] | 16.0 | 9.4 | [15] | [16] | 1.01[17] | 33.2 |
| November | - | - | - | - | - | 0.2 | - | 0.2 | [9] | 0 | 0 | 3.3 | [15] | [16] | [17] | 0.0 |
| December | - | - | - | - | - | - | *0.1*[7] | - | [9] | 0 | 0 | *0.5*[13] | [15] | [16] | [17] | 0.0 |
| **Total** | **276.4** | **363.6** | **196.4** | **462.21** | **305.5** | **137.01** | **200.1** | **211.6** | **375.7** | **115.9** | **299.1** | **431.4** | **216.2** | **489.7** | **297.76** | **243.6** |

***Notes:***

*Values in grey italics indicate a partial month.*

*[1] Station commissioned June 15, 2007.*

*[2] Rainfall gauge malfunction on June 11; total rainfall provided for June 1-11, 2009.*

*[3] Rainfall gauge back online; total rainfall provided for July 7-31, 2009.*

*[4] Calculated from MAYO A data.*

*[5] Tipping bucket malfunction – no proxy data available.*

*[6] Tipping bucket repaired July 4th; total rainfall provided for July 4-31, 2012.*

*[7] The station was down from December 12, 2013 to January 31, 2014.*

*[8] Station was down between June 26 and July 31, 2014.*

*[9] Data missing from September 17, 2015 to January 5, 2016.*

*[10] Rainfall data missing from June 23, 2016 to October 23, 2016.*

*[11] Rain data missing between January 26, 2017 and March 4, 2017.*

*[12] Data missing between April 7, 2017 and July 17, 2017.*

*[13] Meteorological Station sustained damage, no data available between December 12th, 2018 and April 19, 2019.*

*[14] Data missing between May 8, 2019 and August 3, 2019. Solar panel issues.*

*[15] Data missing between October 4, 2019 and March 21, 2020.*

*[16] Data missing due to a power issue August 14, 2020 to April 13, 2021.*

*[17] Station down between October 16, 2021 and January 26, 2022 due to a depleted battery.*

### 3.1.2 DISTRICT MILL WEATHER STATION

The District Mill Campbell Scientific automated meteorological station was installed above the DSTF and below the old Keno City dump near Keno, YT (UTM coordinates: 08 V 0484009 7086872, elevation: 936 masl) in 2011. In May 2022 the meteorological station was disassembled, and components sent to the manufacturer for maintenance, replacement, and calibration. The station was moved to Flame & Moth vent raise when it was reinstalled in November 2022 (Zone 8V -483859, 7086534, elevation: 900m), as its original location was within the phase 1 of the DSTF footprint. All the District Mill meteorological station components are present in Table 3-4.

**Table 3-4: District Mill Campbell Scientific Meteorological Station**

| Component | Model | Serial Number |
|---|---|---|
| Air Temperature and Relative Humidity Sensor | HMP45C212 | n/a |
| Tipping Bucket Rain Gauge | TE525M | 45303-910 |
| Wind Speed and Direction Sensor | 05103AP-10-L | WM105907 |
| Solar Panel | SX320J | T21008289B30EC8 |
| Datalogger | CR800 | 16119 |
| Battery | PS-12120 F2 | 06299-HC |
| Pyranometer | SP Lite2 | 125766 |
| Barometric Pressure | PTB110 1B0CA | P3220823 |

Monthly averages since 2011 were calculated from hourly values recorded by the datalogger (averaged values from a 10 seconds sampling interval) for the following parameters: temperature, daily maximum temperature, daily minimum temperature, relative humidity, wind speed, maximum wind speed, barometric pressure, and solar radiation. Annual temperature, humidity, windspeed, solar radiation wind speed and direction, and total rainfall are shown on Table 3-5 below. The barometric pressure has not been corrected for elevation and therefore represents the absolute pressure.

Wind data from time of commissioning to the end of May 2022 are also depicted in the wind rose presented in Figure 3-2, which was produced using WRPLOT View software. This period has a 92% data availability, i.e., refers to the available wind data in the total dataset, with the remaining 8% missing data attributed to periods of frozen sensors and maintenance.

**Table 3-5: Monthly values for meteorological parameters collected at District Mill Weather Station 2011-2022**

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s) [1] | Extreme Max. Wind Speed (m/s) [1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m²) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun-11 [2] | 24.72 | 18.59 | 11.96 | 6.3 | -2.56 | n/a | n/a | 1.35 | 9.14 | n/a | n/a | n/a |
| Jul-11 | 25.67 | 18.5 | 12.91 | 8 | 5.09 | n/a | n/a | 1.15 | 8.02 | n/a | n/a | n/a |
| Aug-11 | 22.32 | 15.58 | 9.78 | 5.37 | 1.93 | n/a | n/a | 1.18 | 9.15 | n/a | n/a | n/a |
| Sep-11 | 17.97 | 11.29 | 6.07 | 1.85 | -2.47 | n/a | n/a | 1.43 | 11.36 | n/a | n/a | n/a |
| Oct-11 | 7.2 | 0.2 | -2.74 | -5.41 | -9.84 | n/a | *2.603* | 0.94 | 13.12 | n/a | n/a | n/a |
| Nov-11 | -4.23 | -16.79 | -19.54 | -22.47 | -34.99 | n/a | 0 | 0.58 | 12.05 | n/a | n/a | n/a |
| Jan-12 | -0.96 | -19.1 | -23.13 | -26.79 | -37.32 | n/a | 0 | *0.59* | *9.51* | n/a | n/a | n/a |
| Feb-12 | 2.77 | -6.77 | -10 | -13.07 | -26.78 | n/a | 0.10 [4] | *1.38* | *15.62* | n/a | n/a | n/a |
| Mar-12 | 5.33 | -7.69 | -13.37 | -18 | -27.8 | n/a | 0 | *0.97* | *9.24* | n/a | n/a | n/a |
| Apr-12 | 9.69 | 6.13 | 0.96 | -3.87 | -15.92 | n/a | 0.60 [4] | 1.37 | 10.27 | n/a | n/a | n/a |
| May-12 | 17.78 | 10.73 | 6.31 | 1.91 | -3.47 | *51.81* [5] | 18.3 | 1.78 | 10.6 | n/a | n/a | n/a |
| Jun-12 | 27.62 | 18.41 | 13.46 | 8.29 | 4.42 | 56.35 | 21.7 | 1.44 | 10.26 | n/a | n/a | n/a |
| Jul-12 | 25.14 | 18.07 | 12.75 | 7.73 | 1.64 | 69.26 | 85.8 | 1.36 | 12.99 | n/a | n/a | n/a |
| Aug-12 | 21.72 | 16.31 | 11.25 | 6.56 | -0.89 | 67.79 | 47 | 1.62 | 9.41 | n/a | n/a | n/a |
| Sep-12 | 20.24 | 10.33 | 5.9 | 2.08 | -5.22 | 69.51 | 36.4 | 1.84 | 14.27 | n/a | n/a | n/a |
| Oct-12 | 7.6 | -3.95 | -7.35 | -10.32 | -20.62 | 79.54 | 7.6 | 1.13 | 10.37 | n/a | n/a | n/a |
| Nov-12 | -8.98 | -19.55 | -21.9 | -24.32 | -33.36 | 81.43 | 0 | 0.94 | 9.36 | n/a | n/a | n/a |
| Dec-12 | -3.36 | -21.3 | -23.44 | -25.58 | -36.32 | 81.34 | 0 | *0.26* | *5.93* | n/a | *1.01* [6] | *0.05* [7] |
| Jan-13 | -1.59 | -17.06 | -20.01 | -23.08 | -41.48 | 82.92 | 0 | *0.76* | *14.48* | n/a | 1.06 | 0.81 |
| Feb-13 | 1.54 | -9.1 | -12.52 | -15.46 | -23.74 | 88.36 | 0.30 [4] | *0.85* | *12.25* | n/a | 10.26 | 1.27 |
| Mar-13 | 3.26 | -7.52 | -13.16 | -17.99 | -29.96 | 64.08 | 3.9 | 1.59 | 12.47 | n/a | 95.82 | 6.33 |
| Apr-13 | 6.07 | -2.76 | -7.94 | -13.69 | -25.07 | 54.5 | 8.2 | 2.44 | 12.93 | n/a | 190.02 | 14.48 |

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s) [1] | Extreme Max. Wind Speed (m/s) [1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m²) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| May-13 | 23.31 | 10.2 | 5.27 | 0.23 | -9.46 | 61.83 | 39.60 | 1.77 | 11.76 | n/a | 215.44 | 21.7 |
| Jun-13 | 30.51 | 19.97 | 14.27 | 8.30 | 1.84 | 58.72 | 57.30 | 1.82 | 12.87 | n/a | 234.69 | 29.79 |
| Jul-13 | 24.93 | 19.40 | 14.01 | 8.60 | 2.25 | 62.67 | 46.90 | 1.75 | 16.14 | n/a | 211.00 | 27.10 |
| Aug-13 | 27.34 | 18.54 | 12.98 | 8.01 | -0.38 | 66.30 | 51.90 | 1.49 | 11.05 | n/a | 156.25 | 21.38 |
| Sep-13 | 16.11 | 9.69 | 5.81 | 2.26 | -3.74 | 77.52 | 59.70 | 1.54 | 10.99 | n/a | 79.69 | 10.88 |
| Oct-13 | 8.25 | 1.61 | -1.32 | -4.21 | -10.10 | 86.75 | 44.60 | 1.11 | 11.62 | n/a | 35.75 | 4.26 |
| Nov-13 | 0.18 | -13.41 | -16.68 | -20.08 | -37.96 | 84.26 | 10.60 | *1.02* | *10.96* | n/a | 4.93 | *1.08* |
| Dec-13 | -1.73 | -21.23 | -23.91 | -26.70 | -35.29 | 78.77 | 4.90 | *0.75* | *9.47* | n/a | 0.57 | *0.62* |
| Jan-14 | 3.74 | -9.33 | -12.16 | -15.10 | -32.22 | 89.44 | 24.90 | *0.72* | *10.03* | n/a | 2.42 | *0.64* |
| Feb-14 | -1.93 | -15.25 | -19.40 | -23.02 | -33.55 | 75.20 | 2.90 | 0.87 | 10.85 | n/a | 31.34 | 1.99 |
| Mar-14 | 4.57 | -5.31 | -11.29 | -16.16 | -26.79 | 54.77 | 0.70 | 1.57 | 11.98 | n/a | 115.54 | 9.17 |
| Apr-14 | 10.93 | 4.09 | -0.96 | -5.78 | -17.33 | 57.54 | 5.10 | 1.64 | 12.05 | n/a | 171.28 | 15.77 |
| May-14 | 21.30 | 12.70 | 7.64 | 2.03 | -3.03 | 52.18 | 12.80 | 2.09 | 19.21 | n/a | 217.91 | 29.81 |
| Jun-14 | 24.93 | 16.21 | 11.39 | 5.95 | -0.13 | 56.14 | 40.40 | 1.78 | 10.43 | n/a | 217.90 | 28.58 |
| Jul-14 | 23.44 | 18.49 | 13.68 | 8.73 | -0.04 | 65.01 | 31.00 | 1.63 | 13.38 | n/a | 187.31 | 23.84 |
| Aug-14 | 22.09 | 15.57 | 10.87 | 6.93 | 0.06 | 74.59 | 67.70 | 1.44 | 11.85 | n/a | 139.84 | 15.72 |
| Sep-14 | 17.70 | 8.76 | 4.28 | 0.49 | -6.74 | 70.54 | 36.40 | 1.37 | 11.32 | n/a | 93.38 | 11.56 |
| Oct-14 | 7.47 | -0.91 | -3.79 | -6.33 | -15.42 | 88.21 | 15.70 | 1.24 | 12.80 | n/a | 24.83 | 3.39 |
| Nov-14 | -2.21 | -12.15 | -14.34 | -16.59 | -30.16 | 88.64 | 1.40 | *0.59* | *6.27* | n/a | 3.12 | *0.60* |
| Dec-14 | -0.09 | -11.05 | -13.67 | -16.31 | -26.66 | 89.06 | 1.40 [9] | *0.51* | *8.87* | n/a | 0.33 | *0.40* |
| Jan-15 | -0.34 | -13.69 | -16.50 | -19.11 | -34.86 | 85.85 | 1.90 | *0.49* | *5.49* | n/a | 1.30 | *0.43* |
| Feb-15 | 2.87 | -12.92 | -15.93 | -18.75 | -39.39 | 84.95 | 12.70 | 0.75 | 10.36 | n/a | 9.06 | 0.86 |
| Mar-15 | 5.54 | -4.76 | -9.83 | -14.21 | -28.70 | 70.52 | 4.10 | 1.45 | 12.60 | n/a | 86.48 | 6.29 |
| Apr-15 | 10.90 | 5.36 | 0.56 | -3.86 | -10.48 | 61.71 | 4.20 | 1.75 | 12.37 | n/a | 163.45 | 16.03 |
| May-15 | 26.51 | 16.95 | 10.96 | 4.66 | -7.00 | 45.35 | 1.40 | 1.89 | 10.64 | n/a | 246.80 | 34.67 |

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s) [1] | Extreme Max. Wind Speed (m/s) [1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m²) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jun-15 | 23.18 | 16.65 | 11.37 | 5.90 | 0.52 | 61.05 | 26.30 | 1.85 | 12.62 | n/a | 219.18 | 26.46 |
| Jul-15 | 25.43 | 17.60 | 12.54 | 7.77 | 4.73 | 68.63 | 72.40 | 1.48 | 12.62 | n/a | 190.74 | 19.98 |
| Aug-15 | 24.63 | 14.03 | 9.35 | 5.20 | -3.09 | 75.14 | 54.90 | *1.47* | *9.86* | n/a | 146.76 | *13.87* |
| Sep-15 | 13.57 | 7.10 | 2.77 | -0.61 | -7.72 | 79.33 | 32.60 | 1.71 | 15.64 | n/a | 83.01 | 10.12 |
| Oct-15 | 7.32 | 0.92 | -1.78 | -4.12 | -13.22 | 89.14 | 19.40 | *1.08* | *10.07* | n/a | 32.52 | *2.92* |
| Nov-15 | 0.83 | -11.09 | -13.75 | -17.21 | -31.38 | 89.09 | 22.80 | *0.71* | *12.15* | n/a | 4.03 | *0.60* |
| Dec-15 | 0.18 | -12.37 | -14.60 | -16.94 | -31.06 | 89.01 | 4.00 | *4.59* | *14.24* | n/a | 0.63 | *0.13* |
| Jan-16 | 1.17 | -8.92 | -11.14 | -13.55 | -21.91 | 88.06 | 24.90 | *0.83* | *15.35* | n/a | 1.67 | *1.45* |
| Feb-16 | 2.04 | -7.62 | -10.94 | -14.22 | -26.68 | 82.96 | 2.30 | 0.86 | 9.55 | n/a | 22.80 | 2.32 |
| Mar-16 | 12.35 | -0.54 | -4.96 | -8.68 | -16.96 | 73.13 | 7.10 | 1.26 | 8.11 | n/a | 82.81 | 7.12 |
| Apr-16 | 13.50 | 7.12 | 2.28 | -2.15 | -12.45 | 63.20 | 3.80 | 1.64 | 10.66 | n/a | 159.95 | 15.86 |
| May-16 | 22.80 | 13.61 | 8.44 | 3.08 | -1.59 | 54.73 | 14.70 | 1.89 | 11.89 | n/a | 210.96 | 25.97 |
| Jun-16 | 25.98 | 18.41 | 12.88 | 7.21 | 2.27 | 56.52 | 40.00 | 1.76 | 13.37 | n/a | 234.99 | 29.78 |
| Jul-16 | 23.73 | 17.73 | 13.37 | 9.12 | 1.71 | 73.05 | 63.40 | 1.46 | 12.54 | n/a | 173.59 | 17.36 |
| Aug-16 | 24.42 | 16.71 | 11.92 | 7.91 | 1.22 | 70.86 | 42.20 | 1.50 | 10.69 | n/a | 152.32 | 17.72 |
| Sep-16 | 17.42 | 10.02 | 5.01 | 1.02 | -6.18 | 71.05 | 28.90 | 1.50 | 10.81 | n/a | 100.94 | 14.02 |
| Oct-16 | 2.43 | -3.18 | -7.07 | -9.98 | -17.15 | 79.60 | 11.40 | 1.12 | 8.29 | n/a | 50.66 | 4.15 |
| Nov-16 | 4.05 | -8.14 | -10.89 | -13.43 | -25.46 | 86.45 | 7.60 | *0.80* | *9.57* | n/a | 5.70 | *1.99* |
| Dec-16 | -4.20 | -17.41 | -19.62 | -21.87 | -32.16 | 83.76 | 1.30 | *0.62* | *8.45* | n/a | 0.56 | *0.51* |
| Jan-17 | -0.10 | -13.15 | -16.02 | -18.93 | -33.59 | 82.95 | 0.80 | *1.06* | *11.03* | n/a | 1.64 | *1.76* |
| Feb-17 | 5.04 | -11.33 | -14.85 | -17.99 | -28.26 | 78.03 | 21.60 | 1.12 | 11.61 | n/a | 26.93 | 3.17 |
| Mar-17 | 9.56 | -10.51 | -16.13 | -20.24 | -32.14 | 64.03 | 8.40 | 1.72 | 8.83 | n/a | 100.75 | 6.51 |
| Apr-17 | 12.09 | 4.12 | -1.23 | -6.29 | -16.26 | 57.70 | 7.10 | 1.81 | 10.50 | n/a | 173.66 | 15.44 |
| May-17 | 19.93 | 12.88 | 7.90 | 2.98 | -2.30 | 54.38 | 16.80 | 1.92 | 11.54 | n/a | 211.85 | 27.95 |
| Jun-17 | 25.34 | 17.47 | 12.38 | 6.78 | -0.90 | 54.93 | 20.20 | 1.73 | 13.32 | n/a | 225.93 | 28.61 |

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s) [1] | Extreme Max. Wind Speed (m/s) [1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m$^2$) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jul-17 | 28.09 | 20.67 | 14.99 | 9.50 | 4.21 | 64.01 | 39.40 | 1.57 | 13.65 | n/a | 212.94 | 25.50 |
| Aug-17 | 28.31 | 18.22 | 12.83 | 8.25 | 1.95 | 64.85 | 16.70 | 1.46 | 11.01 | n/a | 156.87 | 21.67 |
| Sep-17 | 19.06 | 11.19 | 6.96 | 3.51 | -2.32 | 77.06 | 48.70 | 1.34 | 11.06 | n/a | 78.21 | 10.37 |
| Oct-17 | 10.14 | -0.30 | -3.40 | -6.24 | -12.54 | 87.16 | 28.00 | *1.05* | *8.65* | n/a | 31.26 | *3.40* |
| Nov-17 | -5.89 | -17.86 | -20.14 | -22.28 | -33.90 | 83.46 | 0.00 | *0.45* | *5.47* | n/a | 5.37 | *0.45* |
| Dec-17 | 4.27 | -10.02 | -12.27 | -14.73 | -31.16 | 86.62 | 19.80 | *1.78* | *12.28* | n/a | 0.74 | 2.00 |
| Jan-18 | 6.35 | -14.26 | -17.11 | -19.90 | -33.78 | 82.19 | 9.60 | 0.34 | 12.84 | n/a | 2.84 | *1.68* |
| Feb-18 | -6.39 | -17.06 | -20.32 | -22.93 | -33.41 | 79.90 | 0.10 | 0.76 | 7.80 | n/a | 11.40 | *1.01* |
| Mar-18 | 9.71 | -5.00 | -10.46 | -14.86 | -27.81 | 63.15 | 17.20 | 1.55 | 14.32 | n/a | 84.89 | *7.56* |
| Apr-18 | 10.91 | 2.25 | -3.44 | -8.99 | -21.32 | 50.97 | 0.00 | 1.77 | 9.28 | n/a | 180.88 | 15.92 |
| May-18 | 20.56 | 11.41 | 6.40 | 1.46 | -10.30 | 61.61 | 67.60 | 1.75 | 11.42 | n/a | 186.76 | 21.96 |
| Jun-18 | 27.11 | 16.54 | 11.63 | 6.75 | 3.61 | 65.23 | 75.80 | 1.59 | 12.21 | n/a | 200.62 | 21.82 |
| Jul-18 | 27.68 | 20.26 | 14.32 | 8.36 | 3.78 | 59.75 | 19.70 | 1.66 | 10.06 | n/a | 212.37 | 28.97 |
| Aug-18 | 25.11 | 14.43 | 9.91 | 6.11 | -0.43 | 79.09 | 110.60 | 1.47 | 17.10 | n/a | 132.47 | 12.32 |
| Sep-18 | 13.12 | 9.00 | 4.30 | -0.37 | -3.93 | 63.01 | 14.00 | 1.55 | 10.73 | n/a | 118.01 | *6.56* |
| Oct-18 | 10.16 | 2.57 | -0.57 | -3.65 | -13.06 | 72.22 | 4.23 | 1.32 | 10.79 | 89.71 | 31.70 | *4.56* |
| Nov-18 | 2.31 | -9.04 | -11.41 | -14.11 | -25.19 | 89.76 | 0.00 | 0.56 | 10.49 | 90.09 | 3.34 | *0.78* |
| Dec-18 | 1.81 | -10.91 | -13.42 | -16.22 | -27.70 | 83.56 | 0.00 | 0.95 | 13.48 | 89.38 | 1.21 | *2.63* |
| Jan-19 | -1.90 | -15.40 | -18.09 | -20.82 | -33.36 | 85.24 | 0.00 | 0.38 | 7.68 | 89.98 | 1.13 | *0.40* |
| Feb-19 | -6.32 | -16.42 | -19.72 | -22.27 | -33.39 | 80.90 | 0.00 | 0.70 | 5.91 | 91.01 | 10.94 | 0.96 |
| Mar-19 | 12.89 | 1.69 | -3.45 | -7.58 | -20.19 | 63.64 | 0.00 | 1.63 | 13.70 | 90.47 | 81.56 | 12.21 |
| Apr-19 | 9.18 | 4.20 | -0.73 | -5.51 | -19.91 | 55.50 | 5.99 | 1.83 | 12.09 | 89.98 | 168.31 | 17.60 |
| May-19 | 25.43 | 14.51 | 9.42 | 4.00 | -7.11 | 46.76 | 14.89 | 1.87 | 11.64 | 90.38 | 226.08 | 32.54 |
| Jun-19 | 25.09 | 18.50 | 13.19 | 7.57 | 3.39 | 52.95 | 29.48 | 1.90 | 11.74 | 90.55 | 244.49 | 35.61 |
| Jul-19 | 26.14 | 21.07 | 15.11 | 9.48 | 6.69 | 61.29 | 39.55 | 1.57 | 13.40 | 90.59 | 210.36 | 27.86 |

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s)[1] | Extreme Max. Wind Speed (m/s)[1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation ($W/m^2$) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-19 | 21.95 | 14.62 | 9.20 | 4.19 | -3.42 | 63.17 | 19.99 | 1.82 | 12.46 | 90.73 | 154.50 | 23.31 |
| Sep-19 | 23.52 | 11.86 | 6.61 | 2.48 | -6.15 | 69.22 | 16.32 | 1.35 | 10.92 | 90.14 | 91.68 | *37.1* |
| Oct-19 | 9.26 | -0.90 | -3.96 | -6.78 | -15.44 | 88.66 | 0.80 | 0.95 | 7.76 | 90.06 | 25.51 | *4.26* |
| Nov-19 | -0.82 | -10.64 | -13.43 | -16.46 | -26.14 | 87.87 | 0.10 | 0.80 | 11.13 | 90.05 | 5.24 | *1.71* |
| Dec-19 | -1.43 | -13.83 | -17.20 | -21.19 | -32.37 | 85.42 | 0.00 | 0.76 | 10.79 | 89.08 | 0.70 | *1.78* |
| Jan-20 | -0.70 | -20.54 | -23.42 | -26.41 | -36.14 | 78.70 | 0.10 | 0.64 | 4.52 | 89.57 | 2.56 | *1.72* |
| Feb-20 | -0.39 | -14.65 | -18.31 | -22.15 | -37.03 | 80.67 | 3.00 | 1.04 | 8.85 | 89.66 | 16.12 | *3.63* |
| Mar-20 | 0.80 | -9.68 | -14.88 | -19.56 | -30.93 | 69.81 | 15.60 | 1.43 | 5.74 | 90.36 | 56.86 | *7.57* |
| Apr-20 | 10.70 | 2.20 | -2.80 | -7.69 | -18.36 | 59.73 | 8.90 | 1.80 | 5.65 | 90.21 | 169.99 | *22.06* |
| May-20 | 20.29 | 12.98 | 7.48 | 1.97 | -5.09 | 48.06 | 8.10 | 1.84 | 5.54 | 90.55 | 253.76 | *48.75* |
| Jun-20 | 22.57 | 15.51 | 10.68 | 6.28 | 2.57 | 69.21 | 44.00 | 1.44 | 4.48 | 90.11 | 185.80 | *25.83* |
| Jul-20 | 27.68 | 16.72 | 11.50 | 6.96 | 1.38 | 73.88 | 39.10 | 1.38 | 4.46 | 90.35 | 183.23 | *23.8* |
| Aug-20 | 26.13 | 15.59 | 10.94 | 7.06 | 3.58 | 75.83 | 53.70 | 1.24 | 4.11 | 90.06 | 131.31 | *20.05* |
| Sep-20 | 14.79 | 9.61 | 5.32 | 2.24 | -1.95 | 78.21 | 45.80 | 1.25 | 6.29 | 90.31 | 82.70 | *14.23* |
| Oct-20 | 13.77 | -4.06 | -7.01 | -9.65 | -23.35 | 84.29 | 37.32 | 1.01 | 7.00 | 90.38 | 28.37 | *7.51* |
| Nov-20 | -3.01 | -14.17 | -16.95 | -19.50 | -27.22 | 86.08 | 19.41 | 0.71 | 5.34 | 89.50 | 4.09 | *1.51* |
| Dec-20 | 5.31 | -1.91 | -5.52 | -8.79 | -17.47 | 85.44 | 12.69 | 2.10 | 9.78 | 88.73 | 1.82 | *2.94* |
| Jan-21 | 0.89 | -9.93 | -13.06 | -16.39 | -33.06 | 84.31 | 24.36 | 0.77 | 11.6 | 89.23 | 28.95 | 3.12 |
| Feb-21 | -7.44 | -18.53 | -22.65 | -25.93 | -38.29 | 78.89 | 35.75 | 0.73 | 7.61 | 90.14 | 88.45 | 1.11 |
| Mar-21 | 0.8 | -8.25 | -14.22 | -19.32 | -26.87 | 72.32 | 0 | 1.47 | 9.06 | 89.63 | 592.98 | 6.34 |
| Apr-21 | 13.75 | 1.85 | -4.96 | -11.58 | -27.79 | 52.27 | 0 | 2.01 | 14.11 | 90.52 | 1648.04 | 27.62 |
| May-21 | 14.9 | 10.66 | 5.61 | 1.04 | -5.09 | 62.81 | 36.77 | 1.79 | 11.73 | 90.31 | 1638.02 | 30.33 |
| Jun-21 | 25.66 | 19.93 | 13.81 | 7.97 | 2.60 | 52.48 | 15.94 | 2.03 | 14.31 | 90.17 | 1850.27 | 56.6 |
| Jul-21 | 28.98 | 21.13 | 14.41 | 8.41 | 2.61 | 59.16 | 73.7 | 1.74 | 10.41 | 90.57 | 1757.92 | 45.98 |

| Date | Extreme Max. Temp. (ºC) | Average Max. Temp. (ºC) | Average Temp. (ºC) | Average Min. Temp. (ºC) | Extreme Min. Temp. (ºC) | Average Relative Humidity (%) | Total Precip. (mm) | Average Wind Speed (m/s) [1] | Extreme Max. Wind Speed (m/s) [1] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m²) | Total Evapo-transpiration (mm)[8] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-21 | 28.74 | 16.67 | 11.08 | 6.18 | 0.34 | 72.71 | 76.9 | 1.51 | 10.23 | 90.22 | 1195.82 | 23.56 |
| Sep-21 | 19.24 | 9.39 | 4.43 | 0.51 | -7.94 | 79 | 15.2 | 1.39 | 9.3 | 89.5 | 703.12 | 12.59 |
| Oct-21 | 6.35 | 1.22 | -1.81 | -4.34 | -11.41 | 83.89 | 0 | 1.05 | 11.65 | 87.11 | 252.03 | 3 |
| Nov-21 | 4.96 | -2.33 | -5.75 | -9 | -16.95 | 76.61 | 0 | 1.33 | 8.94 | 86.02 | 143.49 | - |
| Dec-21 | -13.02 | -20.19 | -23.75 | -27.14 | -37.52 | 80.40 | 3.00 | 0.40 | 3.20 | 89.44 | 3.84 | 5.67 |
| Jan-22 | -2.96 | -16.25 | -19.84 | -23.10 | -36.71 | 83.17 | 17.80 | 0.82 | 6.04 | 89.57 | 5.47 | n/a |
| Feb-22 | -3.71 | -14.63 | -18.13 | -22.70 | -34.75 | 83.50 | 5.30 | 0.74 | 4.14 | 89.42 | 97.63 | n/a |
| Mar-22 | 2.44 | -4.71 | -9.99 | -14.74 | -29.17 | 74.96 | 11.10 | 1.42 | 5.35 | 89.94 | 602.95 | n/a |
| Apr-22 | 9.33 | 1.35 | -3.99 | -10.37 | -25.08 | 53.92 | 3.90 | 1.76 | 5.91 | 90.36 | 1612.12 | n/a |
| May-22 | 15.41 | 8.59 | 4.51 | -0.63 | -2.75 | 61.49 | 14.60 | 2.05 | 5.98 | 90.07 | 1786.11 | n/a |
| Jun-22 [11] | | | | | | | | | | | | |
| Jul-22 [11] | | | | | | | | | | | | |
| Aug-22 [1] | | | | | | | | | | | | |
| Sep-22 [11] | | | | | | | | | | | | |
| Oct-22 | 10.77 | 6.31 | -5.81 | -15.30 | -18.30 | 89.98 | n/a | n/a | n/a | 88.20 | n/a | n/a |
| Nov-22[12] | 3.58 | -0.72 | -14.20 | -27.61 | -32.18 | 87.24 | 0.00 | 0.83 | 2.85 | 90.81 | n/a | n/a |
| Dec-22 | -2.18 | -1.67 | -21.60 | -33.44 | -38.22 | 85.01 | 0.00 | 0.10 | 2.39 | 90.66 | n/a | n/a |

***Notes:***

*Values in grey italics indicate a partial month.*

*[1] Wind Sensor was not operating properly:*

- *January 2012 – 25 days of complete wind data*
- *February 2012 – 28 days of complete wind data*
- *March 2012 – 30 days of complete wind data*
- *December 2012 – 15 days of complete wind data*
- *January 2013 – 21 days of complete wind data*

*[2] June 2011 has 29 days of complete data (station commissioned on June 2)*

*[3] 16 days of complete rain data*

*[4] Rainfall recorded at temperatures below zero may be due to snowmelt*

*[5] 25 days of complete RH data*

*[6] 18 days of complete solar radiation data*

***Notes:***

- *February 2013 – 26 days of complete wind data*
- *November 2013 – 24 days of complete wind data*
- *December 2013 – 20 days of complete wind data*
- *January 2014 – 9 days of complete wind data*
- *November 2014 – 23 days of complete wind data*
- *December 2014 - days of complete wind data*
- *January 2015 – 24 days of complete wind data*
- *August 2015 - days of complete wind data*
- *October 2015 – 29 days of complete wind data*
- *November 2015 – 9 days of complete wind data*
- *December 2015 – 0 days of complete wind data*
- *January 2016 – 16 days of complete wind data*
- *November 2016 – 23 days of complete wind data*
- *December 2016 - 22 days of complete wind data*
- *January 2017 – 25 days of complete wind data*
- *October 2017 – 28 days of complete wind data*
- *November 2017 – 19 days of complete wind data*
- *January 2018 – 19 days of complete wind data*
- *February 2018 – 27 days of complete wind data*
- *March 2018 – 30 days of complete wind data*
- *September 2018 – 13 days of complete wind data*
- *October 2018 – 21 days of complete wind data*
- *November 2018 – 20 days of complete wind data*
- *December 2018 – 29 days of complete wind data*
- *January 2019 – 15 days of complete wind data*
- *October 2019 – 29 days of complete wind data*
- *January 2021 – 25 days of complete wind data*
- *February 2021 – 27 days of complete wind data*
- *September 2021 – 28 days of complete wind data*
- *October 2021 – 23 days of complete wind data*
- *December 2021 – 21 days of complete wind data*
- *January 2022 – 22 days of complete wind data*
- *February 2022 – 26 days of complete wind data*
- *May 2022 – 22 days of complete wind data*
- *November 2022 – 5 days of complete wind data*

*[7] 7 days of complete evapotranspiration data*

*[8] Evapotranspiration is invalid where wind is invalid*

*[9] Total precipitation likely underestimated due to partial freezing in snowfall conversion adaptor*

*[10] Evapotranspiration invalid due to coding error*

*[11] Station was disassembled for calibration, maintenance, and relocation, no data available.*

*[12] The station was re-installed in November 2022, therefore, no data from May-November was recorded. Some sensors (wind speed and direction) were re-installed incorrectly causing no data to be collected in November, these sensors were fixed during the December trip. Station missing data from November 23-24, 2022.*

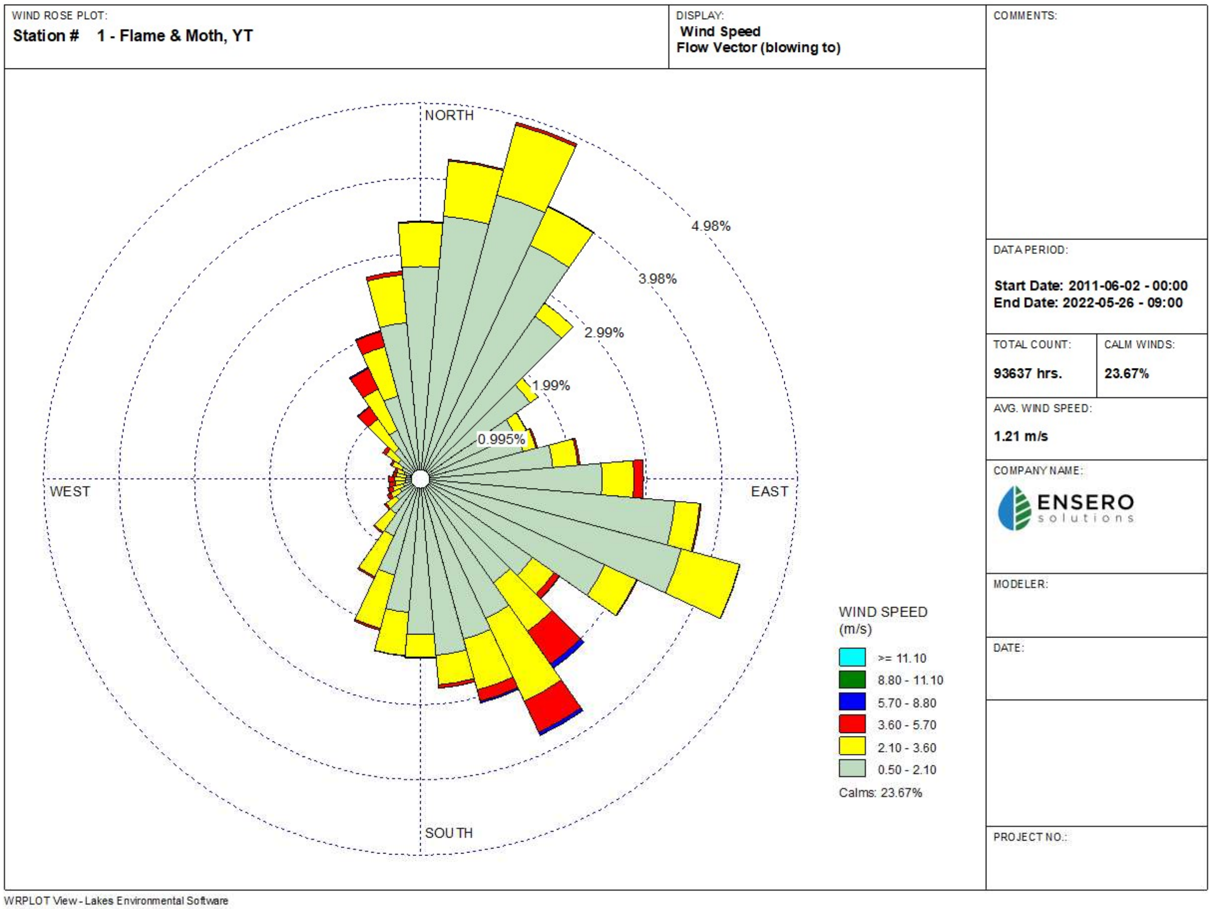



**Figure 3-2: District Mill Wind Rose, June 2011 to May 2022**

Evapotranspiration rates were not calculated for 2011 and 2012 as the pyranometer was only installed in December 2012. Estimates for evapotranspiration were developed previously from the 1996 data set using the computer program WREVAP developed by Environment Canada's National Hydrology Research Institute (Access, 1996). Since 2013, evapotranspiration is calculated in the datalogger program from local meteorological parameters. During fall 2019 winterization, a change in the program code affected the evapotranspiration rate calculations, and thus the evapotranspiration rates calculated by the program from September 2019 are erroneous. Given the program code error, evapotranspiration for September 2019 to December 2019, and 2020-2022 were manually calculated using RefET, using the ASCE Penman-Monteith Standardized Form of Evapotranspiration Reference (ETr). RefET calculates reference evapotranspiration from the measured daily precipitation, relative humidity, solar radiation, and atmospheric pressure like how the program code previously did. Due to the station being down from May to November 2022, there is no representative data for the year 2022.

The Campbell Scientific station at the District Mill historically has performed well and has comparable results to the Mayo A station (Figure 3-3, Figure 3-4). The location for the District Mill weather was changed in 2022 and it is now located near the Flame & Moth vent raise on the Duncan Creek. The station was previously located within the DSTF phase 1 footprint.

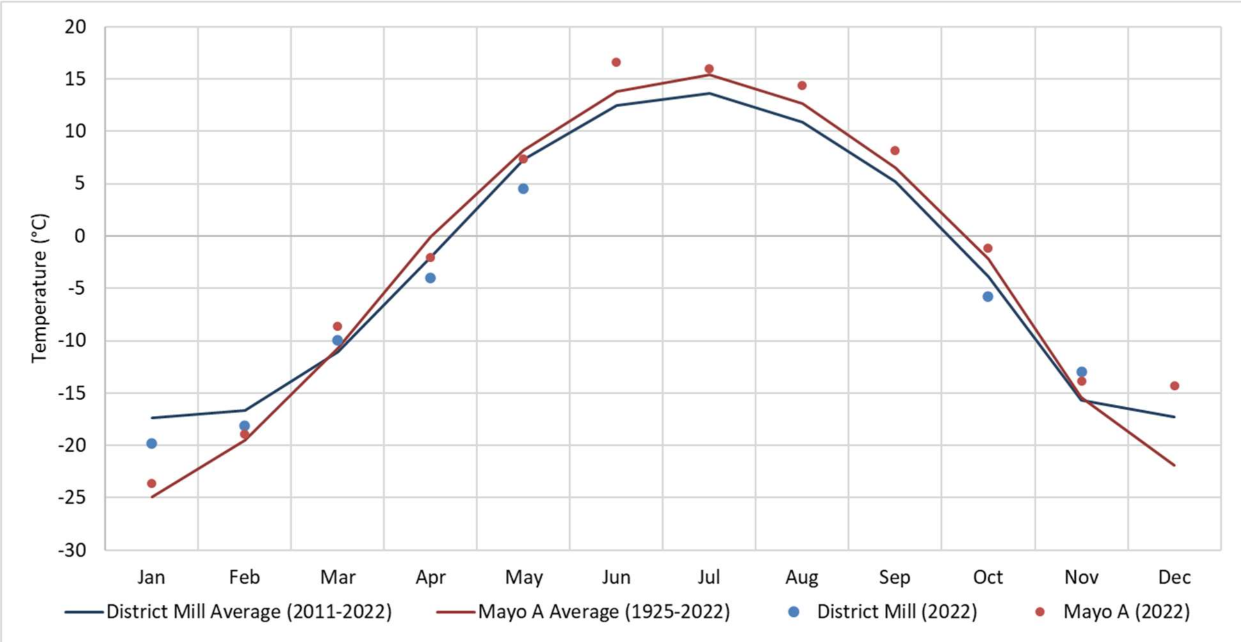



**Figure 3-3: Monthly Temperature Trends, District Mill and Mayo A Stations**

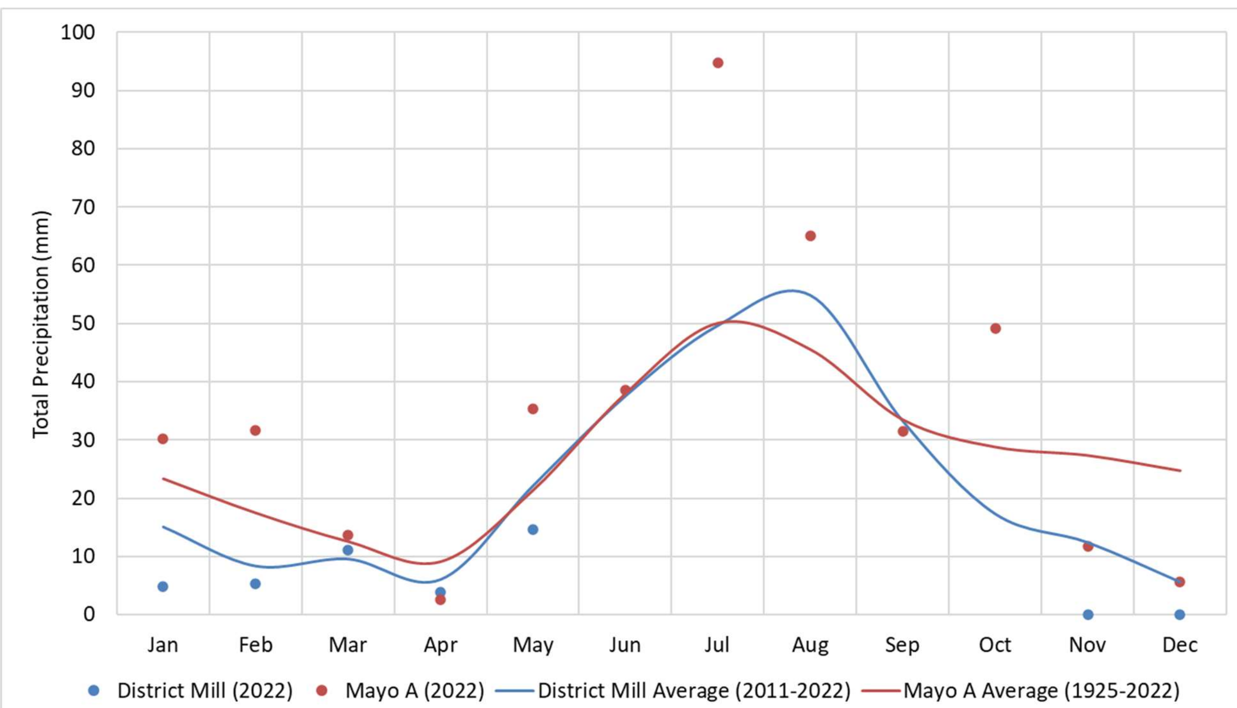



**Figure 3-4: Monthly Total Precipitation Trends, District Mill and Mayo A stations**

### 3.1.3 VALLEY TAILINGS WEATHER STATION

The Valley Tailings Onset HOBO automated meteorological station is located near the Valley Tailings at UTM coordinates: 08 V 0475799 7088130 and at an elevation of 718 masl. All components of the station are presented in Table 3-6.

**Table 3-6: Valley Tailings HOBO Meteorological Station**

| Component | Model | Serial Number |
|---|---|---|
| Datalogger | U30 NRC | 10231016 |
| Input Expander kit | | |
| Solar Panel | SOLAR-6W<br>Installed August 3, 2019: SOLAR-15W | |
| AC Power Adaptor | 120V - 60Hz | |
| HOBOware | Pro | 2580 2976 6309 4793 |
| Temp & RH Sensor | THB-M002 | 10220040 |
| Solar Radiation Shield | RS3 | |
| Pyranometer | LIB-M003 | 10191222 |
| Rain Gauge | RGB-M002 | 10222664 |
| Light Sensor Bracket | LBB | |
| Light Sensor Level | LLA | |
| Wind Speed & Direction Sensor | WSET-A | 10233230 |
| Full Cross Arm | CAA | |
| Barometric Pressure | BPB-CM50 | 10212093 |
| Soil Moisture Sensor | SMC-M005 | 10225679 |
| Tripod | TPA-KIT 3m | |

Monthly averages from installation to December 2022 calculated from instantaneous 15-minute values recorded by the datalogger for the following parameters: temperature, daily maximum temperature, daily minimum temperature, relative humidity, wind speed, gust speed, barometric pressure, and solar radiation. Monthly extreme maximum temperature, extreme minimum temperature, maximum and minimum relative humidity, maximum gust speed and total rainfall are also shown in Table 3-7 below. The barometric pressure has not been corrected for elevation and therefore represents the absolute pressure.

**Table 3-7: Monthly Values for Meteorological Parameters Collected at Valley Tailings Station**

| Date | Extreme Min. Temp. (ºC) | Average Min. Temp. (ºC) | Average Temp. (ºC) | Average Max. Temp. (ºC) | Extreme Max. Temp. (ºC) | Average Relative Humidity (%) | Max. Relative Humidity (%) | Min. Relative Humidity (%) | Total Rain (mm)[2] | Average Wind Speed (m/s)[3] | Average Max. Wind Speed (m/s)[3] | Extreme Max. Wind Speed (m/s)[3] | Average Baro-metric Pressure (kPa) | Average Solar Radiation ($W/m^2$) | Soil Average Water Content (%)[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct-12 [1] | -23.84 | -20.12 | -15.71 | -9.71 | -4.05 | 81.92 | 89.16 | 70.76 | n/a | 0.51 | 1.39 | 7.81 | 93.9 | 34.14 | n/a |
| Nov-12 | -40.71 | -27.24 | -23.77 | -20.42 | -8.07 | 82.04 | 90.97 | 69.24 | n/a | 0.59 | 1.66 | 7.81 | 93.22 | 7.72 | n/a |
| Dec-12 | -44.2 | -29.97 | -26.29 | -22.98 | -3.99 | 82.75 | 97.2 | 71.67 | n/a | 0.52 | 1.75 | 6.04 | 92.61 | 1.48 | n/a |
| Jan-13 | -45.56 | -25.98 | -21.58 | -17.72 | 0.74 | 84.73 | 94.43 | 72.6 | n/a | 0.94 | 2.1 | 14.61 | 92.96 | 4.78 | n/a |
| Feb-13 | -24.88 | -16.72 | -12.96 | -8.8 | 2.4 | 90.08 | 96.67 | 81.42 | n/a | 0.9 | 2.09 | 10.83 | 91.99 | 23.7 | n/a |
| Mar-13 | -33.45 | -21.4 | -13.93 | -5.74 | 5.57 | 68.05 | 92.35 | 53.08 | n/a | 0.84 | 2 | 13.85 | 93.18 | 93.31 | n/a |
| Apr-13 | -25.05 | -14.66 | -7.17 | -0.87 | 8.37 | 53.23 | 81.57 | 39.58 | n/a | 2.01 | 4.1 | 16.62 | 93.01 | 171.18 | n/a |
| May-13 | -8.36 | 0.1 | 6.08 | 11.66 | 23.35 | 62.9 | 95 | 40.13 | 4.8 | 1.42 | 3.26 | 11.84 | 92.88 | 186.87 | 12.3 |
| Jun-13 | 1.64 | 8.2 | 15.63 | 22 | 32.82 | 58.66 | 84.24 | 42.04 | 46.2 | 1.5 | 3.45 | 22.66 | 93.08 | 215.51 | 8 |
| Jul-13 | 1.59 | 8.95 | 15.68 | 21.9 | 29.32 | 60.65 | 87.5 | 38.38 | 25.4 | 1.39 | 3.22 | 16.12 | 93.17 | 194.18 | 6.9 |
| Aug-13 | -1.9 | 6.94 | 13.85 | 20.49 | 29.49 | 68.65 | 95.18 | 44.98 | 43 | 0.93 | 2.45 | 13.6 | 92.69 | 144.34 | 9.6 |
| Sep-13 | -2.45 | 2 | 6.39 | 10.85 | 18.06 | 80.7 | 98.19 | 60.89 | 64.8 | 1.19 | 2.83 | 17.38 | 92.14 | 71.21 | 14.4 |
| Oct-13 | -11.22 | -5.32 | -1.54 | 2.56 | 9.11 | 91.89 | 99.04 | 68.02 | 49.4 | 0.61 | 1.86 | 11.58 | 92.72 | 32.16 | 12.2 |
| Nov-13 | -42.69 | -22.4 | -18.25 | -14.23 | -0.59 | 88.31 | 99.71 | 75.5 | 0 | 0.55 | 1.71 | 11.58 | 93.12 | 8.07 | n/a |
| Dec-13 | -40.38 | -30.71 | -27.25 | -23.5 | -2.48 | 83.73 | 95.83 | 72.42 | 0 | 0.49 | 1.72 | 9.07 | 93.68 | 1.69 | n/a |
| Jan-14 | -37.92 | -18.28 | -14.5 | -10.52 | 1.67 | 93.54 | 99.99 | 81.1 | 0 | 0.17 | 1.96 | 6.3 | 92.62 | 2.73 | n/a |
| Feb-14 | -39.42 | -27.88 | -22.85 | -14.48 | -3.33 | 84.27 | 91.09 | 77.57 | 0 | 0.34 | 1.43 | 8.31 | 93.37 | 27.52 | n/a |
| Mar-14 | -30.55 | -20.48 | -12.32 | -3.5 | 5.85 | 63.32 | 80.35 | 46.47 | 7 | 0.75 | 2.17 | 9.57 | 92.85 | 103.16 | n/a |
| Apr-14 | -20.69 | -6.99 | -0.45 | 6.19 | 11.52 | 59.76 | 87.11 | 43.1 | 5 | 1.34 | 3.2 | 13.09 | 92.37 | 152.86 | n/a |
| May-14 | -3.24 | 1.34 | 8.66 | 14.54 | 21.94 | 53.49 | 74.94 | 35.74 | 11.4 | 1.39 | 3.41 | 13.35 | 93.1 | 201.57 | 17.3 |
| Jun-14 | -0.85 | 6.35 | 12.79 | 18.09 | 28.17 | 56.74 | 87.94 | 38.68 | 56.8 | 1.39 | 3.45 | 15.61 | 92.66 | 206.09 | 14 |
| Jul-14 [5] | 6.86 | 9.96 | 16.01 | 21.5 | 24.85 | 64.71 | 82.34 | 48.07 | 32.2 | 1.3 | 3.24 | 13.35 | 93 | 193.02 | 14 |
| Aug-14 [5] | | | | | | | | | | | | | | | |
| Sep-14 [5] | | | | | | | | | | | | | | | |
| Oct-14 [5] | -17.47 | -12.34 | -7.87 | -4.47 | -1.47 | 93.68 | 95.52 | 90.51 | 0 | 0.69 | 1.93 | 7.05 | 92.34 | 16.88 | n/a |
| Nov-14 | -35.71 | -18.96 | -15.69 | -12.75 | -2.25 | 89.63 | 99.47 | 80.36 | 0 | 0.75 | 2.09 | 8.06 | 93.25 | 8.54 | n/a |
| Dec-14 | -29.59 | -18.7 | -15.22 | -12.12 | -1.73 | 92.55 | 98.58 | 85.41 | 0 | 0.59 | 1.93 | 10.32 | 92.47 | 1.53 | n/a |
| Jan-15 | -41.27 | -22.34 | -19.15 | -15.78 | -0.14 | 90.13 | 99.54 | 78.03 | 0 | 0.32 | 1.68 | 9.07 | 93.24 | 2.93 | n/a |
| Feb-15 | -41.5 | -21.41 | -17.51 | -12.68 | 3.85 | 89.56 | 99.96 | 78.51 | 13.6 | 0.46 | 1.8 | 12.34 | 93.59 | 22.75 | n/a |
| Mar-15 | -31.12 | -16.89 | -10.2 | -3.39 | 6.84 | 75.01 | 91.08 | 58.48 | 3.2 | 1 | 2.33 | 13.35 | 92.71 | 84.81 | n/a |
| Apr-15 | -11.15 | -4.79 | 1.23 | 7.51 | 12.53 | 64.06 | 88.56 | 50.4 | 13.8 | 1.45 | 3.36 | 12.84 | 92.18 | 153.92 | n/a |
| May-15 | -6.99 | 3.25 | 11.76 | 18.45 | 27.55 | 48.65 | 67.29 | 33.82 | 6 | 1.43 | 3.41 | 17.12 | 93.28 | 235.7 | 21.4 |
| Jun-15 | 1.24 | 5.77 | 12.99 | 19 | 25.82 | 59.92 | 81.85 | 34.81 | 27.2 | 1.48 | 3.49 | 16.62 | 92.96 | 213.66 | 13.1 |
| Jul-15 | 4.14 | 7.64 | 13.9 | 19.65 | 27.16 | 69.15 | 93.72 | 43.99 | 82.6 | 1.05 | 2.63 | 10.83 | 92.77 | 180.54 | 17.2 |

| Date | Extreme Min. Temp. (ºC) | Average Min. Temp. (ºC) | Average Temp. (ºC) | Average Max. Temp. (ºC) | Extreme Max. Temp. (ºC) | Average Relative Humidity (%) | Max. Relative Humidity (%) | Min. Relative Humidity (%) | Total Rain (mm)[2] | Average Wind Speed (m/s)[3] | Average Max. Wind Speed (m/s)[3] | Extreme Max. Wind Speed (m/s)[3] | Average Baro-metric Pressure (kPa) | Average Solar Radiation ($W/m^2$) | Soil Average Water Content (%)[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-15 | -2.57 | 4.53 | 10.52 | 15.76 | 25.84 | 76.2 | 95.53 | 54.67 | 69.2 | *1.01* | *2.48* | *10.83* | 92.7 | 138.77 | 20.2 |
| Sep-15 | -8.1 | -0.86 | 3.67 | 8.66 | 16.03 | 81.3 | 93.24 | 61.31 | 42.6 | *1.29* | *2.97* | *21.4* | 92.34 | 80.01 | 20.7 |
| Oct-15 | -12.79 | -4.25 | -1.37 | 1.63 | 7.7 | 91.95 | 99.99 | 65.89 | 14 | *0.75* | *2.01* | *8.56* | 92.48 | 33.28 | 8.6 |
| Nov-15 | -36.15 | -18.71 | -14.44 | -10.89 | 2.64 | 92.87 | 99.34 | 82.48 | 0 | *0.4* | *1.71* | *7.05* | 92.19 | 6.59 | n/a |
| Dec-15 | -33.38 | -18.58 | -15.58 | -12.85 | 3.01 | 92.73 | 97.5 | 83.71 | 0 | *0.46* | *2.12* | *11.84* | 91.92 | 1.26 | n/a |
| Jan-16 | -26.91 | -16.61 | -13.08 | -10.02 | 4.17 | 91.42 | 98.22 | 78.66 | 0 | *0.69* | *2.08* | *17.38* | 92.23 | 4.92 | n/a |
| Feb-16 | -34.26 | -17.54 | -12.62 | -7.02 | 2.96 | 89.23 | 97.6 | 79.77 | 2 | *0.49* | *1.71* | *9.82* | 92.45 | 26.62 | n/a |
| Mar-16 | -15.91 | -9.95 | -4.83 | 0.67 | 13.83 | 76.08 | 94.59 | 62.59 | 4.8 | *1.34* | *2.86* | *9.82* | 92.29 | 80.42 | n/a |
| Apr-16 | -10.97 | -2.76 | 2.77 | 8.43 | 15.25 | 65.43 | 92 | 46.16 | 3.2 | *1.53* | *3.4* | *14.1* | 92.58 | 151.79 | 6.8 |
| May-16 | -2.1 | 2.56 | 9.64 | 15.44 | 23.88 | 56.1 | 83.81 | 36.95 | 16.4 | *1.66* | *3.66* | *15.11* | 93.1 | 205.21 | 25.5 |
| Jun-16 | 3.01 | 7.16 | 14.43 | 20.48 | 27.53 | 55.89 | 88.06 | 36.6 | 40.4 | 1.63 | 3.64 | 15.11 | 92.8 | 233.69 | 21.6 |
| Jul-16 | 0.63 | 9.33 | 14.84 | 20.11 | 26.92 | 73.54 | 93.34 | 54.86 | 67.2 | 1.08 | 2.67 | 11.84 | 92.94 | 173.57 | 23.9 |
| Aug-16 | -1.47 | 7.05 | 12.77 | 18.13 | 24.8 | 73.62 | 94.25 | 58.18 | 45.8 | 1.15 | 2.75 | 15.11 | 93.26 | 146.43 | 23.6 |
| Sep-16 | -6.14 | 0.03 | 5.67 | 11.48 | 18.11 | 73.7 | 94.96 | 34.79 | 39.4 | *0.96* | *2.56* | *14.86* | 92.74 | 98.46 | 23.4 |
| Oct-16 | -22.37 | -11.82 | -7.27 | -1.85 | 5 | 84.13 | 97.87 | 63.33 | 0.6 | *0.57* | *1.77* | *9.32* | 92.97 | 47 | 5.2 |
| Nov-16 | -32.83 | -17.19 | -13.41 | -9.77 | 5.62 | 90.97 | 99.91 | 74.28 | 6.8 | *0.49* | *1.84* | *10.83* | 91.99 | 6.43 | 1 |
| Dec-16 | -39.74 | -25.23 | -21.84 | -18.83 | -3.42 | 87.07 | 96.7 | 76.06 | 0 | *0.43* | *1.68* | *6.55* | 93.13 | 1.78 | 0.2 |
| Jan-17 | -39.63 | -23.21 | -18.99 | -15.19 | 2.5 | 88.2 | 98.17 | 78.4 | 0 | *0.49* | *1.89* | *10.32* | 92.77 | 3.89 | 0.8 |
| Feb-17 | -29.66 | -22.73 | -17.66 | -11.55 | 7.82 | 82.12 | 91.64 | 60.38 | 10.8 | *0.71* | *1.99* | *12.34* | 92.71 | 32.39 | 0.8 |
| Mar-17 | -36.15 | -22.13 | -16.15 | -8.77 | 7.92 | 67.82 | 91.29 | 50.83 | 0.4 | *1.28* | *2.73* | *10.07* | 92.93 | 96.16 | 0.7 |
| Apr-17 | -16.87 | -7.31 | -0.65 | 5.49 | 12.61 | 59.67 | 90.36 | 41.47 | 1.8 | *1.7* | *3.5* | *13.85* | 92.78 | 168.37 | 7.5 |
| May-17 | -2.68 | 2.29 | 8.72 | 13.8 | 20.41 | 57.98 | 79.38 | 32.28 | 21.8 | *1.67* | *3.88* | *12.34* | 92.66 | 196.72 | 20.4 |
| Jun-17 | -0.7 | 6.84 | 13.8 | 19.6 | 27.46 | 55.91 | 89.64 | 34.15 | 33.2 | 1.5 | 3.48 | 14.1 | 92.68 | 216.92 | 10.6 |
| Jul-17 | 5.59 | 9.64 | 16.44 | 22.52 | 30.12 | 64.72 | 91.24 | 37.41 | 58.8 | 1.2 | 2.84 | 15.61 | 92.95 | 207.55 | 12.7 |
| Aug-17 | 0.58 | 7.36 | 13.81 | 19.9 | 29.32 | 67.3 | 87.41 | 49.47 | 23.2 | 1.14 | 2.86 | 13.09 | 92.63 | 153.3 | 13.4 |
| Sep-17 | -2.83 | 2.39 | 7.32 | 12.48 | 20.17 | 82.07 | 96.67 | 61.41 | 73.6 | *0.73* | *2.09* | *11.08* | 92.63 | 78.23 | 18.5 |
| Oct-17 | -16.28 | -7.33 | -3.35 | 0.57 | 10.12 | 90.46 | 99.4 | 76.38 | 17 | *0.49* | *2.02* | *11.58* | 92.5 | 30.46 | 5 |
| Nov-17 | -39.85 | -25.71 | -22.67 | -19.4 | -6.26 | 87.45 | 94.86 | 78 | 0 | *0.14* | *2.43* | *4.78* | 93.1 | 7.36 | n/a |
| Dec-17 | -38.41 | -19.18 | -15.91 | -12.92 | 5 | 90.91 | 99.85 | 78.97 | 28.6 | *0.6* | *2.4* | *11.58* | 93.29 | 1.27 | n/a |
| Jan-18 | -40.27 | -23.62 | -19.76 | -16.06 | 9.015 | 87.65 | 98.91 | 66.34 | 22.4 | 0.1 | 0.37 | 14.86 | 92.9 | 3.94 | -0.06 |
| Feb-18 | -38.21 | -27.19 | -23.1 | -16.9 | -5.48 | 83.22 | 91.95 | 69.66 | 0 | 0.24 | 0.69 | 9.82 | 93.69 | 23.91 | -0.06 |
| Mar-18 [6] | *-33.3* | *-18.23* | *-11.63* | *-3.79* | *17.06* | *79.08* | *88.52* | *59.93* | *6.2* | *0.49* | *1.54* | *12.09* | *93.12* | *77.13* | *-0.04* |
| Apr-18 [6] | | | | | | | | | | | | | | | |
| May-18 [6] | | | | | | | | | | | | | | | |
| Jun-18 [6] | | | | | | | | | | | | | | | |
| Jul-18 [6] | | | | | | | | | | | | | | | |

| Date | Extreme Min. Temp. (ºC) | Average Min. Temp. (ºC) | Average Temp. (ºC) | Average Max. Temp. (ºC) | Extreme Max. Temp. (ºC) | Average Relative Humidity (%) | Max. Relative Humidity (%) | Min. Relative Humidity (%) | Total Rain (mm)[2] | Average Wind Speed (m/s)[3] | Average Max. Wind Speed (m/s)[3] | Extreme Max. Wind Speed (m/s)[3] | Average Baro-metric Pressure (kPa) | Average Solar Radiation (W/m²) | Soil Average Water Content (%)[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-18 [6] | -1.33 | 5.08 | 10.06 | 12.9 | 21.1 | 77.11 | 93.85 | 61.77 | 25.2 | 1.48 | 3.28 | 12.34 | 92.82 | 126.5 | 0.21 |
| Sep-18 [7] | -4.71 | -0.01 | 5.76 | 11.93 | 14.91 | 73.75 | 89.08 | 64.18 | 6.4 | 0.088 | 2.23 | 9.07 | 93.4 | 122.4 | 0.2 |
| Oct-18 [7] | -15.87 | -6.28 | -2.09 | 2.61 | 9.63 | 86.94 | 98.84 | 56.67 | 9.4 | 0.53 | 1.68 | 13.09 | 92.5 | 31.57 | -0.02 |
| Nov-18 | -32.29 | -15.51 | -12.42 | -9.16 | 1.56 | 91.81 | 99.7 | 83.05 | 0.2 | 0.32 | 0.95 | 8.06 | 92.74 | 9.53 | -0.003 |
| Dec-18 | -30.69 | -19.42 | -15.31 | -11.67 | 3.99 | 89.00 | 96.19 | 66.25 | 5.80 | 0.26 | 0.79 | 13.85 | 92.12 | 1.89 | -0.01 |
| Jan-19 | -39.32 | -24.69 | -20.79 | -17.04 | -2.89 | 88.50 | 97.19 | 77.47 | 0.00 | 0.00 | 0.02 | 4.53 | 92.87 | 2.79 | -0.01 |
| Feb-19 | -40.49 | -26.88 | -22.49 | -15.47 | -3.48 | 85.07 | 91.46 | 78.07 | 0.00 | 0.04 | 0.35 | 5.04 | 93.96 | 30.10 | -0.01 |
| Mar-19 | -26.67 | -10.74 | -4.37 | 2.81 | 12.85 | 71.05 | 94.67 | 49.27 | 10.40 | 0.96 | 2.38 | 13.60 | 93.09 | 87.29 | 0.04 |
| Apr-19 | -18.83 | -5.70 | -0.38 | 4.79 | 10.76 | 61.28 | 81.21 | 42.47 | 2.60 | 1.51 | 3.33 | 13.09 | 92.14 | 140.93 | 0.04 |
| May-19 | | | | | | | | | | | | | | | |
| Jun-19 | | | | | | | | | | | | | | | |
| Jul-19 | | | | | | | | | | | | | | | |
| Aug-19 | -4.20 | 3.38 | 10.03 | 16.39 | 21.60 | 62.48 | 85.84 | 51.03 | 10.20 | 1.42 | 3.19 | 11.08 | 93.22 | 155.57 | 0.10 |
| Sep-19 | -7.90 | 0.80 | 6.78 | 13.11 | 22.97 | 75.23 | 96.72 | 51.50 | 34.60 | 0.67 | 1.87 | 15.86 | 92.64 | 89.10 | 0.10 |
| Oct-19 | -17.51 | -7.39 | -3.75 | 0.16 | 10.57 | 91.88 | 100.00 | 65.75 | 11.60 | 0.36 | 1.08 | 10.32 | 92.69 | 32.02 | 0.03 |
| Nov-19 | -32.29 | -18.28 | -14.68 | -11.26 | 2.74 | 91.91 | 99.93 | 78.03 | 2.80 | 0.44 | 0.94 | 14.10 | 92.82 | 5.61 | 0.03 |
| Dec-19 | -39.32 | -23.64 | -19.26 | -2.98 | -2.77 | 90.26 | 98.84 | 79.63 | 0.00 | 0.08 | 0.36 | 18.63 | 91.93 | 1.69 | 0.03 |
| Jan-20 | -44.07 | -31.50 | -27.92 | -24.72 | -4.38 | 84.53 | 100.00 | 74.10 | 0.00 | 0.12 | 0.55 | 8.31 | 92.90 | 4.35 | 0.00 |
| Feb-20 | -40.82 | -24.78 | -19.79 | -14.93 | 2.32 | 86.41 | 98.00 | 51.50 | 0.20 | 0.39 | 1.81 | 11.58 | 92.56 | 24.37 | 0.00 |
| Mar-20 | -36.33 | -21.52 | -14.92 | -7.97 | 2.72 | 73.43 | 98.00 | 26.00 | 5.20 | 0.87 | 2.69 | 6.80 | 93.17 | 85.52 | |
| Apr-20 | -23.73 | -8.40 | -1.95 | 5.05 | 15.32 | 61.74 | 99.20 | 26.10 | 3.40 | 1.19 | 3.38 | 5.79 | 92.81 | 166.02 | |
| May-20 | -4.02 | 1.49 | 8.34 | 14.17 | 20.79 | 51.38 | 100.00 | 20.80 | 11.40 | 1.88 | 5.17 | 8.81 | 93.06 | 239.54 | |
| Jun-20 | 1.75 | 6.82 | 12.77 | 16.55 | 23.06 | 71.66 | 100.00 | 21.50 | 74.20 | 1.35 | 5.18 | 8.56 | 92.50 | 169.35 | |
| Jul-20 | | | | | | | | | | | | | | | |
| Aug-20 | 4.74 | 7.52 | 11.70 | 16.87 | 21.56 | 80.17 | 100.00 | 31.50 | 47.60 | 0.67 | 3.43 | 7.55 | 92.60 | 116.56 | |
| Sep-20 | -3.21 | 1.56 | 5.86 | 11.31 | 16.68 | 82.48 | 100.00 | 33.30 | 30.40 | 0.64 | 3.33 | 6.55 | 92.83 | 83.90 | |
| Oct-20 | -4.05 | 0.27 | 3.33 | 5.49 | 14.79 | 87.36 | 100.00 | 47.10 | 18.20 | 0.44 | 2.25 | 5.29 | 92.21 | 42.35 | |
| Nov-20 | | | | | | | | | | | | | | | |
| Dec-20 | | | | | | | | | | | | | | | |
| Jan-21 | -38.02 | -21.29 | -17.93 | -14.02 | -0.34 | 89.55 | 100.00 | 71.90 | 0.00 | 0.08 | 4.16 | 4.53 | 9.28 | 5.56 | -0.01 |
| Feb-21 | -41.73 | -29.43 | -25.12 | -19.45 | -7.71 | 83.85 | 95.20 | 33.00 | 0.00 | 0.18 | 2.14 | 4.28 | 9.32 | 12.87 | -0.01 |
| Mar-21 | -30.97 | -20.78 | -14.09 | -6.54 | 1.48 | 74.87 | 97.40 | 16.40 | 2.84 | 0.69 | 2.66 | 4.53 | 9.23 | 90.93 | -0.01 |
| Apr-21 | -31.85 | -12.57 | -3.93 | 4.14 | 16.13 | 54.22 | 98.80 | 27.00 | 1.39 | 1.17 | 3.80 | 6.80 | 9.32 | 190.54 | 0.01 |
| May-21 | -6.04 | -1.03 | 5.65 | 12.04 | 15.41 | 56.23 | 97.90 | 14.60 | 0.20 | 1.46 | 4.03 | 5.29 | 9.29 | 196.30 | 0.13 |
| Jun-21 | 5.41 | 10.49 | 17.33 | 23.21 | 28.22 | 50.60 | 95.50 | 18.20 | 4.40 | 1.74 | 6.12 | 25.18 | 92.87 | 246.77 | 0.16 |
| Jul-21 | 0.61 | 8.49 | 15.87 | 22.16 | 30.12 | 60.41 | 100.00 | 20.10 | 40.00 | 1.21 | 4.16 | 6.30 | 93.04 | 213.19 | 0.17 |

| Date | Extreme Min. Temp. (ºC) | Average Min. Temp. (ºC) | Average Temp. (ºC) | Average Max. Temp. (ºC) | Extreme Max. Temp. (ºC) | Average Relative Humidity (%) | Max. Relative Humidity (%) | Min. Relative Humidity (%) | Total Rain (mm)[2] | Average Wind Speed (m/s)[3] | Average Max. Wind Speed (m/s)[3] | Extreme Max. Wind Speed (m/s)[3] | Average Baro-metric Pressure (kPa) | Average Solar Radiation ($W/m^2$) | Soil Average Water Content (%)[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aug-21 | 0.52 | 6.17 | 11.86 | 17.53 | 31.31 | 76.04 | 100.00 | 31.60 | 83.00 | 0.81 | 3.55 | 6.30 | 92.67 | 134.98 | 0.19 |
| Sep-21 | *-1.21* | *3.56* | *9.74* | *16.17* | *19.82* | *78.88* | *100.00* | *0.00* | *6.00* | *0.62* | *3.14* | *4.78* | *92.47* | *106.80* | *0.18* |
| Oct-21 | | | | | | | | | | | | | | | |
| Nov-21 | | | | | | | | | | | | | | | |
| Dec-21 | | | | | | | | | | | | | | | |
| Jan-22 | *-34.76* | *-26.00* | *-23.21* | *-19.21* | *-15.75* | *83.03* | *91.20* | *71.80* | *0.00* | *6.55* | *3.28* | *18.14* | *93.06* | *14.31* | *-0.01* |
| Feb-22 | -38.51 | -24.55 | -19.53 | -14.54 | -2.33 | 86.10 | 98.20 | 51.40 | 0.60 | *1.80* | *2.25* | *29.92* | 93.01 | 25.00 | -0.01 |
| Mar-22 | -34.10 | -15.81 | -10.00 | -4.06 | 6.43 | 76.96 | 98.70 | 33.40 | 3.20 | *3.57* | *2.84* | *19.94* | 92.64 | 88.63 | -0.01 |
| Apr-22 | -27.83 | -11.37 | -3.72 | 3.08 | 10.69 | 56.11 | 96.80 | 23.60 | 2.00 | *4.42* | *3.79* | *23.58* | 92.99 | 183.46 | 0.00 |
| May-22 [12] | *-4.14* | *-0.45* | *4.41* | *8.72* | *10.64* | *63.87* | *100.00* | *31.30* | *6.20* | *5.48* | *4.97* | *29.02* | *92.14* | *203.93* | *0.14* |
| Jun-22 [12] | *4.82* | *7.69* | *14.87* | *20.70* | *27.80* | *59.68* | *98.80* | *15.00* | *25.80* | *1.12* | *4.29* | *9.32* | *106.80* | *229.45* | *0.18* |
| Jul-22 | 1.51 | 8.63 | 14.68 | 20.22 | 29.29 | 68.85 | 100.00 | 23.10 | 56.60 | *1.06* | *4.44* | *8.31* | 106.50 | 167.36 | 0.79 |
| Aug-22 | 0.16 | 7.05 | 12.56 | 18.19 | 25.79 | 75.13 | 100.00 | 29.90 | 52.60 | *1.25* | *4.52* | *8.31* | 106.75 | 144.47 | 0.74 |
| Sep-22 | -4.56 | 1.29 | 6.41 | 12.04 | 18.49 | 80.32 | 100.00 | 32.80 | 56.00 | *0.87* | *3.80* | *9.07* | 106.94 | 82.82 | 0.85 |
| Oct-22 | -19.01 | -6.92 | -3.10 | 0.37 | 14.17 | 93.96 | 100.00 | 34.40 | 51.00 | *0.62* | *2.55* | *10.32* | 106.94 | 30.79 | 0.91 |
| Nov-22 | -37.06 | -18.68 | -14.51 | -10.51 | 5.67 | 91.63 | 100.00 | 66.70 | 0.60 | 0.13 | 0.97 | 4.03 | 106.94 | 6.76 | 0.63 |
| Dec-22 | -45.14 | -26.94 | -23.48 | -19.64 | -1.50 | 87.53 | 100.00 | 73.70 | 0.00 | 0.03 | 1.97 | 2.27 | 106.94 | 1.23 | 0.61 |

***Notes:***

*Values in grey italics indicate a partial month.*

*Cells highlighted grey indicate station was down and no data are available.*

*[3] Wind Sensor was not operating properly:*

- *October 2012 has 2 days of complete and 11 days of partial wind data*
- *November 2012 has 5 days of complete and 24 days of partial wind data*
- *December 2012 has 2 days of complete and 16 days of partial wind data*
- *January 2013 has 5 days of complete and 16 days of partial wind data*
- *February 2013 has 2 days of complete and 26 days of partial wind data*
- *March 2013 has 4 days of complete and 27 days of partial wind data*
- *April 2013 has 14 days of complete and 16 days of partial wind data*
- *May 2013 has 15 days of complete and 16 days of partial wind data*
- *June 2013 has 29 days of complete and 1 day of partial wind data*
- *August 2013 has 29 days of complete and 2 days of partial wind data*
- *September 2013 has 15 days of complete and 15 days of partial wind data*
- *October 2013 has 6 days of complete and 25 days of partial wind data*
- *November 2013 has 1 day of complete and 28 days of partial wind data*
- *December 2013 has 2 days of complete and 23 days of partial wind data*
- *January 2014 has 0 days of complete and 12 days of partial wind data*
- *February 2014 has 0 days of complete and 13 days of partial wind data*
- *March 2014 has 1 days of complete and 30 days of partial wind data*
- *April 2014 has 10 days of complete and 20 days of partial wind data*
- *May 2014 has 21 days of complete and 10 days of partial wind data*
- *December 2014 has 3 days of complete and 12 days of partial wind data*
- *January 2015 has 0 days of complete and 14 days of partial wind data*
- *February 2015 has 1 day of complete and 17 days of partial wind data*
- *March 2015 has 5 days of complete and 26 days of partial wind data*
- *April 2015 has 12 days of complete and 18 days of partial wind data*
- *May 2015 has 27 days of complete and 4 days of partial wind data*
- *August 2015 has 29 days of complete and 2 days of partial wind data*

*[1] Station was commissioned on October 19, so October 2012 has 12 days of complete data*

*[2] May 2013 has 14 days of compete rain data*

*[4]Negative values reported from Oct 2012 to April 2013, from Nov 2013 to Apr 2014, from Oct 2014 to Apr 2015 and from Nov 2015 to March 2016 were invalidated – soil assumed to be frozen*

*[5] Station was down between July 16 and October 26, 2014*

*[6]Station was down between March 13 and August 15, 2018*

*[7]Station down between September 10 and October 9, 2018*

*[8] Station was down between April 20 and August 3, 2019*

*[9] Soil moisture logger down as of February 19, 2020*

*[10] Station down between June 25 to August 11, 2020*

*[11] Battery and Datalogger removed in October, station stopped recording on October 12, 2020*

*[12] Battery was depleted May 13 to June 9, 2022*

***Notes:***

- *September 2015 has 14 days of complete and 16 days of partial wind data*
- *October 2015 has 12 days of complete and 19 days of partial wind data*
- *November 2015 has 1 day of complete and 23 days of partial wind data*
- *December 2015 has 0 day of complete and 9 days of partial wind data*
- *January 2016 has 4 days of complete and 19 days of partial wind data*
- *February 2016 has 2 days of complete and 17 days of partial wind data*
- *March 2016 has 8 days of complete and 23 days of partial wind data*
- *April 2016 has 22 days of complete and 4 days of partial wind data*
- *May 2016 has 30 days of complete and 1 day of partial wind data*
- *September 2016 has 22 days of complete and 8 days of partial wind data*
- *October 2016 has 4 days of complete and 27 days of partial wind data*
- *November 2016 has 3 days of complete and 11 days of partial wind data*
- *December 2016 has 0 day of complete and 18 days of partial wind data*
- *January 2017 has 0 day of complete and 17 days of partial wind data*
- *February 2017 has 6 days of complete and 21 days of partial wind data*
- *March 2017 has 15 days of complete and 16 days of partial wind data*
- *April 2017 has 17 days of complete and 13 days of partial wind data*
- *May 2017 has 24 days of complete and 7 days of partial wind data*
- *September 2017 has 25 days of complete and 5 days of partial wind data*
- *October 2017 has 3 days of complete and 22 days of partial wind data*
- *November 2017 has 0 day of complete and 1 day of partial wind data*
- *December 2017 has 1 day of complete and 6 days of partial wind data*
- *January 2018 has 12 days of partial wind data*
- *February 2018 has 28 days of partial wind data*
- *March 2018 has 13 days of partial wind data*
- *August 2018 has 17 days of partial wind data*
- *March 2017 has 15 days of complete and 16 days of partial wind data*
- *April 2017 has 17 days of complete and 13 days of partial wind data*
- *May 2017 has 24 days of complete and 7 days of partial wind data*
- *September 2017 has 25 days of complete and 5 days of partial wind data*
- *October 2017 has 3 days of complete and 22 days of partial wind data*
- *November 2017 has 0 day of complete and 1 day of partial wind data*
- *December 2017 has 1 day of complete and 6 days of partial wind data*
- *January 2018 has 12 days of partial wind data*
- *February 2018 has 28 days of partial wind data*
- *March 2018 has 13 days of partial wind data*
- *August 2018 has 17 days of partial wind data*
- *September 2018 only has 16 days of partial wind data*
- *October 2018 only has 23 days of partial wind data*
- *November 2018 has 30 days of partial wind data*
- *December 2018 only has 18 days of partial wind data*
- *January 2019 only has 3 days of partial wind data*
- *February 2019 only has 19 days of partial wind data*
- *March 2019 has 8 days of complete and 23 days of partial wind data*
- *April 2019 has 7 days of complete and 13 days of partial wind data*
- *August 2019 has 16 days of complete and 12 days of partial wind data*
- *September 2019 has 9 days of complete and 21 days of partial wind data*
- *October 2019 has 1 day of complete and 30 days on partial wind data*
- *November 2019 has 2 days of complete and 13 days of partial wind data*
- *January 2020 has 6 days of partial wind data*
- *February 2020 has 18 days of partial wind data*
- *March 2020 has 28 days of partial wind data and 1 complete day*
- *April 2020 has 27 days of partial wind data and 3 complete days*
- *March 2017 has 15 days of complete and 16 days of partial wind data*
- *April 2017 has 17 days of complete and 13 days of partial wind data*
- *May 2020 has 18 days of partial wind data and 13 complete days*
- *June 2020 has 19 days of partial wind data and 7 complete days*
- *August 2020 has 20 days of partial wind data and 1 complete day*
- *September 2020 has 25 days of partial wind data and 5 complete days*
- *October 2020 has 9 days of partial wind data and 2 complete days*
- *January 2022 has 3 days of complete and 27 days of partial wind data*
- *February 2022 has 28 days of complete and 9 days of partial wind data*
- *March 2022 has 31 days of complete and 7 days of partial wind data*
- *April 2022 has 30 days of complete and 2 days of partial wind data*
- *May 2022 has 11 days of complete and 20 days of partial wind data*
- *June 2022 has 20 days of complete and 10 days of partial wind data*
- *July 2022 has 31 days of complete and 3 days of partial wind data*
- *August 2022 has 1 days of complete and 3 days of partial wind data*
- *September 2022 has 30 days of complete and 7 days of partial wind data*

***Notes:***

- *October 2022 has 31 days of complete and 10 days of partial wind data*
- *November 2022 has 22 days of complete and 19 days of partial wind data*

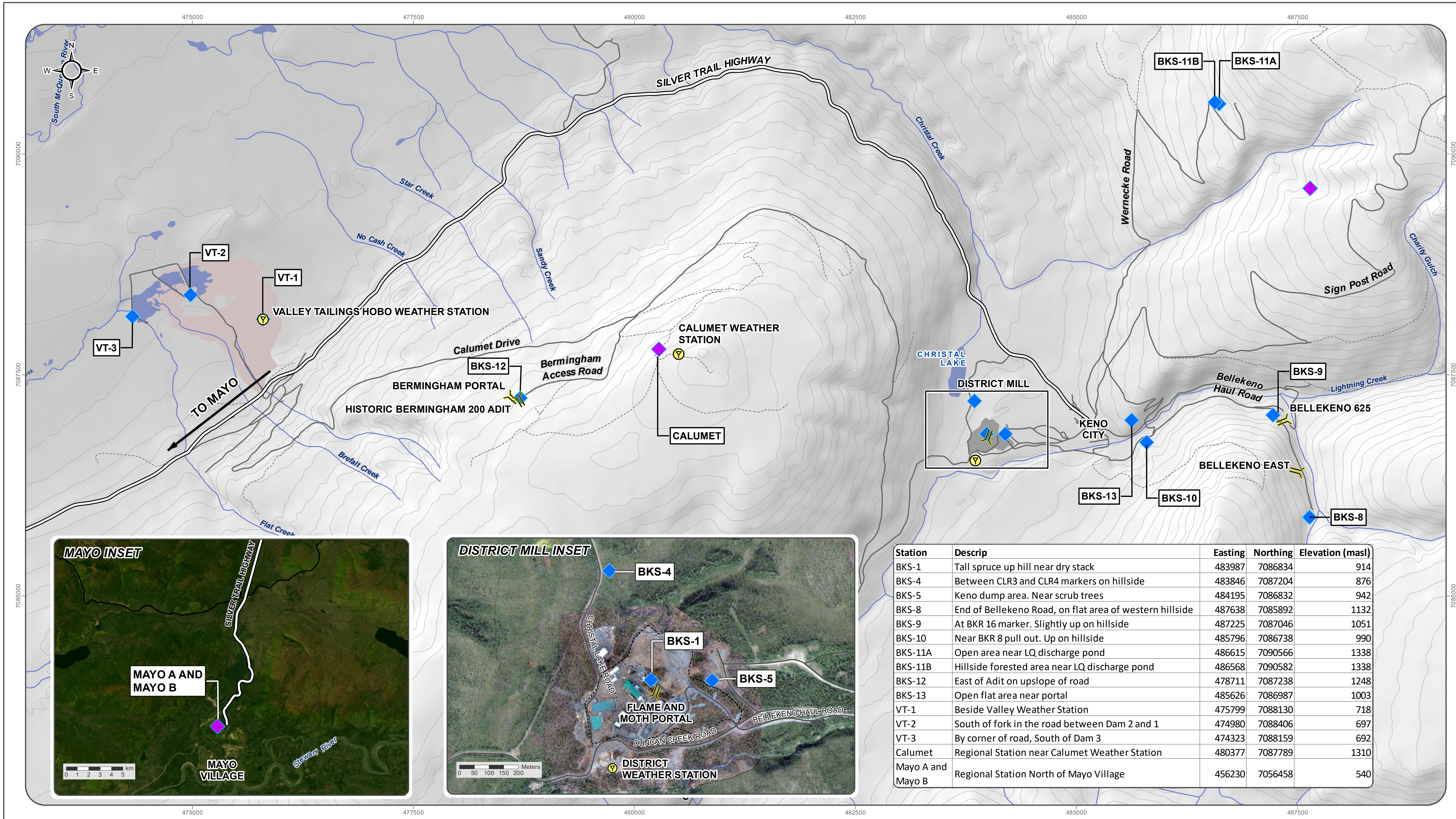
### 3.1.4 SNOW SURVEYS

There are three regional snow survey sites that are monitored by the Yukon Government: Mayo Airport A, Mayo Airport B, and Calumet. Mayo Airport A and B are located in the Village of Mayo at an elevation of 540 masl and Calumet is on Galena Hill, near Keno City at an elevation of 1310 masl. The March and April monthly snow water equivalent (SWE) statistics for the three regional sites are shown in Table 3-8.

**Table 3-8: Regional Snow Survey Station Values**

| Station | Elevation (masl) | Period | Month | Min | Max (mm) | Average (mm) |
|---|---|---|---|---|---|---|
| Mayo A | 540 | 1968-2022 | March | 30 | 160 | 92 |
| | | n = 51 | April | 10 | 176 | 96 |
| Mayo B | 540 | 1987-2022 | March | 52 | 172 | 96 |
| | | n = 32 | April | 48 | 192 | 108 |
| Calumet | 1310 | 1975-2022 | March | 94 | 298 | 176 |
| | | n = 44 | April | 95 | 305 | 197 |

The locations of the snow survey stations are shown on Figure 3-5. The annual snow water equivalent (SWE) results for each of the 13 KHSD snow survey stations are presented in Table 3-9.




| Station | Descrip | Easting | Northing | Elevation (masl) |
|---|---|---|---|---|
| BKS-1 | Tall spruce up hill near dry stack | 483987 | 7086834 | 914 |
| BKS-4 | Between CLR3 and CLR4 markers on hillside | 483846 | 7087204 | 876 |
| BKS-5 | Keno dump area. Near scrub trees | 484195 | 7086832 | 942 |
| BKS-8 | End of Bellekeno Road, on flat area of western hillside | 487638 | 7085892 | 1132 |
| BKS-9 | At BKR 16 marker. Slightly up on hillside | 487225 | 7087046 | 1051 |
| BKS-10 | Near BKR 8 pull out. Up on hillside | 485796 | 7086738 | 990 |
| BKS-11A | Open area near LQ discharge pond | 486615 | 7090566 | 1338 |
| BKS-11B | Hillside forested area near LQ discharge pond | 486568 | 7090582 | 1338 |
| BKS-12 | East of Adit on upslope of road | 478711 | 7087238 | 1248 |
| BKS-13 | Open flat area near portal | 485626 | 7086987 | 1003 |
| VT-1 | Beside Valley Weather Station | 475799 | 7088130 | 718 |
| VT-2 | South of fork in the road between Dam 2 and 1 | 474980 | 7088406 | 697 |
| VT-3 | By corner of road, South of Dam 3 | 474323 | 7088159 | 692 |
| Calumet | Regional Station near Calumet Weather Station | 480377 | 7087789 | 1310 |
| Mayo A and Mayo B | Regional Station North of Mayo Village | 456230 | 7056458 | 540 |

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Satelite imagery obtained from ESRI ArcGIS map service https://services.arcgisonline.com/ArcGIS/rest/service on February 03 2023
Datum: NAD 83; Map Projection: UTM Zone 8N



1:40,000 (when printed on 11 x17 inch paper)

Meters 0 500 1,000 1,500 2,000

ERDC Snow Monitoring Station
Regional Snow Monitoring Stations
Audit

AKHM District Mill
Tailings Area
Waterbody
Watercourse

Silver Trail Highway
Other Road
Limited-Use Road
Contours (100 ft)

HECLA KENO HILL

FIGURE 3-5

METEOROLOGICAL STATIONS AND SNOW SURVEY STATIONS LOCATION

FEBRUARY 2023

**Table 3-9: Snow Survey (SWE) Results (mm)**

| Station | BKS-1 | BKS-2 | BKS-3 | BKS-4 | BKS-5.0 | BKS-5.1 | BKS-6 | BKS-7 | BKS-8 | BKS-9 | BKS-10 | BKS-11 | BKS-12 | BKS-13 | Monthly Mean | Mayo A | Mayo B | Calumet |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation (m) | 914 | 907 | 878 | 876 | 942 | 942 | 938 | 1032 | 1132 | 1051 | 990 | 1338 | 1248 | 1003 | | 540 | 540 | 1310 |
| Description | Tall spruce up hill near dry stack | Log pile near dry stack | Between 1 and 2 marker on CLR road | Down road from BKS 3, closer to #2 CLR marker | Keno dump area. Near scrub trees | Keno dump area. Near scrub trees | Keno dump area. On sloping hillside | Uphill from Bellekeno treatment pond | Far end of Bellekeno East. Nr explosive storage shed | At BKR 16 marker. Slightly up on hillside | Near BKR 8 pull out. Up on hillside | Lucky Queen, upslope of the pond | East of Bermingham 200 adit, Upslope of road | Onek, upslope of portal near powerline | | Mayo Airport | Mayo Airport | Calumet Hill |
| Jan-11 | 7.6 | 7.6 | 7.6 | 7.6 | 5.1 | - | 2.5 | 7.6 | 7.6 | 7.6 | 10.1 | - | - | - | 7.1 | - | - | - |
| Feb-11 | 7.6 | 7.6 | 10.2 | 7.6 | 7.6 | - | 2.5 | 10.2 | 7.6 | 10.2 | 7.6 | - | - | - | 7.9 | - | - | - |
| Mar-11 | 5.1 | 7.6 | 7.6 | 7.6 | 5.1 | - | | 7.6 | 5.1 | 10.2 | 5.1 | - | - | - | 6.1 | 9.0 | 8.4 | 13.9 |
| Jan-12 | 6.0 | 12.2 | 9.6 | 8.5 | 13.7 | - | 11.2 | 12.5 | 9.9 | 12.4 | 13.3 | - | - | - | 10.9 | - | - | - |
| Feb-12 | 16.1 | 13.6 | 12.5 | 17.6 | - | 11.3 | 12.6 | 13.6 | 13.8 | 13.3 | 16.5 | - | - | - | 14.1 | - | - | - |
| Mar-12 | 18.7 | 9.3 | 4.4 | 12.3 | - | 12.2 | 14.8 | 4.8 | 17.6 | 17.1 | 27.7 | - | - | - | 13.9 | 7.8 | 10.0 | 15.1 |
| Apr-12 | 8.7 | 20.8 | 7.7 | 8.8 | - | 9.6 | 19.8 | 8.5 | 19.5 | | 10.7 | - | - | - | 11.4 | 14.4 | 15.6 | 18.0 |
| Jan-13 | 7.3 | 9.3 | 7.3 | 9.3 | - | 6.7 | 6.7 | 6.7 | 8.0 | 7.3 | 9.3 | - | - | - | 7.8 | - | - | - |
| Feb-13 | 11.3 | 10.7 | 10.0 | 11.7 | - | 9.7 | 9.2 | 11.0 | 10.0 | 10.0 | 10.0 | - | - | - | 10.4 | - | - | - |
| Mar-13 | 13.0 | 11.7 | 14.3 | 18.3 | - | 13.3 | 12.0 | 10.3 | 18.5 | 15.0 | 12.3 | - | - | - | 13.9 | 12.9 | 8.0 | 15.8 |
| Apr-13 | 15.0 | 13.8 | 14.7 | 14.3 | - | 13.0 | 11.3 | 13.7 | 19.7 | 14.0 | 14.3 | - | - | - | 14.4 | 12.0 | - | 18.6 |
| Jan-14 | 12.3 | 10.3 | 13.0 | 12.7 | - | 11.0 | 10.7 | 13.3 | 9.3 | 12.3 | 14.0 | - | - | - | 11.9 | - | - | - |
| Feb-14 | 14.0 | 10.7 | 12.3 | 12.0 | - | 12.0 | 10.3 | 13.0 | 12.7 | 11.7 | 15.7 | - | - | - | 12.4 | - | - | - |
| Mar-14 | 12.3 | 10.0 | 11.0 | 11.7 | - | 10.7 | 8.7 | 13.0 | 12.7 | 11.3 | 14.3 | - | - | - | 11.6 | 10.3 | 12.0 | 18.9 |
| Apr-14 | 9.7 | 7.7 | 9.7 | 7.3 | - | 8.7 | 8.3 | 10.0 | 10.7 | 9.0 | 7.0 | - | - | - | 8.8 | 12.3 | 12.6 | 20.7 |
| Feb-15 | 8.0 | 9.0 | 9.3 | 3.7 | - | 8.3 | 7.3 | 9.0 | 6.7 | 7.7 | 10.0 | - | - | - | 7.9 | - | - | - |
| Mar-15 | 9.3 | 10.3 | 7.0 | 8.7 | - | 10.7 | 8.7 | 12.7 | 17.0 | 10.7 | 10.0 | - | - | - | 10.5 | 7.6 | 9.0 | 18.4 |
| Apr-15 | 8.7 | 9.0 | 10.7 | 7.3 | - | 12.0 | 9.0 | 14.0 | 12.3 | 8.3 | 12.0 | - | - | - | 10.3 | 10.3 | 11.8 | 23.2 |
| Feb-16 | 4.0 | 8.0 | 8.0 | 10.0 | - | 10.0 | 8.0 | 7.3 | 7.3 | 7.3 | 10.7 | 20.3 | - | - | 8.1 | - | - | - |
| Mar-16 | 8.7 | 11.0 | 9.3 | 8.7 | - | 8.7 | 8.0 | 7.0 | 9.3 | 7.0 | 6.0 | 20.7 | - | - | 8.4 | 11.3 | 10.4 | 20.2 |
| Apr-16 | 7.7 | 10.3 | 10.7 | 12.3 | - | 10.7 | 8.3 | 11.3 | - | | 11.7 | 15.0 | 23.3 | - | 9.8 | 7.0 | 4.8 | 18.1 |
| Feb-17 | 5.7 | 6.7 | 4.0 | 5.7 | - | 5.7 | 7.3 | 7.0 | 7.7 | 7.0 | 6.0 | 11.0 | 7.0 | 3.0 | 6.4 | - | - | - |
| Mar-17 | 8.7 | 9.3 | 9.3 | 10.3 | - | 8.3 | 8.0 | 8.3 | 10.7 | 7.3 | 9.3 | 16.0 | 8.7 | 4.0 | 9.1 | 3.8 | 4.2 | 15.0 |
| Apr-17 | 9.3 | 11.7 | 13.0 | 11.3 | - | 10.7 | 9.3 | 11.0 | 13.0 | 6.7 | 6.7 | 18.0 | 14.3 | | 10.4 | 8.8 | 8.0 | 16.5 |
| Jan-18 | 4.3 | 6.0 | 6.3 | 6.3 | - | 6.0 | 5.7 | 5.7 | 9.0 | 8.0 | 8.7 | 8.7 | 6.3 | 6.3 | 6.7 | - | - | - |
| Feb-18 | 6.7 | 7.3 | 10.0 | 8.7 | - | 9.3 | 8.0 | 8.7 | 10.7 | 10.0 | 10.0 | 11.7 | 11.0 | 6.0 | 9.1 | - | - | - |
| Mar-18 | 8.7 | 10.0 | 10.0 | 10.7 | - | 13.3 | 11.3 | 11.3 | 11.3 | 13.3 | 12.0 | 18.0 | - | - | 10.0 | 4.8 | 6.5 | 14.2 |
| Apr-18 | 4.0 | 4.3 | 4.0 | 5.0 | - | 5.0 | 5.0 | 5.0 | 5.7 | 4.3 | 4.7 | - | 4.3 | 5.3 | 4.4 | 5.6 | 6.4 | 17.2 |
| Jan-19 | 4.7 | 4.7 | 6.0 | 6.7 | - | 4.0 | 4.0 | 7.6 | 5.3 | 6.0 | 5.3 | 6.7 | 10.7 | 4.7 | 6.0 | - | - | - |
| Feb-19 | 6.0 | 6.0 | 6.0 | 6.0 | - | 8.0 | 8.0 | 6.0 | 8.0 | 8.0 | 7.3 | 8.0 | - | 6.0 | 7.4 | - | - | - |
| Mar-19 | 5.3 | 4.7 | 5.3 | 5.3 | - | 5.3 | 5.3 | 5.3 | 6.7 | 6.7 | 6.7 | - | 10.0 | - | 6.6 | 6.8 | 6.0 | 13.0 |
| Apr-19 | - | - | - | - | - | - | - | - | 9.3 | 7.3 | 8.0 | - | 14.0 | - | 9.7 | 0.0 | 0.0 | 9.5 Estimated |
| Jan-20 | - | - | 5.3 | 7.3 | - | 6.7 | 12.0 | - | - | - | - | - | 11.3 | - | 10.0 | - | - | - |
| Feb-20 | - | 16.0 | 15.3 | 14.0 | - | 16.0 | 14.0 | 12.0 | 15.3 | 15.3 | 16.7 | - | 16.7 | - | 15.1 | - | - | - |

| **Station** | **BKS-1** | **BKS-2** | **BKS-3** | **BKS-4** | **BKS-5.0** | **BKS-5.1** | **BKS-6** | **BKS-7** | **BKS-8** | **BKS-9** | **BKS-10** | **BKS-11** | **BKS-12** | **BKS-13** | **Monthly Mean** | **Mayo A** | **Mayo B** | **Calumet** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Elevation (m)** | 914 | 907 | 878 | 876 | 942 | 942 | 938 | 1032 | 1132 | 1051 | 990 | 1338 | 1248 | 1003 | | 540 | 540 | 1310 |
| **Description** | Tall spruce up hill near dry stack | Log pile near dry stack | Between 1 and 2 marker on CLR road | Down road from BKS 3, closer to #2 CLR marker | Keno dump area. Near scrub trees | Keno dump area. Near scrub trees | Keno dump area. On sloping hillside | Uphill from Bellekeno treatment pond | Far end of Bellekeno East. Nr explosive storage shed | At BKR 16 marker. Slightly up on hillside | Near BKR 8 pull out. Up on hillside | Lucky Queen, upslope of the pond | East of Bermingham 200 adit, Upslope of road | Onek, upslope of portal near powerline | | Mayo Airport | Mayo Airport | Calumet Hill |
| Mar-20 | 17.0 | 17.3 | 15.3 | 18.0 | - | 11.3 | 15.7 | 14.0 | 21.3 | 23.3 | 19.3 | - | - | - | 17.5 | 15.4 | 15.0 | 27.7 |
| Apr-20 | 18.7 | 17.0 | 16.0 | 20.7 | - | 19.3 | 16.7 | 15.3 | - | 26.0 | 23.3 | 11.3 | 27.3 | - | 19.9 | 17.3 | 16.6 | 30.5 |
| Feb-21 | 8.0 | - | - | 6.3 | - | 8.7 | - | - | 8.7 | 12.0 | 8.3 | - | 12.3 | - | 10.0 | - | - | - |
| Mar-21 | 10.0 | - | - | 9.3 | - | 10.0 | - | - | 12.3 | 13.7 | 11.0 | 19.3 | 16.7 | 11.0 | 13.4 | 9.8 | 9.0 | 16.7 |
| Apr-21 | 13.0 | - | - | 13.7 | - | 14.0 | - | - | 15.0 | 13.3 | 13.3 | - | 18.7 | - | 14.9 | 7.9 | 13.8 | 18.4 |
| Feb-22 | 10.7 | - | - | 15.7 | | 9 | - | - | 7.7 | 14 | 10.3 | 15.3 | 20.7 | 11.3 | 10.3 | - | - | 21.3 |
| Mar-22 | 14.0 | - | - | 17.0 | - | 10.0 | - | - | 18.7 | 9.3 | 16.3 | 18.0 | 25.3 | 15.3 | 15.8 | 16.0 | 17.2 | 24.6 |
| Apr-22 | 19.3 | - | - | 14.3 | - | 16.0 | - | - | 16.3 | 15.7 | 19.7 | - | 26.7 | - | 18.9 | 16.7e | 18.0 | 27.3 |

Manual snow surveys have been conducted in the KHSD since 2011 at ten monitoring stations in order to represent the varying snow conditions as a function of aspect and elevation. Two additional stations (BKS-11 Lucky Queen and BKS-12 Bermingham) were established in 2016 and a third one (BKS-13 Onek) was established in 2017. In April 2020, snow surveys were also conducted in the Valley Tailings area in three new locations; data is presented in Table 3-10 below.

**Table 3-10: Valley Tailings Snow Survey Stations SWE (cm)**

| Station | VT-1 | VT-2 | VT-3 |
|---|---|---|---|
| Elevation (masl) | 718 | 697 | 692 |
| *Description* | *Located at the Valley Tailing Weather Station* | *South of the middle pond on the Valley Tailings Road* | *West of Valley Tailings Dam facility* |
| Apr-20 | 16.7 | 19.3 | 17.3 |
| Feb-21 | 7.7 | 9.0 | 10.3 |
| Mar-21 | 11.0 | 11.3 | 14.3 |
| Apr-21 | 12.7 | 12.7 | 15.3 |
| Feb-22 | 9.7 | 17.7 | 11.7 |
| Mar-22 | 18.3 | 17 | 18 |
| Apr-22 | 15 | 15.3 | 15.3 |

In 2022, surveys were conducted on February 17-22, March 30, and April 27-28. Site stations are presented for comparison with the regional stations in Figure 3-6. Station BKS-1 is at 914 masl and is an open space near the DSTF above the Flame & Moth mine. Station BKS-3 is located on the Christal Lake Road at an elevation of 878 masl, and station BKS-4 is also on Christal Lake Road, between kilometer 3 and 4 markers on the uphill side of the road. Station BKS-5.1, at 942 masl, is located near the Keno transfer station just up the hill from KV-87N at 876 masl. Station BKS-7 is uphill form the Bellekeno treatment pond at an elevation of 1032 masl, and BKS-8 is at the far end of Bellekeno East at an elevation of 1132 masl. BKS-10 is at 990 masl and is on the uphill side of the Bellekeno road at the kilometer 8 pullout. BKS-12 is at 1248 masl and is located near KV-78B. Mayo A and B are collected at the Mayo airport at an elevation of 540 masl and finally Calumet station is found near the Galena Hill weather station at 1310 masl. These stations were chosen based on elevation variation and their recorded SWE over the surveyed period.

Figure 3-7 presents SWE as a function of elevation, as predicted the higher the elevation, the more snow is accumulated. The highest station, BKS-12 at 1248 masl, has shown the highest SWE for 2022 in February, March, and April. The measured SWE of BKS-12 is comparable to Calumet station SWE which has a similar northwest aspect and elevation of 1310 masl. In March 2022, BKS-12 SWE measurement was 114.5% higher than the average historical SWE at this site. BKS-12 has showed the highest SWE consistently from 2016 to 2022. The lowest SWE of 2022 was recorded at station BKS-9 which has an elevation of 1051 masl and is comparable to BKS-5.1 SWE at 942 masl, regardless of elevation difference. BKS-4 March SWE measurement is 24.6% below March historical average at this site. April showed a decrease in average SWE by 26.4%c compared to the 2021 increase of 18.7% across all surveyed sites, showing a total decrease in accumulated SWE around the Keno Valley.

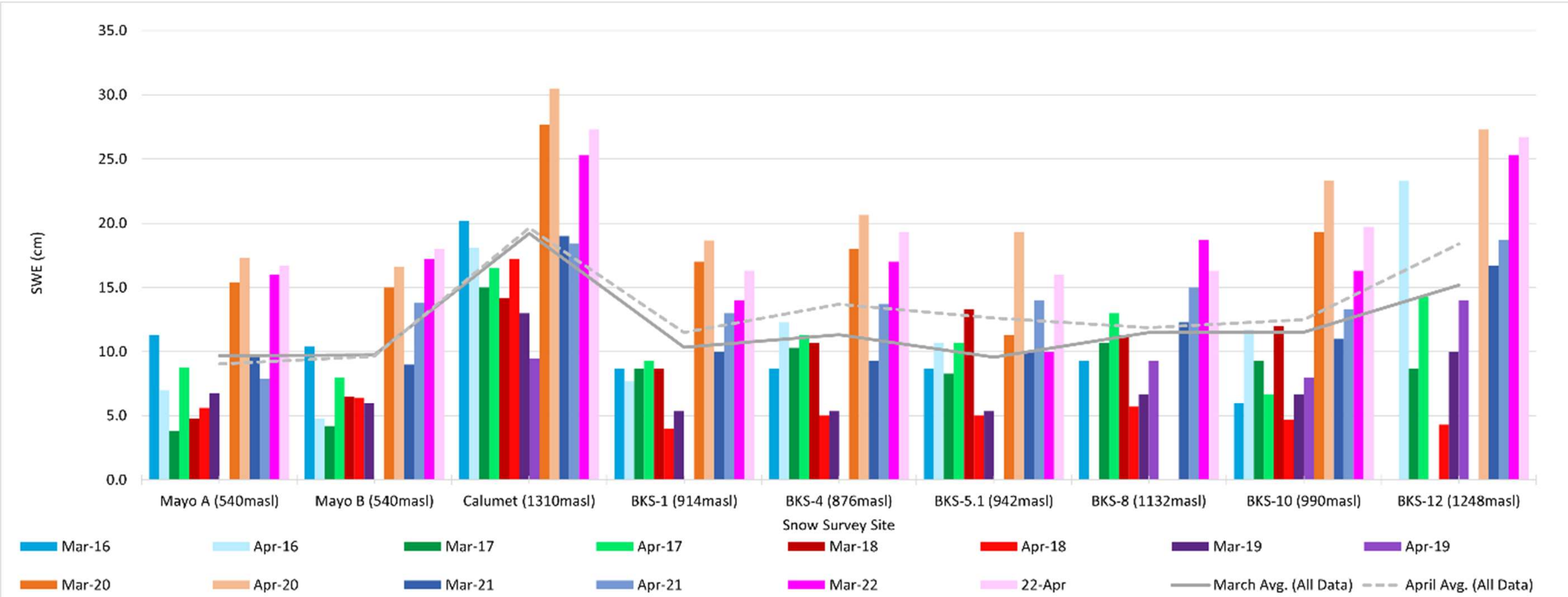



**Figure 3-6: Regional Snow Water Equivalents Compared to BKS-1, 4, 5.1, 8, 10, and 12 for 2016-2022**

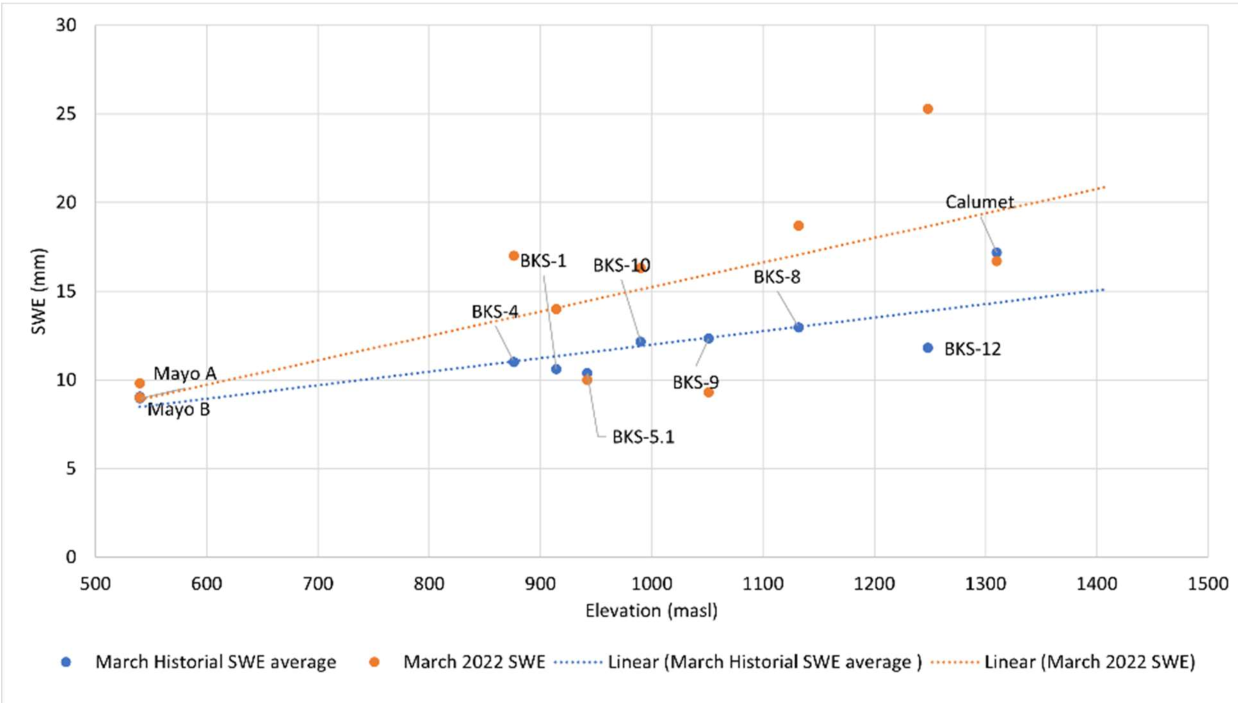



**Figure 3-7: March Snow Water Equivalent as a Function of Elevation**

### 3.1.5 MEAN ANNUAL PRECIPITATION (MAP)

Mean annual precipitation (MAP) within a mountainous region typically increases with increasing elevation. The significant relief over which the KHSD area spans is well represented by two historical weather stations with Elsa at 814 masl and the Keno Hill weather station at 1472 masl. In 1996, Clearwater Consultants Ltd. (CCL) used data from these two stations as well as from Environment Canada's station located at Mayo airport (504 masl.) to derive a relationship between MAP and elevation (Access, 1996). Assuming a linear relationship, a line was fitted to the data of these stations. Figure 3-8 was reproduced (Access, 1996) and updated to include the three stations in this memo and including more recent data where available. The slope of this line indicates that MAP increases by an average of 27 mm for every 100 m of ascent, a value not too dissimilar from that observed values in other regions of the Yukon interior.

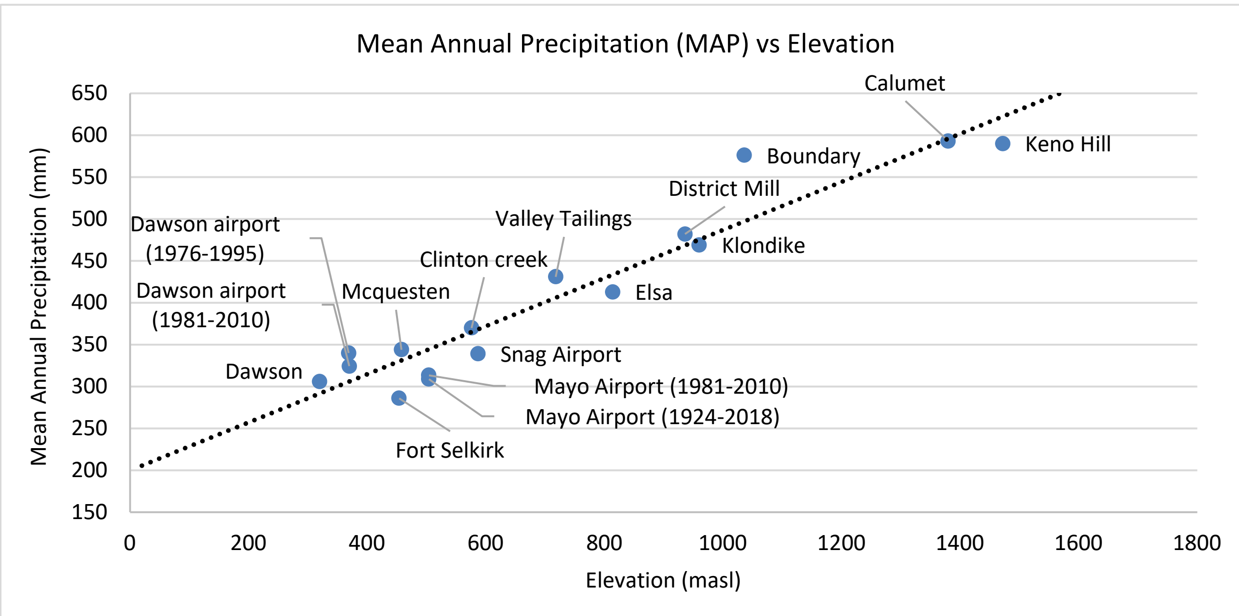



**Figure 3-8: Mean Annual Precipitation as a Function of Elevation**

#### 3.1.5.1 MONTHLY PRECIPITATION

As with MAP, the seasonal or monthly distribution is influenced by elevation. To demonstrate this influence, the monthly distributions for Elsa, Keno Hill and Mayo Airport have been plotted in Figure 3-9, which was part of the same assessment conducted by CCL in 1996 (Access, 1996), but with Mayo Airport updated to include recent data. The proportion of total precipitation which falls as rain decreases as elevation increases (53% of total precipitation at Elsa, 1% at Keno Hill and 60% at Mayo Airport). Again, a simple linear relationship can be derived, and the slope indicates that the proportion of total precipitation that falls as rain decreases by about 2% for every 100 m ascent.

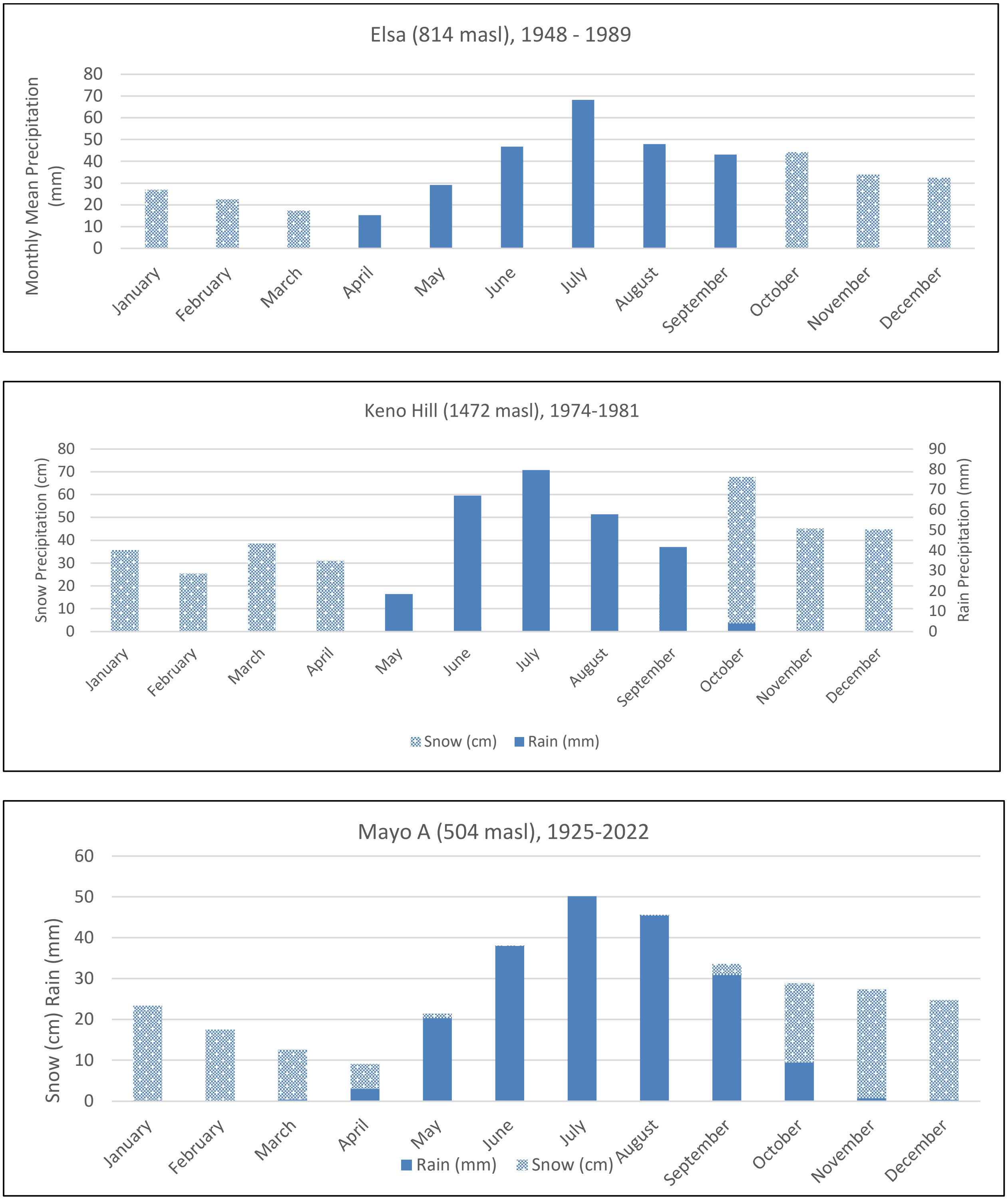



**Figure 3-9: Mean Monthly Precipitation**

*Note: Reproduced from Access (1996) with Mayo Airport updated to include more recent data*

#### 3.1.5.2 MAYO A RECENT PRECIPITATION AND TEMPERATURE COMPARISON TO SITE STATIONS

Recent precipitation data from Mayo A, Calumet, District Mill, and the Valley Tailings weather stations were used to verify the empirical relationships presented above. Validated precipitation data at Mayo A are available until December 12, 2022, with the exception of the year 2013, which is missing. Therefore, the periods of overlap between the Calumet station (2007-2022), the District Mill station (2012-2022), and the Valley Tailings (2014-2022) were used for this comparison. Mayo A reports both rain and total precipitation, while Calumet and the Valley Tailings weather stations record rainfall only. Table 3-11 presents the proportion of total precipitation that fell as rain for the 2007-2022 period at Mayo A. The District Mill weather station recorded rainfall only in 2012 and 2013 and total precipitation since 2014. Additionally, the District Mill station did not record precipitation between May and November 2022, therefore only a partial data set for 2022 and not representative for the year.

**Table 3-11: Annual Precipitation at Mayo A and District Mill Station, 2007-2022**

| Mayo A Station | | | | | District Mill |
|---|---|---|---|---|---|
| **Year** | **Total Rain (mm)** | **Total Snow (cm)** | **Total Precipitation (mm)** | **% Rain** | **Precipitation (mm)** |
| 2007 | 217.2 | 188.4 | 345.8 | 62.8 | - |
| 2008 | 309.3 | 157.8 | 429.3 | 72 | - |
| 2009 | 186.9 | 181.6 | 304.3 | 61.4 | - |
| 2010 | 198.1 | 129.8 | 293.7 | 67.4 | - |
| 2011 | 329.5 | 164.9 | 452.9 | 72.8 | - |
| 2012 | 171.7 | 158.4 | 276.1 | 62.2 | 217.5 |
| 2013 | 226.3 | 144.1 | 359.2 | 63.0 | 400.0 |
| 2014 | 287.7 | 50.3 | 376.3 | 76.5 | 292.6 |
| 2015 | 301 | 173.1 | 408.7 | 73.6 | 296.9 |
| 2016 | 245.6 | 124.4 | 316 | 77.7 | 277.7 |
| 2017 | 246.8 | 94.1 | 312.7 | 78.9 | 265.9 |
| 2018 | 292.5 | 78 | 338 | 86.5 | 344.9 |
| 2019 | 137.8 | 200.9 | 249.3 | 55.3 | 127.0 |
| 2020 | 306 | 206.7 | 435.6 | 70.2 | 287.7 |
| 2021 | 191.1 | 172.4 | 296.2 | 64.5 | 278.6 |
| 2022 | 303.3 | 176.3 | 410 | 74.0 | 56.7 |
| **AVG** | **246.9** | **150.1** | **350.3** | **69.9** | **258.7** |

For this 15-year period, the average proportion of total precipitation that fell as rain was 69.4%, which is slightly higher than the original estimate of 60%. Since the value of 60% was estimated using data collected between 1974 and 1982, it is possible that the proportion of total precipitation falling as rain has increased with the warming temperature trends observed in the Yukon. Figure 3-12 shows the temperature trend at Mayo A since 1925. Maximum, minimum, and mean temperatures recorded over the 1925-2022 period all show an increasing trend, though the minimum temperatures are seeing the greatest increase.

As seen in Figure 3-10 and Figure 3-11, there continues to be a difference between the precipitation collected at the District Mill Weather Station (936 masl until November 2022, 900 masl thereafter) and the Mayo A Station (504 masl). The rain data correlates well for months that the station was in working order. The general trend of snowfall data between the District station and Mayo A are similar; however, the amount is significantly different for months January to March. It is worth noting the precipitation equipment is prone to freezing in the winter and has not always provided reliable data, additionally, a snow fall adapter was only installed in 2013.

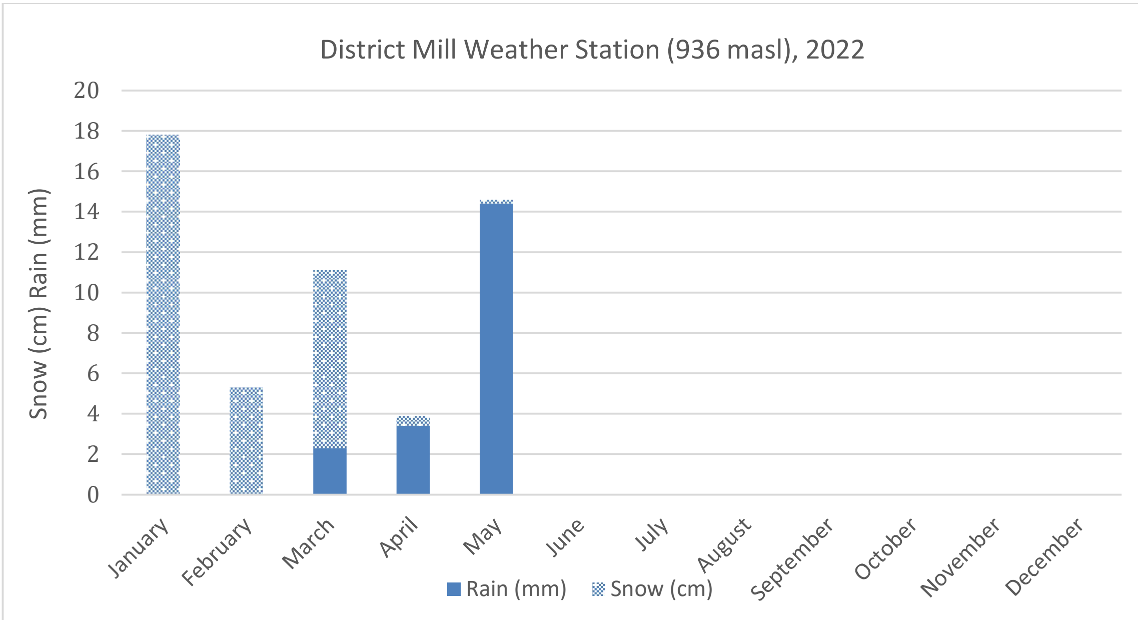



**Figure 3-10: Precipitation at District Mill Weather Station**

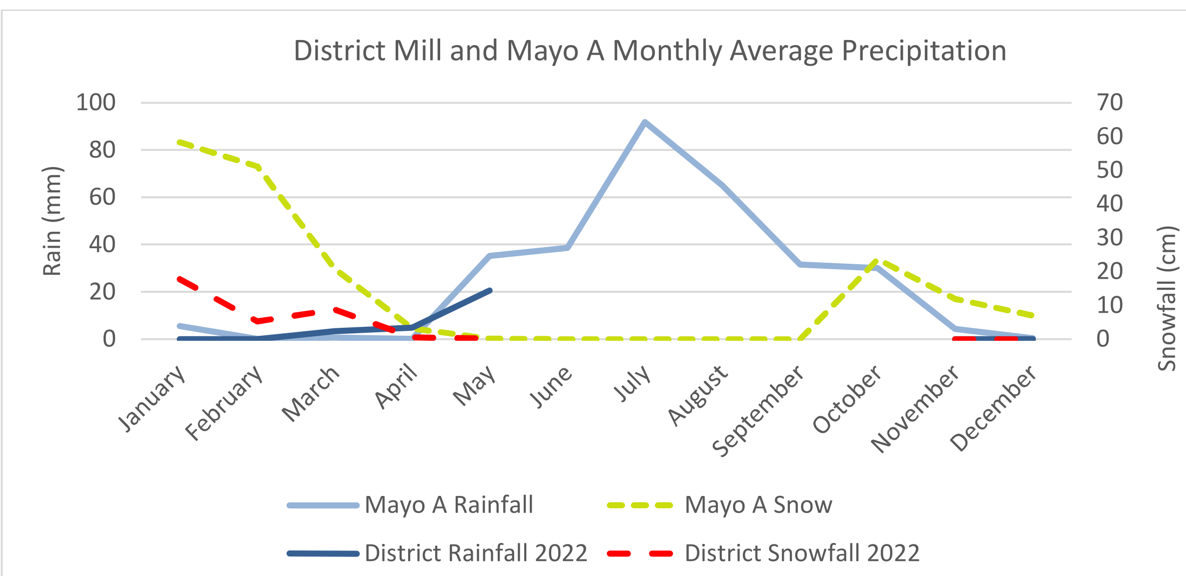



**Figure 3-11: District Mill and Mayo A Average Monthly Precipitation Comparison**

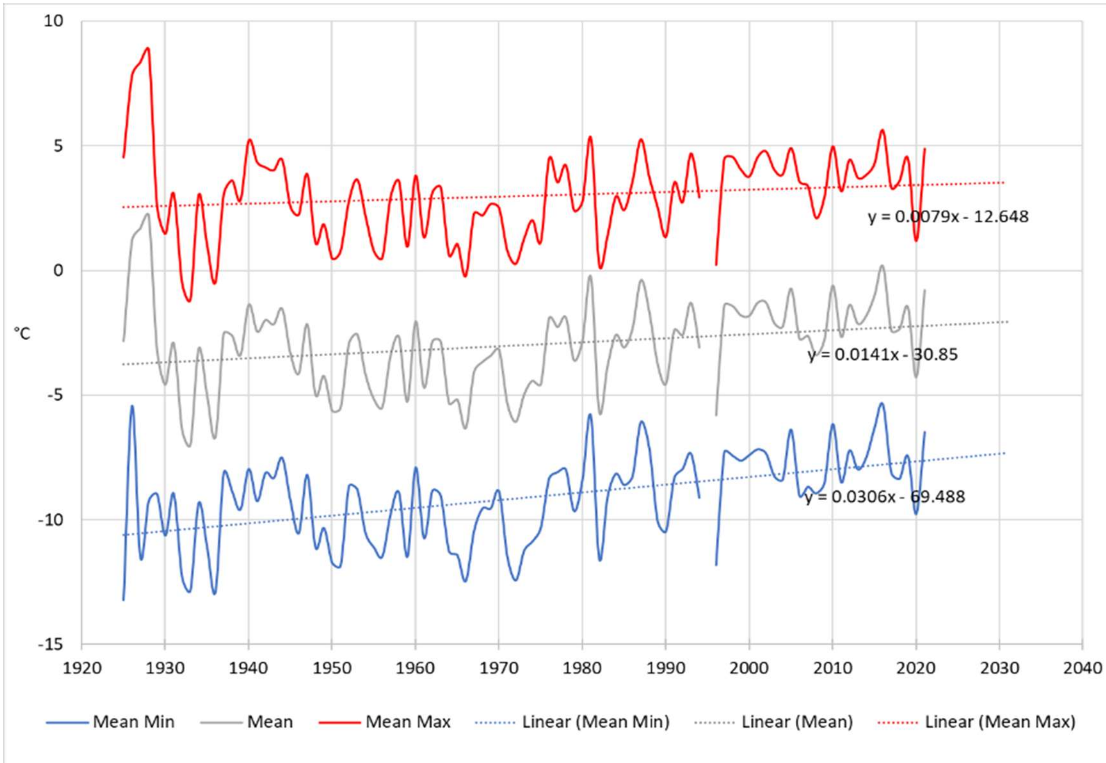



**Figure 3-12: Mayo A Annual Temperatures, 1925-2022**

Assuming the empirical linear relationship where the proportion of total precipitation that falls as rain decreases by about 2% for every 100 m ascent, it is expected that 45.2% of total precipitation falls as rain at Calumet, 54.1% at the District Mill and 58.5% at the Valley Tailings station. Based on Mayo A annual total precipitation from 2007 to 2022 (Figure 3-12), predicted total rainfall is compared to total rainfall measured at Calumet, District Mill, and Valley Tailings (Table 3-12). Note that Calumet observed rainfall data for 2016 and 2017 are largely incomplete and those years were therefore not included in the comparison below. As the District Mill station was not operational from May to November 2022, the precipitation data collected at that station are not representative of the year.

### Table 3-12: Predicted Versus Measured Total Rain (mm)

| Year | Predicted Annual Total Precipitation (mm) | Predicted Total Rain (mm) | Measured Total Precipitation (mm) | Actual - Predicted | % Difference |
|---|---|---|---|---|---|
| Calumet (1380 masl) | | | | | |
| 2007 | 582.3 | 263.1 | *276.4* | 13.3 | 5% |
| 2008 | 665.8 | 300.8 | 363.6 | 62.8 | 17% |
| 2009 | 540.8 | 244.3 | *196.4* | -48.0 | -24% |
| 2010 | 530.2 | 239.6 | 462.2 | 222.7 | 48% |
| 2011 | 689.4 | 311.5 | *305.5* | -6.0 | -2% |
| 2012 | 512.6 | 231.6 | *137.0* | -94.6 | -69% |
| 2013 | 595.7 | 269.1 | 200.6 | -68.5 | -34% |
| 2014 | 612.8 | 276.9 | 264.4 | -12.5 | -5% |
| 2015 | 645.2 | 291.5 | *339.7* | 48.2 | 14% |
| 2016 | 552.5 | 249.6 | *76.9* | -172.7 | -225% |
| 2017 | 549.2 | 248.1 | - | - | - |
| 2018 | 574.5 | 259.6 | 430.9 | 171.3 | 40% |
| 2019 | 485.8 | 219.5 | *216.2* | -3.3 | -2% |
| 2020 | 672.1 | 303.7 | *489.7* | 186.1 | 38% |
| 2021 | 532.7 | 240.7 | *297.8* | 57.1 | 19% |
| 2022 | 646.5 | 292.1 | *254.6* | -37.5 | -15% |
| **AVG** | **586.8** | **264.9** | **289.2** | **23.0** | **-15%** |
| District Mill (936 masl) | | | | | |
| 2012 | 392.7 | 212.3 | 217.5 | 5.2 | 2% |
| 2013 | 475.8 | 257.2 | 400.0 | 142.8 | 36% |
| 2014 | 492.9 | 266.5 | 292.6 | -200.3 | -68% |
| 2015 | 525.3 | 284.0 | 296.9 | -228.4 | -77% |
| 2016 | 432.6 | 233.9 | 277.7 | -154.9 | -56% |
| 2017 | 429.3 | 232.1 | 267.3 | -162.0 | -61% |
| 2018 | 454.6 | 245.8 | 344.9 | -109.7 | -32% |
| 2019 | 365.9 | 197.8 | 127.0 | -238.9 | -188% |
| 2020 | 552.2 | 298.5 | 287.7 | -264.5 | -92% |
| 2021 | 412.8 | 223.2 | 278.6 | -134.2 | -48% |
| 2022 | 526.6 | 284.7 | - | - | - |
| **AVG** | **466.9** | **247.6** | **279.1** | **-134.6** | **-58%** |
| Valley Tailings (718 masl) | | | | | |
| 2014 | 57.8 | 33.8 | *112.4* | 78.6 | 70% |
| 2015 | 57.8 | 33.8 | 272.2 | 238.4 | 88% |
| 2016 | 57.8 | 33.8 | 226.6 | 192.8 | 85% |

| Year | Predicted Annual Total Precipitation (mm) | Predicted Total Rain (mm) | Measured Total Precipitation (mm) | Actual - Predicted | % Difference |
|---|---|---|---|---|---|
| 2017 | 57.8 | 33.8 | 269.20 | 235.4 | 87% |
| 2018 | 57.8 | 33.8 | *75.60* | 41.8 | 55% |
| 2019 | 57.8 | 33.8 | *69.40* | 35.6 | 51% |
| 2020 | 57.8 | 33.8 | *94.40* | 60.6 | 64% |
| 2021 | 57.8 | 33.8 | *137.83* | 104.1 | 76% |
| 2022 | 57.8 | 33.8 | *232.40* | 198.6 | 85% |
| **AVG** | **57.8** | **33.8** | **157.2** | **126.2** | **72%** |

*Values in grey italics indicate that total precipitation is not from the entire year (i.e., some data missing due to weather station malfunctions).*

#### 3.1.5.3 DISCUSSION BETWEEN PREDICTED AND OBSERVED PRECIPITATION

Some years have incomplete rain data at Calumet (refer to Table 3-3 for specific details) and Valley Tailings (refer to Table 3-7), and this could explain the negative difference between actual and predicted rainfall in 2009, 2011-2012, and 2019-2020 at the Calumet station, 2022 at the District Mill station and 2014 and 2018-2021 at the Valley Tailings station (Table 3-7). In other cases, however, the difference is positive even though the Calumet dataset is incomplete (e.g., 2015 and 2021). For three of the years where the Calumet dataset is complete, the difference between actual and predicted total rainfall is positive (2008, 2010 and 2018), and for two other years it is negative (2013 and 2014). The average difference between actual and predicted for those five years is positive (13.3%), implying that the linear relationship between MAP and elevation developed by CCL (Access, 1996) might underestimate total precipitation increase with elevation. A confounding factor is the assumed relationship between the proportion of total precipitation that falls as rain and elevation, which may also need to be refined. At the Valley Tailings station, the 2015, 2016 and 2017 dataset are complete and actual versus predicted rainfall are relatively similar (-2.6%, -3.3% and 13.8% difference, respectively).

In the case of the District Mill, there is good agreement between predicted and measured total rain for the year 2012. From 2014 to 2022, however, comparison is made for total precipitation since a snowfall conversion adaptor was installed in 2013. In that case, the measured amount is considerably less than the predicted amount, indicating probable under catch of the snowfall conversion adaptor. Literature reports a cumulative winter catch efficiency of 0.66 for a Campbell Scientific TE525 tipping bucket gauge with a CS705 snow fall adaptor and alter screen (MacDonald and Pomeroy, 2007). Total precipitation data (2014-2019) from October through April were therefore corrected using this factor. Also, because the use of an alter screen for wind deflection has a documented improvement of 10 to 16% in snow collection efficiency and 6% to 10% for all types of precipitation (Belfort Instrument, 2013), average correction factors of 8% and 13% for summer and winter months respectively were applied to precipitation data collected prior to the installation of the alter screen in June 2015. Corrected total precipitation data are still below the values predicted from the MAP-elevation relationship, suggesting that the snowfall under catch might be greater at this site than the average value reported in the literature, or that there is uncertainty in the MAP-elevation relationship. Refinement of the MAP-elevation relationship derived by CCL (Access, 1996) will be possible as more years of data become available at Calumet and at the District Mill, and as total precipitation data become available at the District Mill weather station.

## 3.2 AIR QUALITY

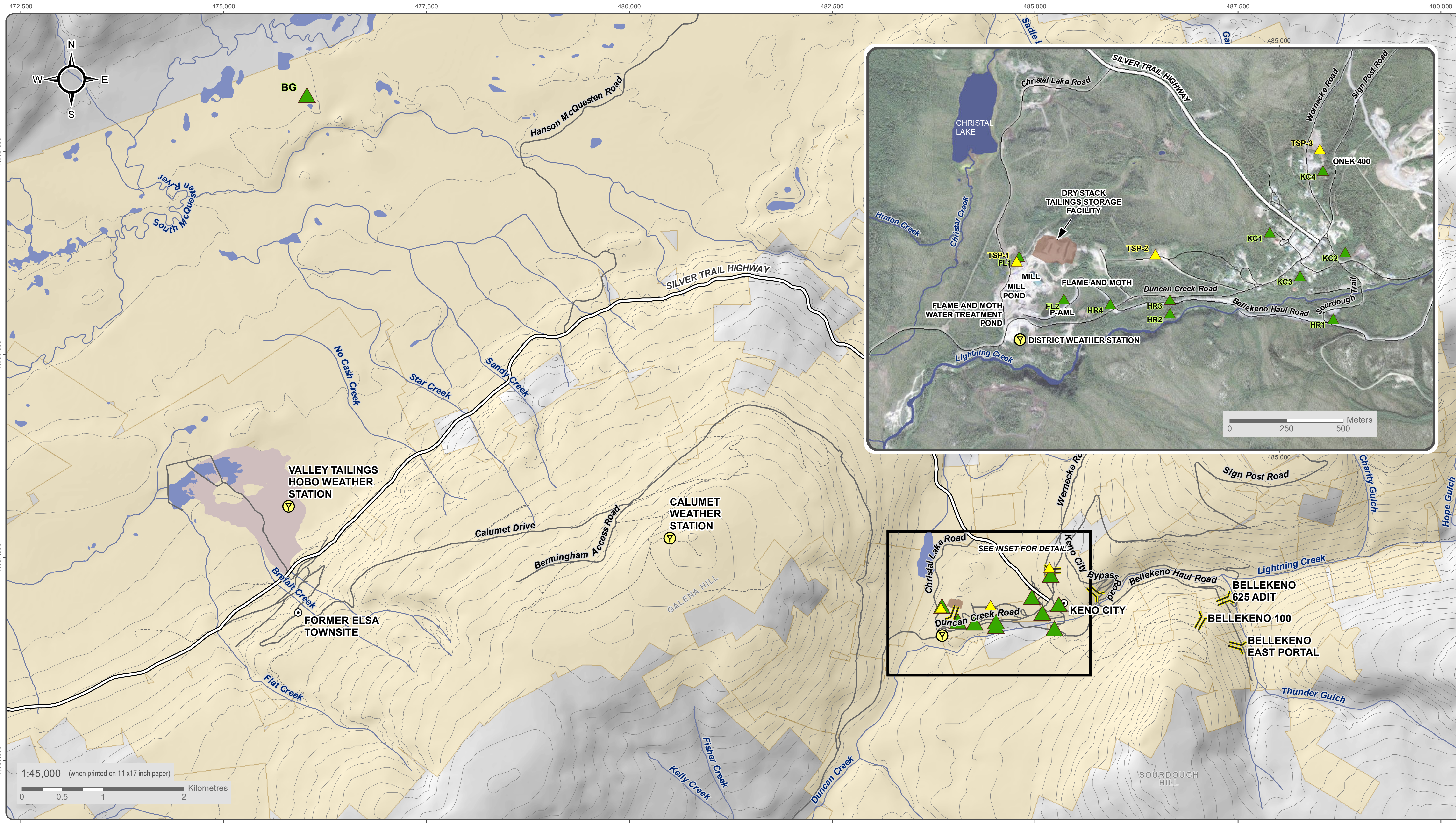
AKHM established an air quality monitoring program in 2009. To assess potential effects of particulate matter, discrete receptors in Keno City were used in the modelling. Ambient concentrations were predicted at six discrete receptors in Keno City (Figure 3-13). Air quality monitoring undertaken by AKHM during periods of suspension of operations of the District Mill represent either ambient conditions or low levels of activity.

Air quality was monitored using dustfall monitoring stations installed at four locations near the District Mill site (2011). Bergerhoff dust monitoring gauges were utilized to carry out this initial program. The Bergerhoff deposit dust gauge is designed to measure dust deposition, which can be reported as a weight per unit area over unit time.

The monitoring program was amended in 2012 to measure total particulates per volume of air for select size fractions (total suspended particulates (TSP)). Total suspended particulates (TSP) and total metal monitoring was undertaken using BGI Omni Ambient Air Quality Samplers at two locations near the District Mill site in August 2012. A third sampler (TSP-3), located in Keno City, was commissioned in December 2014. Additional sampling for coarse and fine fractions of particulate matter ($PM_{10}$ and $PM_{2.5}$, respectively) was instigated in August 2015. In January 2021, the BGI Omni sampler located east of the mill and crusher (TSP-1) was rendered unsalvageable. In 2022 it was replaced at a new location in Keno City. Currently there are three air quality sampling stations in use for the project.

The goal of the current sampling program is to collect samples from three locations (TSP-1, TSP-2, TSP-3: see Figure 3-13) each month, to capture variability in air quality from various weather conditions. Potential dust sources include the DSTF, the crusher, and unpaved access roads.

Results of the gravimetric analyses are converted into 24-hour average ambient concentrations based on the flow rate of the instruments. These are compared with the Yukon Ambient Air Quality Standard (YAAQS) (24-hour average): 120 µg/$m^3$ for TSP; 50 µg/$m^3$ for $PM_{10}$; and 27 µg/$m^3$ for $PM_{2.5}$.




- Alexco TSP Monitoring Stations
- YG PM10 Monitoring Sites 2013
- Weather Station
- Adit
- Mine Feature Footprint
- Current DSTF
- Tailings Area
- Waterbody
- Alexco/ERDC Quartz Claims
- Watercourse
- Silver Trail Highway
- Other Road
- Limited-Use Road

National Topographic Data Base (NTDB) compiled by Natural Resources Canada at a scale of 1:50,000. Cadastral data compiled by Natural Resources Canada. Reproduced underlicense from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on February 2023

Datum: NAD 83; Map Projection: UTM Zone 8N



HECLA KENO HILL

FIGURE 3-13

METEOROLOGICAL AND
AIR QUALITY MONITORING STATIONS LOCATION

FEBRUARY 2023

D:\Project\AllProjects\Keno_Area_Mines\ALL-SITES\02-Map\04-Studies\Air_Noise_Dust\Air_Quality_Stns_YTG_20230203.mxd
(*Last edited by: amatlashevska;2023-02-28/10:25 AM*)

### 3.2.1 AIR PARTICULATE

Summary statistics for 2012-2022 are presented in Table 3-13 for the three sampling locations (TSP-1, TSP-2 and TSP-3). When results were below the detection limit half the detection limit was used to calculate the summary statistics.

The air quality monitors established in 2012 were located 160 m (TSP-1) and 46 m (TSP-2) away from the DSTF and 163 m (TSP-1) and 240 m (TSP-2) away from the crusher, two of the main potential dust sources. The nearest residence is 710 m from the DSTF and 860 m from the crusher. TSP levels experienced at the nearest residence are better approximated by levels observed at air quality monitor TSP-3, located in Keno City. TSP-3 was installed in 2014 950 m from the DSTF and 1240 m from the crusher.

To provide better understanding of how ambient concentrations vary throughout Keno City, in Q2 2022 the following changes were made to the air quality monitoring stations:

- The dust monitor previously located at the north side of Keno City (TSP-3) was relocated adjacent the Onek 400 water treatment plant (near receptor R04). TSP-3 is now 1275 m from the DSTF and 1410 m from the crusher; and
- A third sampler (TSP-1) was installed at the eastern end of Keno City (near noise receptor R01); however, in response to concerns raised by local residents about the noise the sampler generated it was relocated the Keno City Ball Diamond (approximately 300 m west of noise receptor R05).

The sampler at the toe of the DSTF (TSP-2) remains in operation to provide information on ambient concentrations within the Project area and to provide data continuity as this station has been monitored for TSP since August 2012. Operations of the District Mill were suspended between September 2013 and December 2020 and again in June 2022 to date.

#### Table 3-13: Total Suspended Particulates, Coarse and Fine Particulate Matter Summary Statistics 2012 – 2022

| | TSP (µg/m³) | | | $PM_{10}$ (µg/m³) | | | $PM_{2.5}$ (µg/m³) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Yukon Ambient Air Quality Standards** | **120** | | | **50** | | | **27** | | |
| **Sampling Location** | **TSP-1*** | **TSP-2** | **TSP-3** | **TSP-1** | **TSP-2** | **TSP-3** | **TSP-1** | **TSP-2** | **TSP-3*** |
| Average | 6.1 | 6.8 | 6 | 5.2 | 5.5 | 4.5 | 4 | 4.5 | 4.3 |
| Count | 330 | 358 | 270 | 223 | 249 | 252 | 211 | 252 | 251 |
| Minimum | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Maximum | 93.5 | 106.8 | 88.2 | **134.2** | **151.4** | 40.7 | 28.2 | **40.7** | 21.2 |
| Geometric Mean | 4.3 | 4.6 | 4.3 | 3.7 | 3.9 | 3.7 | 3.4 | 3.7 | 3.7 |
| Count <DL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Standard Deviation | 8 | 9.5 | 8.5 | 10.1 | 10.6 | 4.6 | 3.3 | 4.6 | 3.1 |
| 1st Quartile | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Median | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| 3rd Quartile | 7 | 7.2 | 6.4 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 5.6 |
| Count Over Standard | 0 | 0 | 0 | 1 | 1 | 3 | 1 | 3 | 0 |

| | TSP (µg/m³) | | | $PM_{10}$ (µg/m³) | | | $PM_{2.5}$ (µg/m³) | | |
|---|---|---|---|---|---|---|---|---|---|
| % Over Standard | 0 | 0 | 0 | 0.4 | 0.4 | 1.2 | 0.5 | 1.2 | 0 |

*Note: Bold = exceedance of YAAQS*
** Two outliers removed (TSP-1 976.4 µg/m³* on July 1, 2015; TSP-3 65 µg/m³ on July 15, 2017)

From 2012-2022, the greatest average TSP concentration was measured at TSP-2 (6.8 µg/m³; Table 3-14). Concentrations of TSP at stations TSP-1 and TSP-3 measured 6.1 and 6.0 µg/m³ respectively; however, the difference is not statistically significant, and concentrations are less than the YAAQS. For coarse particulate matter ($PM_{10}$), the greatest average concentration was recorded at TSP-2 (5.5 µg/m³) and the lowest average at TSP-3 (4.5 µg/m³). For fine particulate matter ($PM_{2.5}$), the greatest average concentration was recorded at TSP-2 (4.5 µg/m³) and the lowest average at TSP-1 (4.0 µg/m³). These results do not greatly deviate from the 2019 results. In 2022, exceedances were recorded for $PM_{10}$ concentrations at monitoring location TSP-1 (May 17, 2022), TSP-2 (November 7, 2022 due to cold weather), TSP-3 (October 9, 2022). Exceedances of $PM_{2.5}$ concentrations were recorded at location TSP-2 (June 16 and 18, 2022 due to forest fires); however, all of the exceedances coincide with local forest fires or significantly colder weather in 2022; all other results were less than the YAAQS.

### Table 3-14: Total Suspended Particulates, Coarse, and Fine Particulate Matter Summary Statistics 2012 – 2022

| | TSP (µg/m³) | | | $PM_{10}$ (µg/m³) | | | $PM_{2.5}$ (µg/m³) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Yukon Ambient Air Quality Standards** | **120** | | | **50** | | | **27** | | |
| **Sampling Location** | **TSP-1*** | **TSP-2** | **TSP-3** | **TSP-1** | **TSP-2** | **TSP-3** | **TSP-1** | **TSP-2** | **TSP-3*** |
| Average | 6.1 | 6.8 | 6 | 5.2 | 5.5 | 4.5 | 4 | 4.5 | 4.3 |
| Count | 330 | 358 | 270 | 223 | 249 | 252 | 211 | 252 | 251 |
| Minimum | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Maximum | 93.5 | 106.8 | 88.2 | **134.2** | **151.4** | 40.7 | 28.2 | **40.7** | 21.2 |
| Geometric Mean | 4.3 | 4.6 | 4.3 | 3.7 | 3.9 | 3.7 | 3.4 | 3.7 | 3.7 |
| Count <DL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Standard Deviation | 8 | 9.5 | 8.5 | 10.1 | 10.6 | 4.6 | 3.3 | 4.6 | 3.1 |
| 1st Quartile | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| Median | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 |
| 3rd Quartile | 7 | 7.2 | 6.4 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 5.6 |
| Count Over Standard | 0 | 0 | 0 | 1 | 1 | 3 | 1 | 3 | 0 |
| % Over Standard | 0 | 0 | 0 | 0.4 | 0.4 | 1.2 | 0.5 | 1.2 | 0 |

*Note: bold = exceedance of YAAQS*
** Two outliers removed (TSP-1 976.4 µg/m3 on July 1, 2015; TSP-3 65 µg/m3 on July 14, 2017)*

### 3.2.2 METAL SPECIATION

There are no ambient air quality standards for metals in Yukon; however, the Ontario Ministry of Environment has developed a comprehensive list of Ambient Air Quality Criteria (AAQC) that includes 24-hour average concentrations for metals.

Table 3-15 presents the summary statistics for 2012 to 2022 for metal concentrations from samples TSP-1, TSP-2, and TSP-3, while the complete result tables are presented in Attachment A3 to A5. When results were below the detection limit a value of half the detection limit was used to calculate the statistics.

All parameters met AAQC criteria except for cadmium (TSP-2 – 0.6% of samples; TSP-3 – 0.7% of samples), lead (TSP-1 – 0.6% of samples; TSP-2 – 0.3% of samples), and manganese (TSP-2 – 1.1% of samples).

**Table 3-15: Metal Concentrations Summary Statistics (24-hour) 2012 – 2022**

| | Al | Sb | As | Ba | Be | B | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | P | K | Se | Si | Ag | Na | Sr | S | Sn | Ti | V | Zn | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ontario Ambient Air Quality Criteria (µg/m³)** | **n/a** | **25** | **0.3** | **10** | **0.01** | **120** | **0.025** | **n/a** | **0.5** | **0.1** | **50** | **4** | **0.5** | **n/a** | **0.4** | **120** | **2** | **n/a** | **n/a** | **10** | **n/a** | **1** | **n/a** | **120** | **n/a** | **10** | **120** | **2** | **120** | **n/a** |
| **TSP-1** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Average** | 0.155 | 0.0983 | 0.03951 | 0.0025 | 0.00403 | 0.023 | 0.00989 | 0.36 | 0.0752 | 0.02465 | 0.025 | 0.173 | 0.04718 | 0.034 | 0.009 | 0.02463 | 0.02501 | 0.163 | 0.51 | 0.0249 | 0.413 | 0.01482 | 0.238 | 0.00269 | 20 | 0.04016 | 0.014 | 0.019 | 0.0322 | 0.026 |
| **Count** | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 329 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 331 | 265 | 327 | 329 | 331 | 328 | 331 | 331 | 331 | 331 | 331 |
| **Minimum** | 0.014 | 0.00035 | 0.00035 | 0.0003 | 0.00035 | 0.021 | 0.00007 | 0.069 | 0.0208 | 0.00035 | 0 | 0.021 | 0.00035 | 0.021 | 0 | 0.00021 | 0.00035 | 0.056 | 0.035 | 0.00035 | 0.139 | 0.00014 | 0.069 | 0.00035 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0035 | 0.003 |
| **Maximum** | 5.292 | 0.13889 | 0.05556 | 0.0222 | 0.00556 | 0.264 | 0.01389 | 8.722 | 0.1458 | 0.03472 | 0.035 | 2.528 | **1.08333** | 0.429 | 0.301 | 0.03472 | 0.03472 | 0.208 | 1.035 | 0.07917 | 3.875 | 0.02083 | 2.444 | 0.04097 | 69.4 | 0.19306 | 0.042 | 0.021 | 0.8167 | 0.035 |
| **Geometric Mean** | 0.099 | 0.02439 | 0.01371 | 0.0021 | 0.00247 | 0.021 | 0.00378 | 0.237 | 0.0708 | 0.00903 | 0.016 | 0.102 | 0.02362 | 0.027 | 0.006 | 0.00803 | 0.01379 | 0.142 | 0.311 | 0.00907 | 0.262 | 0.00492 | 0.208 | 0.00189 | 0.7 | 0.01289 | 0.014 | 0.019 | 0.0189 | 0.017 |
| **Count <DL** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Standard Deviation** | 0.411 | 0.06314 | 0.02499 | 0.0024 | 0.00237 | 0.019 | 0.00622 | 0.71 | 0.0235 | 0.01567 | 0.015 | 0.233 | 0.07548 | 0.04 | 0.023 | 0.01569 | 0.0151 | 0.069 | 0.294 | 0.01616 | 0.61 | 0.0094 | 0.19 | 0.00347 | 31.4 | 0.02751 | 0.002 | 0.003 | 0.0656 | 0.015 |
| **1st Quartile** | 0.06 | 0.00035 | 0.00094 | 0.0021 | 0.00035 | 0.021 | 0.0004 | 0.139 | 0.0608 | 0.00035 | 0.004 | 0.051 | 0.01051 | 0.021 | 0.006 | 0.00021 | 0.00209 | 0.056 | 0.074 | 0.00035 | 0.208 | 0.00014 | 0.208 | 0.00152 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0139 | 0.003 |
| **Median** | 0.139 | 0.13889 | 0.05556 | 0.0021 | 0.00556 | 0.021 | 0.01389 | 0.139 | 0.0736 | 0.03472 | 0.035 | 0.086 | 0.05556 | 0.021 | 0.006 | 0.03472 | 0.03472 | 0.208 | 0.694 | 0.03472 | 0.208 | 0.02083 | 0.208 | 0.00208 | 0.1 | 0.05556 | 0.014 | 0.021 | 0.0139 | 0.035 |
| **3rd Quartile** | 0.139 | 0.13889 | 0.05556 | 0.0021 | 0.00556 | 0.021 | 0.01389 | 0.431 | 0.0889 | 0.03472 | 0.035 | 0.266 | 0.05556 | 0.021 | 0.006 | 0.03472 | 0.03472 | 0.208 | 0.694 | 0.03472 | 0.208 | 0.02083 | 0.208 | 0.00208 | 69.4 | 0.05556 | 0.014 | 0.021 | 0.0292 | 0.035 |
| **Count Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TSP-2** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Average** | 0.119 | 0.08474 | 0.03438 | 0.0024 | 0.00352 | 0.022 | 0.00878 | 0.334 | 0.0762 | 0.02126 | 0.022 | 0.223 | 0.05118 | 0.04 | 0.021 | 0.02122 | 0.02197 | 0.148 | 0.446 | 0.02126 | 0.402 | 0.01296 | 0.208 | 0.00223 | 26.7 | 0.03402 | 0.014 | 0.018 | 0.043 | 0.022 |
| **Count** | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 360 | 298 | 356 | 360 | 360 | 355 | 360 | 360 | 360 | 360 | 360 |
| **Minimum** | 0.014 | 0.00035 | 0.00035 | 0.0003 | 0.00035 | 0.021 | 0.00007 | 0.069 | 0.0208 | 0.00035 | 0 | 0.021 | 0.00035 | 0.021 | 0 | 0.00021 | 0.00081 | 0.056 | 0.035 | 0.00035 | 0.139 | 0.00014 | 0.069 | 0.00035 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0035 | 0.003 |
| **Maximum** | 1.625 | 0.13889 | 0.05556 | 0.0476 | 0.00556 | 0.099 | **0.04028** | 3.472 | 0.1889 | 0.03472 | 0.035 | 2.778 | **0.73611** | 0.468 | **0.651** | 0.03472 | 0.06417 | 0.208 | 1.014 | 0.03472 | 5.028 | 0.02083 | 1.125 | 0.03167 | 69.4 | 0.05556 | 0.032 | 0.021 | 0.4819 | 0.035 |
| **Geometric Mean** | 0.087 | 0.01499 | 0.01008 | 0.002 | 0.00188 | 0.021 | 0.00294 | 0.256 | 0.0713 | 0.00576 | 0.012 | 0.128 | 0.02728 | 0.031 | 0.008 | 0.00488 | 0.01038 | 0.124 | 0.236 | 0.00574 | 0.253 | 0.00369 | 0.189 | 0.00171 | 1.4 | 0.00809 | 0.014 | 0.018 | 0.0251 | 0.013 |
| **Count <DL** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Standard Deviation** | 0.13 | 0.06758 | 0.02649 | 0.0031 | 0.00255 | 0.006 | 0.00692 | 0.301 | 0.0254 | 0.0168 | 0.016 | 0.274 | 0.06176 | 0.042 | 0.061 | 0.01684 | 0.01627 | 0.074 | 0.316 | 0.0168 | 0.621 | 0.00997 | 0.109 | 0.0025 | 33.7 | 0.0269 | 0.001 | 0.003 | 0.0581 | 0.016 |
| **1st Quartile** | 0.05 | 0.00035 | 0.00076 | 0.0017 | 0.00035 | 0.021 | 0.00042 | 0.139 | 0.0597 | 0.00035 | 0.003 | 0.061 | 0.0158 | 0.021 | 0.006 | 0.00021 | 0.00165 | 0.056 | 0.035 | 0.00035 | 0.139 | 0.00014 | 0.194 | 0.00111 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0139 | 0.003 |
| **Median** | 0.139 | 0.13889 | 0.05556 | 0.0021 | 0.00556 | 0.021 | 0.01389 | 0.285 | 0.075 | 0.03472 | 0.035 | 0.118 | 0.05556 | 0.021 | 0.006 | 0.03472 | 0.03472 | 0.208 | 0.694 | 0.03472 | 0.208 | 0.02083 | 0.208 | 0.00208 | 0.1 | 0.05556 | 0.014 | 0.021 | 0.0139 | 0.035 |
| **3rd Quartile** | 0.139 | 0.13889 | 0.05556 | 0.0021 | 0.00556 | 0.021 | 0.01389 | 0.458 | 0.0922 | 0.03472 | 0.035 | 0.334 | 0.05556 | 0.046 | 0.012 | 0.03472 | 0.03472 | 0.208 | 0.694 | 0.03472 | 0.208 | 0.02083 | 0.208 | 0.00208 | 69.4 | 0.05556 | 0.014 | 0.021 | 0.0484 | 0.035 |

| | Al | Sb | As | Ba | Be | B | Cd | Ca | Cr | Co | Cu | Fe | Pb | Mg | Mn | Mo | Ni | P | K | Se | Si | Ag | Na | Sr | S | Sn | Ti | V | Zn | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ontario Ambient Air Quality Criteria (µg/m³)** | **n/a** | **25** | **0.3** | **10** | **0.01** | **120** | **0.025** | **n/a** | **0.5** | **0.1** | **50** | **4** | **0.5** | **n/a** | **0.4** | **120** | **2** | **n/a** | **n/a** | **10** | **n/a** | **1** | **n/a** | **120** | **n/a** | **10** | **120** | **2** | **120** | **n/a** |
| **Count Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 1.1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **TSP-3** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Average** | 0.127 | 0.0679 | 0.02734 | 0.0021 | 0.00289 | 0.023 | 0.00772 | 0.394 | 0.0738 | 0.01709 | 0.018 | 0.091 | 0.02931 | 0.036 | 0.005 | 0.01704 | 0.01767 | 0.13 | 0.369 | 0.01709 | 0.338 | 0.01023 | 0.2 | 0.00383 | 35 | 0.02733 | 0.014 | 0.017 | 0.0332 | 0.019 |
| **Count** | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 273 | 261 | 273 | 273 | 273 | 270 | 273 | 273 | 273 | 273 | 273 |
| **Minimum** | 0.014 | 0.00035 | 0.00035 | 0.0003 | 0.00035 | 0.021 | 0.00007 | 0.069 | 0.0208 | 0.00035 | 0 | 0.021 | 0.00035 | 0.021 | 0 | 0.00021 | 0.00035 | 0.056 | 0.035 | 0.00035 | 0.139 | 0.00014 | 0.069 | 0.00035 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0035 | 0.003 |
| **Maximum** | 2.778 | 0.13889 | 0.05556 | 0.0236 | 0.00556 | 0.218 | 0.17361 | 6.417 | 0.1583 | 0.03472 | 0.035 | 0.514 | 0.06903 | 0.553 | 0.07 | 0.03472 | 0.03472 | 0.208 | 1.006 | 0.03472 | 3.25 | 0.02083 | 1.472 | 0.175 | 69.4 | 0.05556 | 0.014 | 0.021 | 0.6472 | 0.035 |
| **Geometric Mean** | 0.078 | 0.00675 | 0.00444 | 0.0017 | 0.00135 | 0.022 | 0.00152 | 0.273 | 0.0707 | 0.00329 | 0.008 | 0.067 | 0.01071 | 0.027 | 0.004 | 0.00264 | 0.00664 | 0.106 | 0.168 | 0.00329 | 0.231 | 0.00165 | 0.177 | 0.0015 | 2.8 | 0.00446 | 0.014 | 0.017 | 0.0178 | 0.01 |
| **Count <DL** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Standard Deviation** | 0.277 | 0.06932 | 0.02756 | 0.0023 | 0.00261 | 0.019 | 0.01225 | 0.657 | 0.0212 | 0.01721 | 0.016 | 0.084 | 0.0263 | 0.055 | 0.006 | 0.01726 | 0.01665 | 0.076 | 0.325 | 0.01721 | 0.502 | 0.01035 | 0.117 | 0.01703 | 34.7 | 0.02757 | 0 | 0.004 | 0.0645 | 0.016 |
| **1st Quartile** | 0.043 | 0.00035 | 0.00035 | 0.0013 | 0.00035 | 0.021 | 0.00017 | 0.139 | 0.0597 | 0.00035 | 0.002 | 0.046 | 0.00207 | 0.021 | 0.002 | 0.00021 | 0.00135 | 0.056 | 0.035 | 0.00035 | 0.139 | 0.00014 | 0.167 | 0.00088 | 0.1 | 0.00035 | 0.014 | 0.014 | 0.0139 | 0.003 |
| **Median** | 0.139 | 0.00138 | 0.00294 | 0.0021 | 0.00035 | 0.021 | 0.00974 | 0.361 | 0.0743 | 0.00035 | 0.008 | 0.065 | 0.02569 | 0.021 | 0.006 | 0.00062 | 0.00299 | 0.056 | 0.3 | 0.00035 | 0.208 | 0.00051 | 0.208 | 0.00208 | 69.4 | 0.00185 | 0.014 | 0.014 | 0.0139 | 0.003 |
| **3rd Quartile** | 0.139 | 0.13889 | 0.05556 | 0.0021 | 0.00556 | 0.021 | 0.01389 | 0.458 | 0.0843 | 0.03472 | 0.035 | 0.096 | 0.05556 | 0.021 | 0.006 | 0.03472 | 0.03472 | 0.208 | 0.694 | 0.03472 | 0.208 | 0.02083 | 0.208 | 0.00208 | 69.4 | 0.05556 | 0.014 | 0.021 | 0.0262 | 0.035 |
| **Count Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **% Exceeding Standard** | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*"n/a" was used to signify when no Ontario Ambient Air Quality Criteria (µg/m³) exists for specific metals.*

Half the reportable detection limit (RDL) was used to calculate averages for samples that were below the RDL. As the samples were not normally distributed and variances were not equal, non-parametric tests (Kruskal-Wallis and Mann-Whitney) were used for statistical comparisons of the sample medians of 2022 data only and medians of data from all years (2012 – 2022) at a significance level (p) of 0.05 (Attachment B). The concentrations of total metals were significantly different ($p \ll 0.05$) between stations for aluminum, antimony, arsenic, copper, iron, lead, manganese, silver, and zinc in 2022. Slight differences ($0.01 < p < 0.05$) in metal concentrations were also detected between stations for cadmium and nickel. No detectable differences were found for all other analytes in 2022. Concentrations of total metals measured at TSP-1, TSP-2, and TSP-3 from 2012 to 2022 were significantly different ($p \ll 0.05$) for aluminum, antimony, arsenic, beryllium, cadmium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, phosphorous, potassium, selenium, silver, sodium, strontium, sulfur, tin, vanadium, zinc, and zirconium. Slight differences ($0.01 < p < 0.05$) in metal concentrations were also detected between stations for calcium. Dunn's pairwise post-hoc test was used to determine between which stations (TSP-1, TSP-2, or TSP-3) analytes significantly differed. Usually, concentrations of total metals were greater at TSP-1 (located closest to mining activity) and TSP-2 compared to TSP-3 (located furthest from mining activity). Slight differences ($0.01 < p < 0.05$) were detected for barium, magnesium, and sodium, and no detectable differences were seen for boron, chromium, and titanium.

Dust originating from the DSTF may contain arsenic, aluminum, calcium, iron, magnesium, manganese, lead, and zinc, based on metal characterization analyses of the tailings conducted from 2012 to 2013 and 2021 to 2022. From the wind direction distribution, TSP-2 is more frequently located downwind of the DSTF than TSP-1 and may be expected to record concentrations of the above metals. This was observed for historical maximum lead (August 2012) and manganese (March 2013) concentrations; however, the current average concentrations of these parameters remain below identified standards (Ontario AAQC).

Historically, days where TSP levels were higher than average and where exceedances of the Ontario AAQCs were observed (lead at TSP-1), winds were generally blowing from the northeast and from the east (October 23, 2012 and June 18, 2013 respectively). Site activities occurring in October 2012 and June 2013 included active mining at Bellekeno, development at Lucky Queen and Onek, milling at the District Mill, and explorations activities at Flame & Moth. Unpaved road may have been a contributing source of ambient dust on these occasions. Roads within the vicinity of the TSP stations include mine access roads, as well as public roads including Duncan Creek Road.

Historically, when metals concentrations exceeded the Ontario AAQCs (cadmium, lead, and manganese) at TSP-2, winds were generally blowing from the north-northeast (August 23, 2012). A source of ambient dust in this event could have been the unpaved roads. On days where TSP levels were higher than average and/or where exceedances of the Ontario AAQCs were observed for manganese at TSP-2, winds were generally blowing from the northeast (March 23-24, 2013; August 9, 2017) and from the east (April 7, 2013). On these occasions, the DSTF could have been a source of TSP at TSP-2. Similarly, on days where exceedances of the Ontario AAQCs were observed for cadmium at TSP-2 (on September 28, 2013 and October 21, 2015 respectively), winds were generally from the northeast or north-northeast suggesting a possible influence of the DSTF but also eventually of the unpaved roads. Site activities occurring in August 2012, March 2013 and April 2013 included mining at Bellekeno, development at Lucky Queen and Onek, and milling at the District Mill. Between September 2013 and December 2018, only care and maintenance activities were taking place as the mine and mill were under a temporary suspension of operations with exception of collaring Flame & Moth Portal in 2016 and the preparation of the Flame & Moth Pond. Operations of the District Mill were suspended between September 2013 and December 2020 and again in June 2022 to date.

### 3.2.3 Wind Analysis

Hourly wind speed and direction was recorded between November 2011 and May 2022, at the District Mill weather station. The wind rose plot shown in Section 3.1.2 depicts this information based on 36 wind direction categories. The average wind speed is 1.21 m/s and winds are calm 23.7% of the time. Note that the wind sensor experienced occasional icing during the winter months and extended periods of zero wind speed were excluded from this analysis. Also, winter wind speeds may occasionally be underestimated due to the presence of ice on the sensor, but these occurrences cannot be detected in the data record. Wind speed and direction frequency distribution are compiled in Table 3-16 below, and are based on eight wind direction categories, and six wind speed categories.

**Table 3-16: Wind Frequency Distribution District Mill, June 2011 – May 2022**

| Directions / Wind Classes (m/s) | 0.50 - 2.10 | 2.10 - 3.60 | 3.60 - 5.70 | 5.70 - 8.80 | 8.80 - 11.10 | >= 11.10 | Total (%) |
|---|---|---|---|---|---|---|---|
| N | 12.34 | 3.21 | 0.26 | 0.01 | 0.00 | 0.00 | 15.82 |
| NE | 10.33 | 1.29 | 0.03 | 0.00 | 0.00 | 0.00 | 11.64 |
| E | 11.43 | 1.85 | 0.19 | 0.00 | 0.00 | 0.00 | 13.46 |
| SE | 9.43 | 3.19 | 1.15 | 0.12 | 0.00 | 0.00 | 13.89 |
| S | 8.79 | 2.30 | 0.17 | 0.02 | 0.00 | 0.00 | 11.29 |
| SW | 2.40 | 1.38 | 0.15 | 0.00 | 0.00 | 0.00 | 3.94 |
| W | 0.92 | 0.59 | 0.27 | 0.02 | 0.00 | 0.00 | 1.80 |
| NW | 2.17 | 1.64 | 0.64 | 0.04 | 0.00 | 0.00 | 4.49 |
| Sub-Total | 57.81 | 15.45 | 2.84 | 0.22 | 0.01 | 0.00 | 76.32 |
| | | | | | **Calm** | | 23.67 |
| | | | | | **Total** | | 100 |

The dominant wind direction is from the north (approximately 16% of the time), followed by the southeast (approximately 14%). When the predominant wind direction is from the northeast or southeast, air quality station TSP-2 is located downwind of the DSTF and the crusher. Given these generalities TSP-2 may capture influences from facilities when predominant winds are a blowing from the SE and NE. TSP-1 station is adjacent to the dominant winds and likely will only capture influences when the wind is blowing from the southwest or west directions. Air quality station TSP-3, located on the north side of Keno City, is east of these potential dust sources. Based on

Table 3-16, westerly winds only occur about 2% of the time (or roughly 10% of the time when combining northwest, west, and southwest), so the DSTF and crusher are expected to have very limited influence on air quality in Keno City (TSP-3).

### 3.2.4 $PM_{10}$ SAMPLING BY YUKON GOVERNMENT

Independent $PM_{10}$ sampling was conducted by Yukon Government in 2013 at the locations shown in Figure 3-13. The station labelled BG represents background (8 km outside of Keno), stations labelled KC are in Keno City, stations labelled HR are along the Bellekeno Haul Road and stations labelled FL are fence line stations and correspond to TSP-1 (prior to the relocation of this station to the ball diamond) and TSP-2 locations. 5-minute data averaged over the different sampling periods are presented in Table 3-17 below. The sampling period varies between sites (ranges from about 14 to 53 hours) but for comparison purposes, the average results are all below the 24-hour YAAQS of 50 µg/m$^3$. Note that in some cases the measured background $PM_{10}$ concentration is higher than that measured at some of the receptors, for example during the July 15-17 sampling event site HR1 measured coarse particulate matter at 5.2 µg/m$^3$ and the background at 10.2 µg/m$^3$. This suggests there is some variability in the data and that the difference between background and receptors sites may not be significant. Results are generally comparable to the $PM_{10}$ concentrations measured by AKHM at stations TSP-1, TSP-2, and TSP-3 (August 2015 to December 2017).

**Table 3-17: Average Coarse Particulate Matter ($PM_{10}$) concentrations**

| | $PM_{10}$ (µg/m$^3$) | | |
|---|---|---|---|
| Site Locations | June 11-13, 2013 | July 15-17, 2013 | August 21-22, 2013 |
| BG | 2.8 | 10.2 | 3.8 |
| KC1 | 6.2 | NS | NS |
| KC2 | 3.8 | NS | NS |
| KC3 | 8.3 | NS | NS |
| KC4 | 2.1 | NS | NS |
| HR1 | NS | 5.2 | NS |
| HR2 | NS | 2.1 | NS |
| HR3 | NS | 13.8 | NS |
| HR4 | NS | 16.4 | NS |
| FL1 | NS | NS | 0.8 |
| FL2 | NS | NS | 39.3 |

*Source: Yukon Government, 2014*
*NS: Not Sampled*

## 3.3 NOISE MONITORING

AKHM has monitored noise at the five locations selected in the Noise Impact Assessment (NIA; PAAE, 2014) as being potential noise receptors within a 2 km radius study area around Keno City. Since November 2013, noise has also been monitored at a sixth location, the Keno City Campground. These monitoring locations are listed in Table 3-18 and shown in Figure 3-14.

**Table 3-18: Representative Locations Assessed in Keno City**

| Monitoring Location | GPS Location | Description |
|---|---|---|
| R01 | N63.90827 W135.29599 | East end Residence, north side of Lightning Creek Road |
| R02 | N63.91019 W135.29968 | Residence, east side of Sign Post Road |
| R03 | N63.91023 W135.30205 | Town Center, north from the Snack Bar |
| R04 | N63.91239 W135.30376 | Residence, west side of Wernecke Road |
| R05 | N63.90851 W135.30993 | Residence, about 850 m east from the Mill |
| Campground | N63.90772 W135.29998 | Keno City campground |

The background noise levels at each monitoring location vary considerably and depend on climate parameters like relative humidity, temperature, and temperature inversions. These parameters influence how the receptors interpret sound level and propagation. For example, sound travels faster through hot air since hot air is less dense, resulting in different noise readings compared to a station situated in a cooler area. Humidity has a similar effect on noise. Dry air absorbs far more acoustical energy compared to moist air. Therefore, noise is expected to travel more efficiently in summer months when the ambient air is warmer and drier.


Satelite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on February 2020

Datum: NAD 83; Projection: UTM Zone 8N

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1:6,000 *(when printed on 11 x17 inch paper)*

0 50 100 150 200 250 Meters

Noise Monitoring Station

Adit

Current DSTF

Pond

Mine Feature Footprint

Watercourse

Silver Trail Highway

Secondary Road

Hecla KENO HILL

ENSERO solutions

HECLA KENO HILL

FIGURE 3-14

NOISE MONITORING STATIONS

FEBRUARY 2023

D:\Project\AllProjects\Keno_Area_Mines\ALL-SITES\02-Map\04-Studies\Air_Noise_Dust\Air_Quality_NOise_Mill_20190328.mxd
*(Last edited by: amatlashevska;2020-02-21/13:32 PM)*

### 3.3.1 MONITORING EQUIPMENT

The noise monitoring profiles collected between April 2013 and November 2014 were measured using an Extech Integrating Sound Level Datalogger (Model 407780) to capture average decibels A (dBA) over a single ten-minute period. Starting in December 2014, noise monitoring readings were collected with a Casella CEL-63X Sound Level Meter and a Casella CEL-495 Microphone. In 2022, a Larson Davis Soundtrack LxT device replaced the broken Casella CEL-63X device. Both the Casella and Larson Davis devises utilize a microphone mounted on a tripod at approximately 1.5 meters above ground and fitted with a windscreen to reduce wind impacts. During periods of extended low temperatures (i.e., below -30 C), when the noise monitoring equipment is operating outside of manufacture recommended temperatures, the data collection may be limited.

Wind speed, wind direction, temperature, and precipitation from the District Mill meteorological station are summarised alongside each noise monitoring event because weather can influence measured noise levels. Any noise sources associated with the monitoring event were also documented where possible.

Additional details on sampling events that occurred each year since noise monitoring began are outlined below.

- In 2015, 24-hr period data were collected in January, as well as August through November. Equipment issues prevented the collection of 24-hr period data for the remainder of the year.
- In 2016, 24-hr period data were collected every month; however, not all stations could be monitored every month due to battery or other equipment issues, or the temperature being below operating conditions for the equipment.
- In 2017, a combination of equipment malfunction, equipment vandalism, and very cold temperatures only allowed for 24-hr period noise data collection in June, July, and November.
- In 2018, similar issues were encountered early in the year, samples were collected from March to December 2018.
- In 2019, 57 successful recording were captured from January to December 2019. Some recordings were missed due to battery issues, cold temperatures, and technical difficulties.
- In 2020, 38 recordings were captured from January to December 2020. 24-hr period data were collected every month except for September, October, and November; however, not all stations could be monitored every month due to battery issues, or the temperature being below operating conditions for the equipment.
- In 2021, a Larson Davis Soundtrack LxT device was purchased to replace the broken Casella CEL-63X device. Monitoring resumed in October 2021. Factory calibration of the Larson Davis sound meter was relied on in 2021 due to supply chain issues associated with acquiring the calibration device.
- In 2022, 66 successful recordings were captured from January to September. The device malfunctioned in July, however, the malfunction was not noticed until late fall when it was taken out of service, thus leaving a data gap from July 15, 2022 to December 31, 2022. The Larson Davis sound meter was calibrated in 2022.

### 3.3.2 RESULT

Table 3-19 presents all 24-hr period noise data available from 2014 through 2022 (all data runs with <24-hr have been excluded), and associated meteorological parameters obtained from the District Mill meteorological station (averaged from hourly data for the corresponding 24-hr period). Since noise monitoring began, the LAeq has exceeded the LAF 10 approximately 34% of the time, indicating that the majority of noise measured on site to date can be attributed to general background noise.

The difference between the LAeq and the LAF 90 (the sound level exceeded for 90% of the measurement period – quieter sounds) also indicates if the LAeq has been influenced by short term noise events. If the difference between LAeq and the LAF 90 is greater than 10 dB, then the LAeq is influenced by short-term noise events. However, if the difference between LAeq and the LAF 90 is less than 5 dB, then the LAeq indicates a uniform background level of noise. In 2022, there were no monitoring events where the difference between LAeq and the LAF 90 was greater than 10 dB. From 2014 through 2022, the difference between the LAeq and the LAF 90 was greater than 10 dB 33% of the time, indicating that the LAeq is generally influenced by short-term noise events.

All 24-hr noise recording results from 2014 to 2022 are presented in Figure 3-15 with the NIA values that were calculated in 2014 by PAAE. PAAE estimated that the Predicted Sound Levels with both ambient and day-time activities associated with the mine would be from 32 dBA at R03 to a maximum of 39 dBA at R01. PAAE also predicted an increase above current sound levels associated with the activity changes in Flame & Moth to be a maximum of 2 dB at R04 for both daytime and nighttime conditions. NIA is presented in all the following figures as a minimum of 32 dBA and a maximum of 39 dBA. Throughout 2022 there were no recordings that exceeded the maximum predicted levels from the NIA (39 dB), while all measurements were below the minimum predicted levels from the NIA (32 dB). From 2014 through 2022, approximately 32% of measurements have exceeded the maximum predicted level (39 dB).

**Table 3-19: 24-hr Noise Data and Corresponding Meteorological Data, 2014 to 2022**

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R01 | 2014-12-14 | 43.1 | N/A | N/A | | | 72.7 | 45.3 | 92.4 | 59.4 | 16.4 | -4.8 | -4.4 | 92.6 | n/a |
| R02 | 2014-12-15 | 44.3 | N/A | N/A | | | 77.1 | 49.6 | 93.7 | 64.3 | 20.0 | -4.8 | -1.9 | 76.4 | 1.35 |
| R03 | 2014-12-17 | 58.6 | N/A | N/A | | | 59.4 | 62.0 | 108.0 | 59.2 | 0.6 | -4.8 | -8.4 | 94.4 | 0.7 |
| R05 | 2014-12-18 | 42.0 | N/A | N/A | | | 50.6 | 45.2 | 91.3 | 48.5 | 6.6 | -4.8 | -13.6 | 90.7 | 0.6 |
| Campground | 2014-12-22 | 25.4 | N/A | N/A | | | 43.5 | 27.4 | 74.8 | 38.0 | 12.6 | -4.8 | -9.6 | 93.8 | n/a |
| R01 | 2015-01-10 | 28.8 | N/A | N/A | | | 38.2 | 33.4 | 78.2 | 35.6 | 6.8 | -4.8 | -10.2 | 93.7 | n/a |
| R02 | 2015-01-11 | 33.8 | N/A | N/A | | | 43.8 | 36.0 | 83.2 | 40.3 | 6.5 | -4.8 | -10.1 | 93.3 | n/a |
| R03 | 2015-01-13 | 28.6 | N/A | N/A | | | 40.7 | 31.6 | 78.0 | 37.9 | 9.3 | ---.- | -7.3 | 95.3 | n/a |
| R04 | 2015-01-14 | 36.5 | N/A | N/A | | | 51.4 | 41.8 | 85.9 | 47.6 | 11.1 | -4.8 | -9.4 | 93.9 | n/a |
| R05 | 2015-01-15 | 37.5 | N/A | N/A | | | 47.8 | 42.1 | 86.9 | 41.1 | 3.6 | -4.8 | -1.8 | 99.0 | 0.52 |
| Campground | 2015-01-22 | 23.2 | N/A | N/A | | | 28.0 | 23.4 | 72.6 | 22.5 | -0.7 | ---.- | -9.8 | 93.6 | 0.47 |
| R05 | 2015-11-14 | 32.8 | 17.0 | 15.0 | Yes | 17.8 | 42.4 | 33.6 | 82.2 | 39.2 | 6.4 | 0.3 | -18.4 | 86.5 | n/a |
| R01 | 2015-11-16 | 34.7 | 19.5 | 16.0 | Yes | 18.7 | 51.2 | 37.0 | 84.0 | 49.2 | 14.5 | 0.3 | -17.4 | 87.3 | n/a |
| R04 | 2015-11-17 | 21.3 | 18.0 | 15.5 | Yes | 5.8 | 46.4 | 27.3 | 70.6 | 36.3 | 15.0 | 0.3 | -21.0 | 83.9 | n/a |
| R02 | 2015-11-19 | 33.1 | 16.0 | 15.5 | Yes | 17.6 | 46.9 | 40.3 | 82.4 | 44.2 | 11.1 | 0.3 | -28.4 | 76.7 | n/a |
| R03 | 2015-11-21 | 39.7 | 17.5 | 16.0 | Yes | 23.7 | 47.8 | 46.0 | 89.0 | 46.3 | 6.6 | 0.3 | -9.0 | 94.0 | n/a |
| Campground | 2016-01-07 | 23.2 | 20.0 | 15.5 | Yes | 7.7 | 38.1 | 30.2 | 72.5 | 75.8 | 7.8 | 0.1 | -16.1 | 81.8 | 0.63 |
| R03 | 2016-01-08 | 28.3 | 19.5 | 16.5 | Yes | 11.8 | 40.0 | 35.9 | 77.7 | 74.6 | 4.5 | -0.2 | -11.5 | 90.4 | 0.44 |
| R01 | 2016-01-09 | 39.0 | 20.0 | 15.5 | Yes | 23.5 | 48.9 | 41.7 | 88.4 | 79.3 | 6.4 | -0.2 | -14.6 | 89.7 | 0.51 |
| R05 | 2016-01-10 | 30.6 | 20.5 | 15.5 | Yes | 15.1 | 44.1 | 35.5 | 80.0 | 71.6 | 5.7 | -0.2 | -18.2 | 86.5 | 0.33 |
| R04 | 2016-02-15 | 25.5 | 19.0 | 15.5 | Yes | 10 | 48.5 | 33.9 | 74.9 | 68.1 | 6.3 | 0.3 | -7.8 | 89.0 | 1.12 |
| R03 | 2016-02-17 | 23.9 | 19.0 | 15.0 | Yes | 8.9 | 40.3 | 30.2 | 73.3 | 66.8 | 11.6 | -2.1 | -22.9 | 77.9 | 0.45 |
| Ball Diamond | 2016-02-25 | ---.- | 18.5 | 15.5 | Yes | | 43.7 | 24.4 | 69.3 | 56.2 | 9.2 | -0.2 | -5.5 | 81.4 | 1.27 |
| Campground | 2016-02-26 | 21.4 | 21.5 | 16.0 | No | 5.4 | 43.9 | 26.0 | 68.9 | 57.0 | 9.3 | 0.2 | | | |
| R01 | 2016-02-28 | 22.4 | 20.5 | 16.5 | Yes | 5.9 | 55.1 | 26.1 | 71.8 | 65.0 | 15.6 | -0.5 | -2.8 | 85.0 | 0.92 |
| R04 | 2016-03-12 | 37.5 | 25.0 | 15.5 | Yes | 22 | 56.9 | 44.4 | 86.8 | 82.0 | 3.8 | 0.4 | -5.3 | 62.8 | 1.03 |
| R05 | 2016-03-15 | 26.1 | 22.0 | 17.0 | Yes | 9.1 | 56.1 | 32.5 | 75.5 | 65.4 | 13.8 | -0.1 | -6.2 | 91.4 | 0.86 |
| R03 | 2016-03-17 | 111.8 | 115.5 | 45.5 | No | 66.3 | 127.7 | 120.4 | 161.2 | 136.7 | 7.8 | -0.1 | -4.9 | 70.9 | 1.09 |
| Campground | 2016-03-18 | 27.7 | 30.5 | 18.5 | No | 9.2 | 57.5 | 31.3 | 77.1 | 63.7 | 12.9 | -0.1 | -7.8 | 72.8 | 1.89 |
| R05 | 2016-04-15 | 31.9 | 30.0 | 18.0 | Yes | 13.9 | 54.3 | 34.4 | 81.2 | 67.1 | 9.1 | -0.1 | 3.2 | 63.6 | 1.51 |
| R03 | 2016-04-16 | 41.0 | 34.5 | 17.0 | Yes | 24 | 60.8 | 43.7 | 90.4 | 75.3 | 12.1 | ---- | 3.7 | 57.2 | 1.56 |
| R04 | 2016-04-18 | 28.0 | 27.0 | 17.0 | Yes | 11 | 56.3 | 36.1 | 77.4 | 72.0 | 11.9 | -0.1 | 0.5 | 64.2 | 1.73 |
| R02 | 2016-04-23 | 29.1 | 28.5 | 16.5 | Yes | 12.6 | 65.9 | 38.0 | 78.5 | 66.9 | 20.1 | 0.1 | 7.3 | 59.3 | 1.44 |
| Campground | 2016-04-24 | 35.2 | 34.5 | 27.5 | Yes | 7.7 | 52.4 | 36.9 | 84.5 | 67.9 | 14.3 | -0.1 | 7.6 | 59.9 | 1.28 |
| R01 | 2016-04-25 | 39.1 | 39.5 | 36.5 | No | 2.6 | 55.1 | 39.5 | 88.4 | 73.4 | 13.5 | -0.1 | 5.7 | 57.5 | 1.78 |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAleq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R01 | 2016-05-15 | 49.3 | 50.5 | 48.0 | No | 1.3 | 57.5 | 49.7 | 98.7 | 66.3 | 3.3 | -0.1 | 12.2 | 47.4 | 2.3 |
| R02 | 2016-05-16 | 44.4 | 42.5 | 24.5 | Yes | 19.9 | 64.9 | 56.9 | 93.8 | 84.1 | 10.7 | ---- | 5.9 | 71.5 | 3.12 |
| R03 | 2016-05-18 | 38.7 | 38.5 | 24.5 | Yes | 14.2 | 60.2 | 40.4 | 88.1 | 76.9 | 13.6 | 0.1 | 7.5 | 66.6 | 1.88 |
| R04 | 2016-05-19 | 39.2 | 34.0 | 21.5 | Yes | 17.7 | 59.5 | 46.8 | 88.6 | 81.0 | 6.3 | -0.2 | 10.3 | 56.7 | 1.57 |
| Campground | 2016-05-21 | 47.1 | 48.5 | 44.5 | No | 2.6 | 56.8 | 47.8 | 96.4 | 79.2 | 7.7 | ---- | 16.6 | 39.4 | 1.47 |
| R05 | 2016-05-22 | 41.0 | 44.0 | 30.5 | No | 10.5 | 52.8 | 42.8 | 90.4 | 69.9 | 10.3 | -0.2 | 9.9 | 66.2 | 1.72 |
| R01 | 2016-06-13 | 50.9 | 51.0 | 50.0 | No | 0.9 | 53.8 | 54.5 | 100.2 | 85.4 | 2.5 | ---- | 11.1 | 78.0 | 1.63 |
| R05 | 2016-06-19 | 39.7 | 42.5 | 31.5 | No | 8.2 | 53.0 | 41.6 | 89.1 | 70.4 | 7.5 | 0.1 | 19.6 | 26.9 | 2.28 |
| R04 | 2016-06-20 | 38.5 | 34.0 | 21.0 | Yes | 17.5 | 55.6 | 48.8 | 87.9 | 82.7 | 10.0 | 0.1 | 10.3 | 79.6 | 1.47 |
| R03 | 2016-06-29 | 48.0 | 44.0 | 22.5 | Yes | 25.5 | 61.0 | 53.6 | 97.3 | 91.1 | 10.8 | -0.2 | 15.5 | 67.8 | 1.35 |
| Campground | 2016-06-30 | 51.1 | 51.0 | 15.5 | Yes | 35.6 | 57.0 | 60.1 | 100.5 | 95.4 | 5.0 | 0.1 | 12.7 | 83.3 | 0.69 |
| R05 | 2016-07-17 | 40.5 | 42.0 | 30.5 | No | 10 | 52.9 | 43.3 | 89.9 | 75.8 | 8.9 | ---- | 14.8 | 64.6 | 2.5 |
| Campground | 2016-07-18 | 48.3 | 46.5 | 44.5 | Yes | 3.8 | 54.1 | 56.6 | 97.6 | 90.1 | 4.7 | -0.1 | 11.2 | 82.5 | 1.61 |
| R03 | 2016-07-30 | 40.3 | 38.5 | 27.0 | Yes | 13.3 | 61.1 | 46.4 | 89.7 | 84.8 | 14.0 | ---- | 13.7 | 69.0 | 2 |
| R01 | 2016-07-31 | 91.0 | 92.5 | 61.5 | No | 29.5 | 105.5 | 97.9 | 140.3 | 128.2 | 5.4 | 0.2 | 12.5 | 65.7 | 1.93 |
| Campground | 2016-09-21 | 44.3 | 46.0 | 40.5 | No | 3.8 | 59.3 | 47.9 | 93.7 | 77.5 | 5.1 | ---- | 10.1 | 36.8 | 2.63 |
| R01 | 2016-09-22 | 46.5 | 47.0 | 45.0 | No | 1.5 | 64.8 | 46.9 | 95.8 | 72.8 | 5.2 | 0.1 | 7.2 | 56.4 | 2.47 |
| R04 | 2016-09-23 | 33.9 | 33.5 | 23.5 | Yes | 10.4 | 57.2 | 38.1 | 83.3 | 72.0 | 13.8 | -0.1 | 4.1 | 59.1 | 1.85 |
| R05 | 2016-09-24 | 77.2 | 73.5 | 39.5 | Yes | 37.7 | 89.3 | 89.8 | 126.6 | 122.1 | 4.5 | 0.2 | 0.9 | 94.4 | 0.88 |
| Campground | 2016-11-09 | 34.2 | 34.0 | 32.5 | Yes | 1.7 | 56.4 | 39.5 | 69.2 | 68.0 | 6.3 | 0.1 | | | |
| R05 | 2016-11-10 | 45.6 | 48.5 | 31.0 | No | 14.6 | 72.7 | 53.3 | 94.7 | 85.5 | 13.4 | ---- | | | |
| R01 | 2016-11-11 | 40.4 | 40.5 | 37.5 | No | 2.9 | 53.6 | 42.4 | 89.8 | 83.4 | 7.1 | ---- | 1.3 | 69.8 | 1.9 |
| R05 | 2018-06-14 | 42.4 | | | | | 38.6 | 28.9 | 71.5 | 37.4 | 11.4 | -5.7 | 10.4 | 53.0 | 1.74 |
| R02 | 2018-06-19 | 26.8 | | | | | 40.9 | 26.9 | 69.2 | 34.7 | 10.5 | -5.7 | 17.4 | 45.1 | 2.11 |
| R05 | 2018-06-21 | 34.5 | | | | | 50.6 | 51.3 | 84.0 | 49.4 | 10.1 | -5.7 | 16.9 | 55.8 | 1.47 |
| R01 | 2018-06-26 | 39.2 | | | | | 51.3 | 38.0 | 79.5 | 50.0 | 15.5 | 0.0 | 11.3 | 71.8 | 1.38 |
| R05 | 2018-07-19 | 24.2 | | | | | 43.4 | 31.4 | 72.1 | 40.6 | 13.8 | -3.1 | 11.6 | 64.2 | 1.3 |
| Campground | 2018-07-24 | 26.0 | | | | | 73.5 | 49.0 | 85.9 | 66.1 | 23.7 | 0.1 | 17.3 | 52.9 | 1.17 |
| R04 | 2018-08-29 | 37.1 | 32.5 | 23.5 | Yes | 13.6 | 62.3 | 41.1 | 86.4 | 50.5 | 13.4 | 0.1 | 8.3 | 75.5 | 1.4 |
| R01 | 2018-08-30 | 53.1 | 53.5 | 52.5 | No | 0.6 | 57.4 | 54.6 | 102.4 | 55.9 | 12.8 | -0.1 | 6.7 | 74.7 | 1.46 |
| R03 | 2018-08-31 | 47.4 | 46.0 | 29.5 | Yes | 17.9 | 65.9 | 55.2 | 96.8 | 60.0 | 12.6 | -0.1 | 4.1 | 90.7 | 0.98 |
| Campground | 2018-09-05 | 48.4 | 47.5 | 47.0 | No | 1.4 | 56.8 | 53.3 | 97.8 | 54.2 | 5.8 | -0.1 | 7.1 | 73.0 | 1.37 |
| R03 | 2018-09-06 | 42.2 | 42.0 | 25.5 | Yes | 16.7 | 65.5 | 52.2 | 94.5 | 56.6 | 11.4 | 0.0 | 5.0 | 89.4 | 0.6 |
| R01 | 2018-09-07 | 46.8 | 47.0 | 45.0 | No | 1.8 | 62.7 | 47.6 | 96.2 | 55.1 | 8.3 | 0.0 | 4.7 | 85.5 | 1.07 |
| R02 | 2018-09-09 | 31.0 | 30.5 | 20.5 | Yes | 10.5 | 59.1 | 36.3 | 80.4 | 49.2 | 18.2 | -0.1 | 4.7 | 65.2 | 2.25 |
| R05 | 2018-09-10 | 35.7 | 36.5 | 24.5 | Yes | 11.2 | 63.1 | 38.5 | 85.1 | 50.0 | 14.3 | 0.2 | 5.6 | 57.2 | 1.2 |
| R03 | 2018-10-07 | 45.9 | 40.5 | 21.0 | Yes | 24.9 | 64.7 | 53.1 | 95.3 | 63.3 | 17.4 | -0.2 | -3.5 | 53.8 | 2.26 |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Campground | 2018-10-08 | 127.8 | 129.5 | 124.0 | No | 3.8 | 131.1 | 128.5 | 177.1 | 129.3 | 1.5 | 0.3 | -7.2 | 65.2 | 1.29 |
| Campground | 2019-01-25 | 22.5 | 22.0 | 17.0 | Yes | 5.5 | 44.6 | 28.0 | 71.9 | 37.9 | 15.4 | -0.3 | -10.1 | 92.8 | 0.00 |
| Campground | 2019-02-23 | 20.5 | 19.0 | 17.0 | Yes | 3.5 | 37.2 | 23.7 | 69.8 | 31.1 | 10.6 | 0.1 | -21.5 | 77.9 | 0.95 |
| Campground | 2019-05-10 | 48.5 | 44.5 | 42.0 | Yes | 6.5 | 63.9 | 58.8 | 97.8 | 53.7 | 5.2 | 0.0 | 9.7 | 34.5 | 2.51 |
| Campground | 2019-07-11 | 53.5 | 40.0 | 37.0 | Yes | 16.5 | 67.9 | 62.3 | 102.9 | 65.9 | 12.4 | -0.1 | 13.6 | 77.2 | 1.23 |
| Campground | 2019-10-31 | 34.4 | 35.0 | 32.5 | No | 1.9 | 42.2 | 36.9 | 83.8 | 38.4 | 4.0 | -0.4 | -4.6 | 95.9 | 0.93 |
| Campground | 2019-11-14 | 21.0 | 23.0 | 17.0 | No | 4.0 | 41.8 | 24.8 | 70.4 | 32.6 | 11.6 | 0.2 | -17.3 | 84.4 | 0.90 |
| R01 | 2019-01-29 | 40.6 | 41.0 | 40.0 | No | 0.6 | 50.1 | 40.8 | 84.2 | 39.6 | -1.0 | -0.2 | -16.4 | 87.8 | 0.41 |
| R01 | 2019-02-24 | 43.2 | 43.5 | 42.0 | No | 1.2 | 51.5 | 43.2 | 92.5 | 41.5 | -1.7 | 0.1 | -18.4 | 77.8 | 0.75 |
| R01 | 2019-04-25 | 41.8 | 40.5 | 18.5 | Yes | 23.3 | 59.6 | 43.6 | 91.1 | 58.6 | 16.8 | 0.2 | -3.4 | 63.4 | 1.63 |
| R01 | 2019-05-01 | 34.8 | 38.0 | 21.0 | No | 13.8 | 55.9 | 38.8 | 84.2 | 48.1 | 13.3 | 0.1 | 5.2 | 33.9 | 2.95 |
| R01 | 2019-07-16 | 37.7 | 38.5 | 26.5 | No | 11.2 | 52.6 | 39.8 | 87.0 | 50.3 | 12.6 | -0.1 | 14.8 | 64.7 | 1.54 |
| R01 | 2019-09-24 | 38.3 | 39.0 | 26.5 | No | 11.8 | 50.5 | 39.7 | 87.7 | 49.4 | 11.1 | -0.1 | 2.3 | 71.9 | 1.30 |
| R01 | 2019-10-23 | 49.8 | 40.0 | 39.0 | Yes | 10.8 | 53.9 | 51.1 | 99.1 | 51.1 | 1.3 | -0.1 | -5.5 | 91.5 | 1.02 |
| R02 | 2019-08-28 | 45.5 | 44.0 | 43.0 | Yes | 2.5 | 60.3 | 47.2 | 91.1 | 52.9 | 7.4 | 0.0 | 8.4 | 61.0 | 1.56 |
| R02 | 2019-09-27 | 45.8 | 45.5 | 44.5 | Yes | 1.3 | 61.1 | 46.7 | 84.8 | 51.0 | 5.2 | 0.4 | -1.2 | 64.2 | 1.42 |
| R03 | 2019-03-05 | 41.3 | 44.0 | 17.5 | No | 23.8 | 52.2 | 42.2 | 89.0 | 45.0 | 3.7 | -0.9 | -16.2 | 65.0 | 0.92 |
| R03 | 2019-03-07 | 37.5 | 41.5 | 17.0 | No | 20.5 | 53.1 | 38.6 | 75.1 | 44.6 | 7.1 | -0.9 | -14.9 | 57.5 | 0.92 |
| R03 | 2019-02-22 | 40.3 | 31.0 | 17.5 | Yes | 22.8 | 55.6 | 41.6 | 82.2 | 53.7 | 13.4 | -0.4 | -19.3 | 73.1 | 1.33 |
| R03 | 2019-03-07 | 28.3 | 21.0 | 17.0 | Yes | 11.3 | 48.8 | 30.4 | 70.6 | 45.4 | 17.1 | 0.2 | -14.7 | 61.6 | 1.20 |
| R03 | 2019-04-20 | 45.1 | 39.5 | 21.5 | Yes | 23.6 | 65.3 | 48.4 | 94.5 | 58.8 | 13.7 | -0.1 | 0.4 | 56.1 | 1.84 |
| R03 | 2019-05-23 | 56.4 | 45.5 | 27.0 | Yes | 29.4 | 83.2 | 68.8 | 105.7 | 74.6 | 18.2 | 0.0 | 14.0 | 44.2 | 1.57 |
| R03 | 2019-08-27 | 39.1 | 39.0 | 23.5 | Yes | 15.6 | 60.7 | 42.6 | 84.8 | 53.6 | 14.5 | -0.1 | 8.1 | 61.7 | 1.89 |
| R03 | 2019-09-19 | 43.4 | 45.5 | 24.5 | No | 18.9 | 67.9 | 51.8 | 92.7 | 62.4 | 19.0 | 0.1 | 5.4 | 93.5 | 1.03 |
| R03 | 2019-10-25 | 24.3 | 22.5 | 19.0 | Yes | 5.3 | 42.6 | 32.6 | 71.8 | 38.9 | 14.6 | 0.1 | -5.0 | 91.2 | 0.98 |
| R03 | 2019-11-20 | 40.6 | 23.5 | 17.5 | Yes | 23.1 | 47.3 | 43.6 | 89.9 | 44.3 | 3.7 | 0.1 | -6.0 | 95.5 | 0.80 |
| R03 | 2019-12-17 | 42.4 | 45.0 | 17.5 | No | 24.9 | 50.6 | 42.4 | 91.7 | 42.2 | -0.2 | -0.3 | -21.4 | 83.3 | 0.21 |
| R04 | 2019-01-31 | 39.4 | 40.0 | 39.0 | No | 0.4 | 50.0 | 39.5 | 76.4 | 39.9 | 0.5 | 1.0 | -14.2 | 86.1 | 1.62 |
| R04 | 2019-02-26 | 31.4 | 21.0 | 17.5 | Yes | 13.9 | 41.6 | 34.7 | 80.7 | 38.5 | 7.1 | -0.2 | -14.4 | 78.2 | 0.60 |
| R04 | 2019-04-16 | 27.0 | 30.0 | 20.5 | No | 6.5 | 52.3 | 31.3 | 63.3 | 44.7 | 17.7 | 0.1 | 0.0 | 69.5 | 1.11 |
| R04 | 2019-04-19 | 39.2 | 35.5 | 21.5 | Yes | 17.7 | 61.8 | 42.6 | 88.5 | 55.7 | 16.5 | -0.4 | 2.2 | 60.1 | 2.27 |
| R04 | 2019-05-09 | 33.6 | 34.0 | 20.5 | No | 13.1 | 67.4 | 35.7 | 82.9 | 52.5 | 18.9 | 0.1 | 8.4 | 50.1 | 2.35 |
| R04 | 2019-06-26 | 38.3 | 33.5 | 21.5 | Yes | 16.8 | 58.1 | 42.9 | 87.6 | 46.4 | 8.1 | 0.2 | 15.2 | 49.4 | 1.96 |
| R04 | 2019-07-04 | 39.4 | 32.5 | 20.5 | Yes | 18.9 | 53.9 | 47.1 | 88.7 | 43.0 | 3.6 | 0.1 | 15.7 | 67.6 | 1.42 |
| R04 | 2019-08-23 | 39.2 | 33.0 | 22.5 | Yes | 16.7 | 55.0 | 43.0 | 83.5 | 46.4 | 7.2 | 0.1 | 8.5 | 61.0 | 1.22 |
| R04 | 2019-09-18 | 59.8 | 58.5 | 22.5 | Yes | 37.3 | 69.7 | 72.4 | 109.1 | 63.1 | 3.3 | -0.3 | 5.1 | 86.0 | 1.53 |
| R04 | 2019-10-17 | 29.6 | 28.5 | 20.5 | Yes | 9.1 | 46.8 | 35.4 | 79.0 | 40.4 | 10.8 | -0.3 | -3.2 | 88.3 | 0.77 |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R04 | 2019-11-15 | 43.4 | 45.0 | 18.5 | No | 24.9 | 50.9 | 44.5 | 92.8 | 42.5 | -0.9 | 0.1 | -21.2 | 80.8 | 0.69 |
| R04 | 2019-12-13 | 64.5 | 66.0 | 59.0 | No | 5.5 | 67.0 | 71.5 | 85.3 | 66.0 | 1.5 | 0.3 | -11.1 | 89.6 | 0.35 |
| R05 | 2019-01-23 | 19.8 | 19.5 | 17.0 | Yes | 2.8 | 37.7 | 22.9 | 69.2 | 29.1 | 9.3 | -0.2 | -23.9 | 80.8 | 0.00 |
| R05 | 2019-02-21 | 24.3 | 27.0 | 17.0 | No | 7.3 | 47.4 | 26.0 | 73.1 | 32.6 | 8.3 | -0.4 | -16.9 | 82.0 | 1.66 |
| R05 | 2019-04-15 | 115.0 | 117.5 | 110.0 | No | 5.0 | 124.2 | 117.6 | 164.4 | 120.2 | 5.2 | -0.3 | -0.6 | 66.6 | 1.37 |
| R05 | 2019-05-07 | 33.0 | 35.0 | 19.0 | No | 14.0 | 54.7 | 35.3 | 82.4 | 43.6 | 10.6 | 0.1 | 8.3 | 53.5 | 1.82 |
| R05 | 2019-06-27 | 35.5 | 39.0 | 23.5 | No | 12.0 | 50.3 | 36.3 | 81.1 | 40.9 | 5.4 | -0.2 | 15.4 | 29.8 | 1.64 |
| R05 | 2019-08-22 | 35.4 | 39.0 | 19.5 | No | 15.9 | 49.2 | 37.0 | 79.0 | 42.7 | 7.3 | 0.0 | 4.8 | 66.0 | 1.20 |
| R05 | 2019-10-22 | 23.7 | 26.0 | 19.0 | No | 4.7 | 43.8 | 26.5 | 73.1 | 30.7 | 7.0 | 0.1 | -3.1 | 90.4 | 0.93 |
| Campground | 2020-01-30 | 19.4 | 18.5 | 17.0 | Yes | 2.4 | 45.2 | 23.8 | 68.7 | 27.8 | 8.4 | -0.2 | -12.0 | 90.3 | 0.74 |
| R01 | 2020-02-21 | 19.3 | 20.0 | 17.0 | No | 2.3 | 45.3 | 21.5 | 66.7 | 32.9 | 13.6 | 0.1 | -3.4 | 59.2 | 0.33 |
| R01 | 2020-03-31 | 44.2 | 47.5 | 17.5 | No | 26.7 | 56.2 | 44.2 | 93.5 | 43.7 | -0.5 | 0.0 | -12.5 | 31.6 | 2.27 |
| R01 | 2020-06-25 | 53.3 | 54.0 | 52.5 | No | 0.8 | 64.0 | 53.8 | 102.7 | 56.8 | 3.5 | -0.1 | 10.4 | 72.7 | 1.27 |
| R02 | Station was not monitored in 2020. | | | | | | | | | | | | | | |
| R03 | 2020-02-20 | 44.2 | 48.0 | 18.0 | No | 26.2 | 77.8 | 46.0 | 93.6 | 65.3 | 21.1 | 0.1 | -5.8 | 63.7 | 2.44 |
| R03 | 2020-03-12 | 43.4 | 45.5 | 18.0 | Yes | 25.4 | 52.7 | 43.9 | 92.7 | 46.0 | 2.6 | -0.2 | -21.2 | 57.1 | 0.99 |
| R03 | 2020-05-06 | 40.9 | 34.5 | 20.0 | Yes | 20.9 | 56.2 | 47.6 | 90.3 | 50.4 | 9.5 | 0.0 | 10.0 | 32.4 | 2.27 |
| R03 | 2020-06-23 | 53.2 | 54.0 | 33.0 | No | 20.2 | 60.6 | 65.5 | 102.6 | 56.8 | 3.6 | -0.2 | 5.7 | 94.3 | 1.76 |
| R04 | 2020-01-31 | 47.7 | 46.0 | 45.5 | Yes | 2.2 | 58.8 | 50.0 | 97.0 | 51.8 | 4.1 | 0.4 | -13.0 | 89.6 | 0.54 |
| R04 | 2020-02-18 | 110.7 | 114.0 | 103.0 | No | 7.7 | 123.4 | 116.2 | 160.1 | 116.2 | 5.5 | -0.4 | -21.3 | 80.3 | 0.52 |
| R04 | 2020-03-09 | 34.6 | 31.0 | 19.5 | Yes | 15.1 | 62.8 | 41.0 | 83.9 | 47.8 | 13.2 | 0.2 | -10.5 | 83.3 | 1.01 |
| R04 | 2020-05-07 | 31.8 | 33.0 | 23.5 | Yes | 8.3 | 55.0 | 36.3 | 76.0 | 41.5 | 9.7 | -0.1 | 10.4 | 35.4 | 0.97 |
| R04 | 2020-06-30 | 44.4 | 42.5 | 30.0 | Yes | 14.4 | 51.9 | 53.5 | 93.7 | 50.3 | 5.9 | 0.1 | 11.7 | 72.0 | 2.48 |
| R05 | 2020-01-23 | 19.4 | 20.0 | 17.5 | No | 1.9 | 47.5 | 23.3 | 59.5 | 27.9 | 8.5 | 0.1 | -11.9 | 90.4 | 0.04 |
| R05 | 2020-02-26 | 33.8 | 19.5 | 17.0 | Yes | 16.8 | 44.3 | 41.3 | 83.1 | 41.5 | 7.7 | -0.3 | -18.6 | 83.5 | 1.20 |
| R05 | 2020-03-26 | 44.4 | 47.5 | 21.0 | No | 23.4 | 74.6 | 44.9 | 93.8 | 59.7 | 15.3 | 0.3 | -5.0 | 67.6 | 3.03 |
| R05 | 2020-05-22 | 41.8 | 36.5 | 28.5 | Yes | 13.3 | 60.1 | 46.5 | 80.1 | 52.2 | 10.4 | 0.0 | 16.8 | 21.7 | 2.05 |
| R05 | 2020-06-24 | 51.1 | 43.5 | 27.0 | Yes | 24.1 | 55.9 | 63.2 | 100.5 | 53.3 | 2.2 | 0.1 | 7.2 | 91.8 | 1.38 |
| R03 | 2021-11-10 | 33.1 | 33.2 | 27.2 | No | 5.9 | 82.4 | 44.1 | 11.0 | 39.8 | 33.1 | N/A | -13.7 | 83.2 | 1.69 |
| Campground | 2021-11-11 | 37.3 | 39.7 | 26.4 | No | 10.9 | 86.7 | 39.8 | 2.5 | 41.5 | 37.3 | N/A | -10.0 | 91.9 | 1.01 |
| R04 | 2021-11-12 | 37.6 | 31.9 | 26.8 | Yes | 10.8 | 87.0 | 46.7 | 9.1 | 46.5 | 37.6 | N/A | -12.9 | 86.9 | 0.79 |
| R02 | 2021-11-13 | 31.8 | 28.2 | 26.6 | Yes | 5.2 | 81.2 | 42.6 | 10.8 | 40.7 | 31.8 | N/A | -11.3 | 87.1 | 0.68 |
| R01 | 2021-11-14 | 38.2 | 28.9 | 26.5 | Yes | 11.7 | 87.6 | 51.7 | 13.4 | 45.4 | 38.2 | N/A | -11.8 | 90.1 | 0.67 |
| R05 | 2021-11-16 | 33.2 | 27.3 | 26.5 | Yes | 6.7 | 82.6 | 46.0 | 12.8 | 42.8 | 33.2 | N/A | -19.8 | 84.1 | 0.21 |
| R01 | 2021-12-02 | 38.9 | 27.2 | 26.5 | Yes | 12.4 | 88.3 | 38.9 | 8.9 | 47.5 | 38.9 | N/A | -18.1 | 86.1 | 0.36 |
| R02 | 2021-12-07 | 70.1 | 71.9 | 54.4 | No | 15.7 | 93.3 | 82.4 | 12.3 | 81.9 | 70.1 | N/A | -27.4 | 76.9 | 0.38 |
| R03 | 2021-12-08 | 29.3 | 29.4 | 29.3 | No | 0.0 | 78.7 | 29.7 | 0.4 | 29.5 | 29.3 | N/A | -17.6 | 86.3 | 0.33 |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R04 | 2021-12-09 | 29.4 | 29.5 | 29.3 | No | 0.1 | 78.8 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -17.3 | 86.7 | 0.38 |
| R05 | 2021-12-10 | 29.5 | 29.5 | 29.4 | No | 0.1 | 78.8 | 29.8 | 0.3 | 29.6 | 29.4 | N/A | -20.5 | 83.8 | 0.18 |
| Campground | 2021-12-18 | 30.4 | 30.6 | 30.2 | No | 0.2 | 79.8 | 31.4 | 1.0 | 31.2 | 30.4 | N/A | -26.2 | 78.2 | 0.11 |
| R04 | 2021-12-19 | 30.4 | 30.6 | 30.3 | No | 0.1 | 79.8 | 31.6 | 1.1 | 31.4 | 30.4 | N/A | -24.0 | 80.3 | 0.18 |
| R02 | 2021-12-20 | 30.4 | 30.6 | 30.3 | No | 0.1 | 79.8 | 31.5 | 1.1 | 31.3 | 30.4 | N/A | -24.2 | 80.2 | 0.13 |
| R03 | 2021-12-21 | 30.1 | 30.6 | 29.3 | No | 0.8 | 79.4 | 30.9 | 0.9 | 30.8 | 30.1 | N/A | -18.9 | 85.1 | 0.60 |
| R03 | 2021-12-24 | 29.4 | 29.6 | 29.2 | No | 0.2 | 78.7 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -27.1 | 77.3 | 0.39 |
| R05 | 2021-12-25 | 29.2 | 29.3 | 29.1 | No | 0.1 | 78.5 | 29.5 | 0.4 | 29.4 | 29.2 | N/A | -26.9 | 77.3 | 0.71 |
| Campground | 2021-12-27 | 29.5 | 29.7 | 29.4 | No | 0.1 | 78.9 | 29.8 | 0.3 | 29.7 | 29.5 | N/A | -29.3 | 75.0 | 0.07 |
| R04 | 2021-12-28 | 29.5 | 29.5 | 29.4 | No | 0.1 | 78.8 | 29.8 | 0.3 | 29.6 | 29.4 | N/A | -23.0 | 81.4 | 0.39 |
| R02 | 2021-12-30 | 29.4 | 29.5 | 29.4 | No | 0.0 | 78.8 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -18.7 | 85.4 | 0.02 |
| RO1 | 2022-01-01 | 29.3 | 29.4 | 29.2 | No | 0.1 | 78.7 | 29.3 | 0.3 | 29.5 | 29.3 | N/A | -24.2 | 80.3 | 0.00 |
| RO3 | 2022-01-02 | 29.2 | 29.3 | 29.1 | No | 0.1 | 78.6 | 29.5 | 0.3 | 29.4 | 29.2 | N/A | -25.7 | 77.4 | 1.37 |
| RO2 | 2022-01-15 | 29.7 | 29.8 | 29.5 | No | 0.2 | 79.0 | 29.7 | 0.4 | 29.9 | 29.7 | N/A | -7.2 | 91.6 | 1.44 |
| RO1 | 2022-01-16 | 29.5 | 29.6 | 29.4 | No | 0.1 | 78.9 | 29.5 | 0.3 | 29.7 | 29.5 | N/A | -10.2 | 92.6 | 0.38 |
| RO3 | 2022-01-17 | 29.4 | 29.5 | 29.3 | No | 0.1 | 78.8 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -12.4 | 90.8 | 1.60 |
| RO5 | 2022-01-18 | 29.4 | 29.5 | 29.3 | No | 0.1 | 78.8 | 29.8 | 0.3 | 29.6 | 29.4 | N/A | -21.0 | 83.5 | 0.54 |
| Cmapground | 2022-01-20 | 29.4 | 29.5 | 29.4 | No | 0.0 | 78.8 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -20.7 | 83.9 | 0.28 |
| RO4 | 2022-01-21 | 29.5 | 29.6 | 29.4 | No | 0.1 | 78.7 | 29.8 | 0.3 | 29.7 | 29.5 | N/A | -20.0 | 84.2 | 0.27 |
| RO2 | 2022-01-22 | 29.6 | 29.7 | 29.6 | No | 0.0 | 79.0 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -21.0 | 83.4 | 0.23 |
| RO3 | 2022-01-23 | 29.6 | 29.7 | 29.5 | No | 0.1 | 78.9 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -9.0 | 93.3 | 0.21 |
| RO1 | 2022-01-24 | 29.6 | 29.6 | 29.5 | No | 0.1 | 78.9 | 29.6 | 0.4 | 29.8 | 29.6 | N/A | -5.2 | 96.1 | 0.49 |
| RO5 | 2022-01-25 | 29.6 | 29.7 | 29.6 | No | 0.0 | 79.0 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -7.3 | 94.8 | 0.35 |
| RO2 | 2022-01-27 | 29.6 | 29.6 | 29.5 | No | 0.1 | 78.9 | 29.9 | 0.3 | 29.8 | 29.6 | N/A | -9.1 | 92.4 | 1.09 |
| RO3 | 2022-01-30 | 29.3 | 29.4 | 29.2 | No | 0.1 | 78.7 | 29.6 | 0.3 | 29.5 | 29.3 | N/A | -19.7 | 84.6 | 1.35 |
| RO5 | 2022-02-15 | 29.6 | 29.8 | 29.5 | No | 0.1 | 79.0 | 29.9 | 0.3 | 29.8 | 29.7 | N/A | -12.7 | 89.2 | 1.05 |
| RO3 | 2022-02-16 | 29.5 | 29.6 | 29.4 | No | 0.1 | 78.9 | 29.8 | 0.3 | 29.7 | 29.5 | N/A | -15.8 | 87.3 | 0.55 |
| RO1 | 2022-02-17 | 29.5 | 29.5 | 29.4 | No | 0.1 | 78.8 | 29.8 | 0.3 | 29.7 | 29.5 | N/A | -17.7 | 86.6 | 0.99 |
| RO3 | 2022-02-18 | 29.4 | 29.5 | 29.4 | No | 0.0 | 76.7 | 29.7 | 0.3 | 29.6 | 29.4 | N/A | -20.1 | 83.5 | 1.35 |
| RO5 | 2022-02-25 | 29.6 | 29.8 | 29.4 | No | 0.2 | 79.0 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -14.1 | 88.2 | 0.52 |
| RO3 | 2022-02-27 | 29.7 | 29.9 | 29.6 | No | 0.1 | 28.2 | 30.0 | 0.3 | 30.0 | 29.7 | N/A | -8.2 | 83.3 | 0.77 |
| RO4 | 2022-03-03 | 29.6 | 29.8 | 29.4 | No | 0.2 | 79.0 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -5.7 | 89.4 | 0.52 |
| RO5 | 2022-03-04 | 29.6 | 29.8 | 29.4 | No | 0.2 | 78.8 | 29.9 | 0.3 | 29.8 | 29.6 | N/A | -7.0 | 89.4 | 0.77 |
| RO1 | 2022-03-05 | 29.7 | 29.8 | 29.5 | No | 0.2 | 79.0 | 30.0 | 0.4 | 29.8 | 29.7 | N/A | -11.1 | 79.9 | 1.33 |
| RO2 | 2022-03-08 | 29.6 | 29.7 | 29.4 | No | 0.2 | 78.9 | 29.9 | 0.4 | 29.7 | 29.6 | N/A | -11.8 | 71.1 | 1.54 |
| RO2 | 2022-03-10 | 29.6 | 29.7 | 29.4 | No | 0.2 | 79.0 | 30.0 | 0.4 | 29.8 | 29.6 | N/A | -12.1 | 73.5 | 0.73 |
| RO4 | 2022-03-13 | 29.4 | 29.6 | 29.2 | No | 0.2 | 78.8 | 29.8 | 0.3 | 29.6 | 29.4 | N/A | -21.8 | 56.9 | 3.01 |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RO1 | 2022-04-01 | 29.8 | 30.1 | 29.5 | No | 0.3 | 79.1 | 30.2 | 0.4 | 30.0 | 29.8 | N/A | -13.3 | 55.2 | 2.87 |
| RO2 | 2022-04-02 | 29.7 | 29.9 | 29.6 | No | 0.1 | 78.9 | 30.2 | 0.4 | 29.9 | 29.7 | N/A | -17.5 | 44.2 | 1.67 |
| RO3 | 2022-04-04 | 6.7 | 7.0 | 6.5 | No | 0.2 | 56.1 | 7.1 | 0.4 | 6.9 | 6.7 | N/A | -7.3 | 84.1 | 1.04 |
| RO4 | 2022-04-05 | 6.7 | 6.9 | 6.5 | No | 0.2 | 56.0 | 7.1 | 0.4 | 6.9 | 6.7 | N/A | -2.7 | 73.8 | 1.25 |
| RO5 | 2022-04-06 | 29.8 | 30.0 | 29.6 | No | 0.2 | 79.2 | 30.2 | 0.4 | 30.0 | 29.8 | N/A | -2.9 | 68.6 | 2.17 |
| RO3 | 2022-04-14 | 29.9 | 30.0 | 29.7 | No | 0.2 | 69.0 | 30.3 | 0.4 | 30.0 | 29.9 | N/A | -8.3 | 48.2 | 1.66 |
| RO2 | 2022-04-15 | 29.7 | 29.9 | 29.5 | No | 0.2 | 79.1 | 30.1 | 0.4 | 29.9 | 29.7 | N/A | -4.5 | 49.3 | 1.73 |
| RO4 | 2022-04-16 | 29.6 | 29.8 | 29.4 | No | 0.2 | 79.0 | 30.0 | 0.3 | 29.8 | 29.6 | N/A | -8.2 | 49.1 | 3.65 |
| RO2 | 2022-04-17 | 29.7 | 30.0 | 29.5 | No | 0.2 | 79..1 | 30.1 | 0.4 | 29.9 | 29.7 | N/A | -11.8 | 42.1 | 1.87 |
| RO5 | 2022-04-18 | 29.7 | 29.9 | 29.5 | No | 0.2 | 79.1 | 30.1 | 0.4 | 29.9 | 29.7 | N/A | -10.9 | 39.7 | 1.68 |
| RO2 | 2022-04-22 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.2 | 30.2 | 0.4 | 30.1 | 29.9 | N/A | -2.4 | 48.7 | 1.17 |
| RO4 | 2022-04-23 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 1.8 | 45.6 | 1.97 |
| RO5 | 2022-05-01 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 4.6 | 48.7 | 2.28 |
| RO5 | 2022-05-02 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 5.1 | 49.2 | 4.13 |
| RO3 | 2022-05-05 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 4.3 | 51.6 | 2.18 |
| RO2 | 2022-05-08 | 30.0 | 30.1 | 29.7 | No | 0.3 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 3.2 | 59.7 | 1.50 |
| RO5 | 2022-05-09 | 29.9 | 30.0 | 29.7 | No | 0.2 | 79.2 | 30.2 | 0.4 | 30.1 | 29.9 | N/A | 3.3 | 55.5 | 2.05 |
| Campground | 2022-05-13 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 3.5 | 63.6 | 1.91 |
| RO4 | 2022-05-14 | 29.9 | 30.1 | 29.7 | No | 0.2 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 5.2 | 47.1 | 2.07 |
| RO5 | 2022-05-16 | 29.9 | 30.1 | 29.8 | No | 0.1 | 79.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | 4.5 | 63.4 | 2.52 |
| Campground | 2022-05-19 | 29.9 | 30.1 | 29.7 | No | 0.2 | 76.3 | 30.3 | 0.4 | 30.1 | 29.9 | N/A | Flame & Moth Meteorological Station was dissasembled between May and November 2022; therefore, no data are available. | | |
| RO2 | 2022-05-20 | 30.0 | 30.2 | 29.8 | No | 0.2 | 79.3 | 30.4 | 0.4 | 30.2 | 30.0 | N/A | | | |
| RO2 | 2022-05-21 | 30.0 | 30.2 | 29.8 | No | 0.2 | 79.4 | 30.4 | 0.4 | 30.2 | 30.0 | N/A | | | |
| RO2 | 2022-05-27 | 30.0 | 30.2 | 29.8 | No | 0.2 | 79.3 | 30.4 | 0.4 | 30.2 | 30.0 | N/A | | | |
| RO3 | 2022-05-29 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.4 | 30.5 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO3 | 2022-06-02 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.5 | 30.6 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO2 | 2022-06-03 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.5 | 30.5 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO4 | 2022-06-05 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.4 | 30.5 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO5 | 2022-06-07 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.4 | 30.5 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO2 | 2022-06-09 | 30.1 | 30.2 | 29.9 | No | 0.2 | 80.5 | 30.5 | 0.4 | 30.2 | 30.1 | N/A | | | |
| Campground | 2022-06-11 | 30.0 | 30.1 | 29.8 | No | 0.2 | 79.4 | 30.4 | 0.4 | 30.2 | 30.0 | N/A | | | |
| RO2 | 2022-06-18 | 30.1 | 30.3 | 29.9 | No | 0.2 | 79.5 | 30.6 | 0.4 | 30.3 | 30.1 | N/A | | | |
| RO2 | 2022-06-24 | 30.2 | 30.4 | 30.0 | No | 0.2 | 79.6 | 30.6 | 0.4 | 30.4 | 30.2 | N/A | | | |
| RO3 | 2022-06-26 | 30.3 | 30.5 | 30.1 | No | 0.2 | 79.6 | 30.7 | 0.4 | 30.5 | 30.3 | N/A | | | |
| RO5 | 2022-06-27 | 30.3 | 30.5 | 30.1 | No | 0.2 | 80.8 | 30.7 | 0.4 | 30.5 | 30.3 | N/A | | | |
| RO3 | 2022-07-05 | 30.3 | 30.5 | 30.1 | No | 0.2 | 79.6 | 30.7 | 0.4 | 30.5 | 30.3 | N/A | | | |
| RO4 | 2022-07-07 | 30.2 | 30.4 | 30.0 | No | 0.2 | 79.6 | 30.6 | 0.4 | 30.4 | 30.2 | N/A | | | |

| Station | Start Date | LAeq (dB) | LAF 10% (dB)* | LAF 90% (dB)* | LAeq > LAF 10 | LAeq - LAF 90% (dB) | Lzeq (dB) | LAIeq (dB) | LAE (dB) | LCeq (dB) | LCeq-LAeq (dB) | Calibration Drift (dB) | Temp. (˚C) | R.H. (%) | Avg. WS (m/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RO5 | 2022-07-08 | 30.3 | 30.4 | 30.1 | No | 0.2 | 79.6 | 30.7 | 0.4 | 30.5 | 30.3 | N/A | | | |
| RO2 | 2022-07-11 | 30.2 | 30.3 | 30.0 | No | 0.2 | 79.6 | 30.6 | 0.4 | 30.4 | 30.2 | N/A | | | |
| RO5 | 2022-07-14 | 30.2 | 30.4 | 30.0 | No | 0.2 | 79.5 | 30.6 | 0.4 | 30.4 | 30.2 | N/A | | | |

**Data in 2021 termed LAS 10 and LAS 90.*

*73 data points were collected from unknown stations where the location was not recorded. Data for unknown stations can be found in Ensero (2022b).*

| Legend: | |
|---|---|
| Yes | When LAeq > LAS10 |
| <5 | LAeq - LAS90 (dB) less than 5 |
| >10 | LAeq - LAS90 (dB) greater than 10 |
| Red | Calibration drift greater than 3.0 dB |

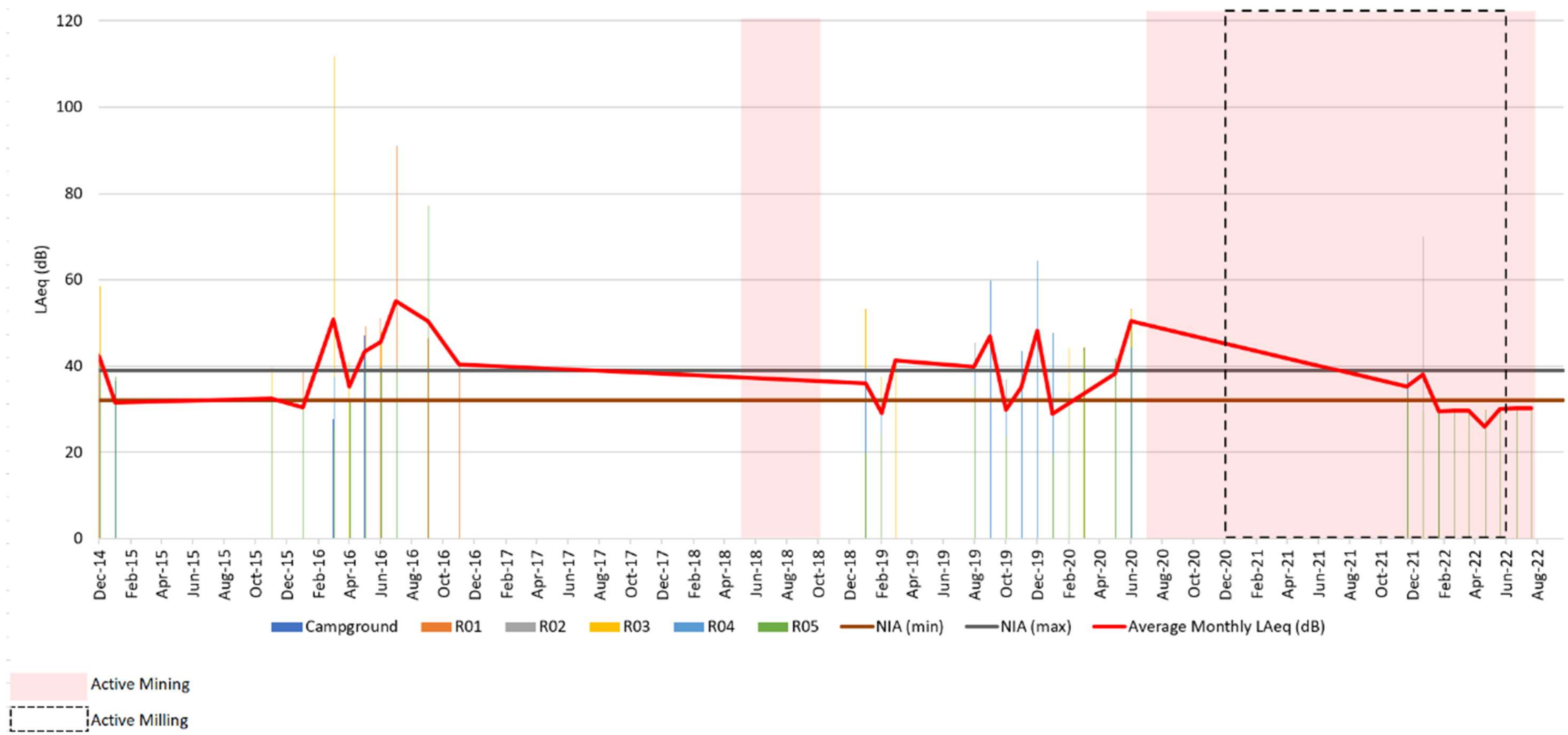



**Figure 3-15: 24-hr Noise Results from 2014-2022 Presented with the Noise Impact Assessment (NIA) Values**

# 4 SURFACE WATER

## 4.1 HYDROLOGY

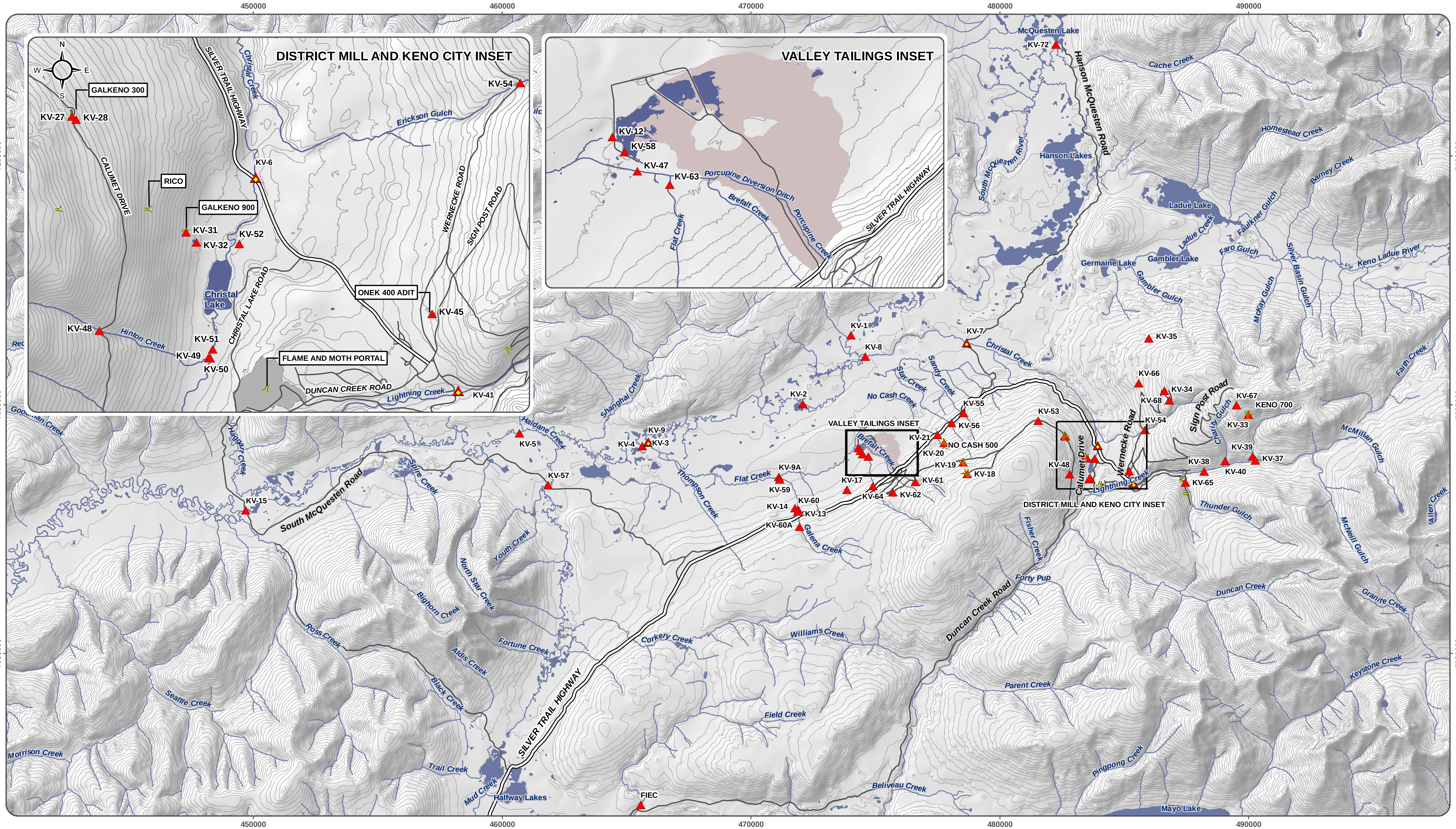
Maximum daily flows typically occur in spring in response to snowmelt and rain on snow events. However, summer and fall rainstorms can produce large events which can in some cases be the maximum annual flood. Large increases in flow in response to rain events is common in the small streams of the area. There are many historical adits in the region, some of which are free draining.

Open water season is typically late May until mid-October. Ice cover can be several feet in some locations and most streams continue to flow year-round though flows may become very low. Low flows typically occur in March-April as the water table drops over the winter.

The New Bermingham Portal and associated infrastructure is in the No Cash Creek Catchment. The No Cash Creek is situated on the northwest slope of Galena Hill and flows down the hillside towards the wetlands northeast of Flat Creek. There is no direct connection between No Cash Creek and either Flat Creek or the South McQuesten River as No Cash Creek ends in a bog. From the headwaters on Galena Hill to dispersion in the bog, the distance is roughly 2.3 km. There is one routine sampling station on No Cash Creek, located just above the Silver Trail Highway (KV-21). Located within the No Cash Creek catchment are the historical Bermingham 200 adit (KV-18), Ruby 400 (KV-19) and No Cash 500 (KV-20) adit discharges monitored by ERDC. The monitoring stations currently monitored in the KHSD are shown on Figure 4-1.

As part of Water Licence QZ18-044 continuous water levels are recorded during the open water season at fifteen minute intervals using Solinst water level recorders at stations KV-6, KV-7, and KV-41 (Figure 4-1). Discharge measurements and staff gauge observations are taken at regular intervals during the open water season, approximately once per month. Occasionally, salt slugs are used to determine flow when conditions do not permit regular velocity-area discharge measurements. These data have been used together to develop rating curves which facilitate the translation of continuous water level data into continuous discharge. Discharge measurements are taken in winter when conditions permit using the salt dilution gauging method.

For the period 2004 to 2009, CCL processed the water level data to produce a flow record on behalf of Access Consulting Group (now Ensero Solutions Canada Inc. [Ensero]) on behalf of the client AKHM. CCL have patched the data record over the winter months when gauging data were not collected and have shown through regional analysis that this practice gives realistic values for the purpose of calculating mean and annual and monthly runoff (CCL, 2008) These data are summarized in memorandums CCL-UKHM-1 and CCL-UKHM2. Since 2010 data have been managed by Ensero.






Datum: NAD 83; Map Projection: UTM Zone 8N



1:145,000
0 1 2 3 4 5 Kilometers

- Automatic Hydrometric Monitoring Stations with Barologger
- Instantaneous Hydrometric Monitoring Stations
- Adit
- Valley Tailings
- Silver Trail Highway
- Other Road
- Watercourse
- Waterbody

HECLA KENO HILL

**FIGURE 4-1**
**KHSD DISCHARGE MONITORING LOCATIONS**

FEBRUARY 2023

D:\Project\AllProjects\ALEX-05-01\gis\mxd\Overview_Maps\WQ\02-SURFACEWATER\Specific_Topic\ContinuousDischargeLocations\ContinuousDischargeLocations_20201217.mxd
(*Last edited by: amatlashevska; 2023-02-03/15:36 PM*)

### 4.1.1 REGIONAL HYDROLOGY

The closest and most relevant hydrometric station in the region is the Water Survey of Canada operated McQuesten River near the Mouth (Stn. # 09DD004) which has been monitored for flow and level from 1979 to present. The drainage area is 4,750 km$^2$ and includes the towns of Keno and Elsa and Christal Creek. The mean annual discharge for the McQuesten River is 3,303,500 m$^3$/d (38.2m$^3$/s) or 8.0 L/s/km$^2$ and the mean annual runoff (MAR) is 253.8 mm. Table 4-1 presents the mean daily as well as mean low flow and mean daily high flow for the 1979 to 2019 at McQuesten River near the mouth.

**Table 4-1: McQuesten River Mean, Mean Minimum, and Mean Maximum Daily Flows**

| Discharge | Mean | Min | Max |
|---|---|---|---|
| m$^3$/d | 3,300,480 | 1,909,440 | 5,590,080 |
| m$^3$/s | 38.2 | 22.1 | 64.7 |
| L/s/km$^2$ | 8.0 | 4.6 | 13.6 |

Return periods for high flow were calculated for this record using the Log Pearson Type III distribution chosen as it is the recommended technique for flood frequency from the US Water Advisory Committee on Water Data (1982). The return periods for low flows were calculated with the Weibull distribution. The results of this analysis are shown in Table 4-2 in both discharge and unit runoff.

**Table 4-2: High and Low Flow for Various Return Periods (Tp) for McQuesten River Near the Mouth**

| | Annual Daily Peak Flow | | | Annual Daily Low Flow | | |
|---|---|---|---|---|---|---|
| $T_p$[1] | m$^3$/d | m$^3$/s | L/s/km$^2$ | m$^3$/d | m$^3$/s | L/s/km$^2$ |
| 2 | 20,364,624 | 235.7 | 49.6 | 639,908 | 7.4 | 1.6 |
| 10 | 30,429,766 | 352.2 | 74.1 | 409,771 | 4.7 | 1.0 |
| 50 | 39,305,725 | 454.9 | 95.8 | 179,634 | 2.1 | 0.4 |
| s100 | 43,136,166 | 499.3 | 105.1 | 80,520 | 0.9 | 0.2 |

*[1] Return period ($T_p$) are in years.*

The mean monthly flow distribution is typical of the region and Yukon in general, exhibiting a snowmelt dominated freshet period. Peak mean monthly and daily flows most often occur in May, but also in June, with summer and early fall rain sustaining flows till the onset of winter at which time discharge begins to decrease, reaching their lowest in March (Figure 4-2). The McQuesten River mean flow data presented below include all available mean monthly flow data including 1979 to 2019.

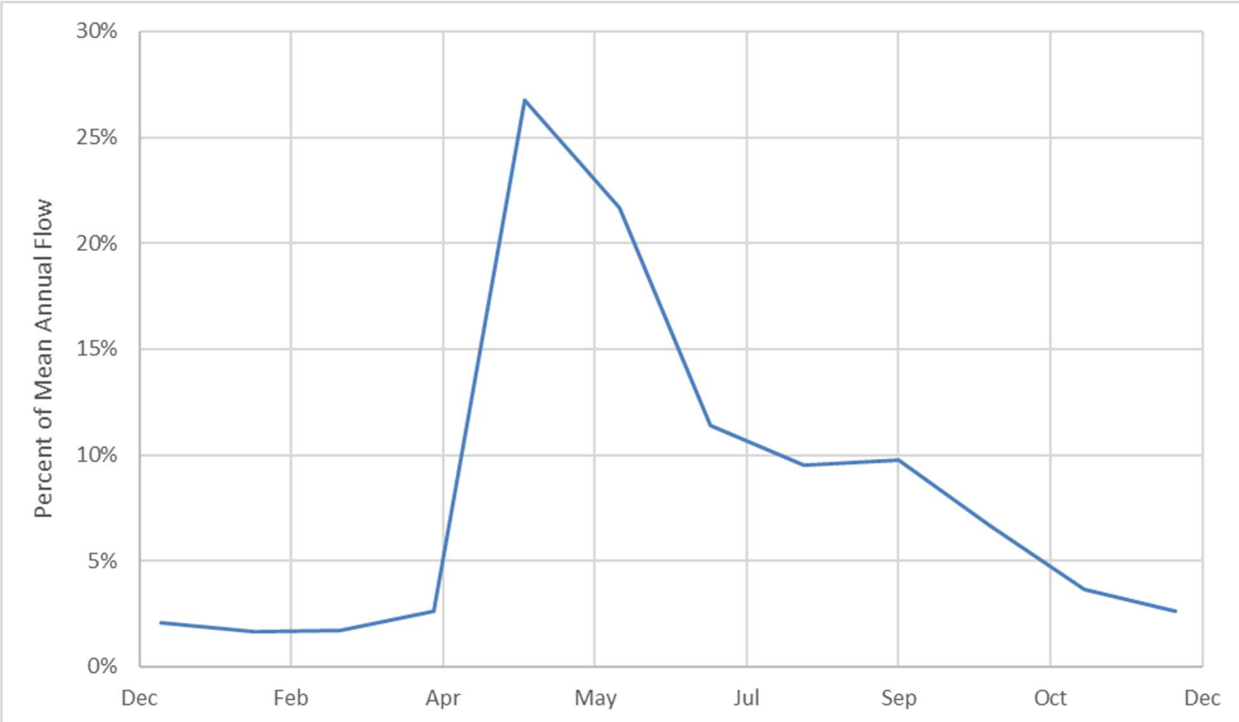



**Figure 4-2: Annual Flow Distribution at McQuesten River Near the Mouth (09DD004)**

*McQuesten mean flow data available from 1979 to 2019.*

### 4.1.2 HYDROMETRIC MONITORING STATIONS

Figure 4-1 shows the hydrometric monitoring stations in the KHSD. The following sections discuss the stations on No Cash Creek, Christal Creek, and Lightning Creek. A summary of the hydrometric stations is provided in Table 4-3.

**Table 4-3: Keno Hill Silver District Hydrometric Stations Summary**

| Site | Description | Sampling Schedule | Continuous (Y/N) | Drainage Area (km²) | Median Elevation (masl) | Station Elevation (masl) | Max Elevation (masl) | Instrumentation | Measurement Frequency | Accuracy (+/- %FS)[1] | Number of Benchmarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **KV-6** | Christal Creek at Silver Trail Highway | Monthly | Y | 6.1 | 1002 | 855 | 1350 | Solinst M5 | 15 min | 0.05 | 3 |
| **KV-7** | Christal Creek at Hanson Road | Monthly | Y | 35.8 | 970 | 675 | 1685 | Solinst M5 | 15 min | 0.05 | 3 |
| **KV-9** | Flat Creek upstream of South McQuesten River | Quarterly | Y | 56.5 | 830 | 625 | 1411 | Solinst M2 | 15 min | 0.05 | 3 |
| **KV-21** | No Cash Creek at Silver Trail Highway | Monthly | Y | 1.4 | 1212 | 821 | 1389 | Solinst M5 | 15 min | 0.05 | 3 |
| **KV-41** | Lightning Creek upstream of bridge at Keno City | Monthly | Y | 59 | 1400 | 935 | 1988 | Solinst M2 | 15 min | 0.05 | 3 |
| **KV-51** | Christal Creek downstream of Hinton Creek | Quarterly | Y | 2.8 | 1172 | 861 | 1443 | Solinst M2 | 15 min | 0.05 | 3 |
| **KV-60** | Galena Creek upstream of Silver King Adit | Quarterly | N discontinued | 9.4 | 997 | 739 | 1400 | Solinst M2 | 15 min | 0.05 | 3 |
| **KV-64** | Flat Creek at Silver Trail Highway | Quarterly | N discontinued | 4.4 | 1159 | 818 | 1412 | Solinst M2 | 15 min | 0.05 | 3 |

*[1] % FS is Percentage of Foresight.*

#### 4.1.2.1 KV-21 NO CASH CREEK AT THE SILVER TRAIL HIGHWAY

No Cash Creek flows just northeast of the former townsite of Elsa and has a catchment area of ~1.4 km$^2$ at the Silver Trail Highway (KV-21). The median elevation is ~1,212 masl and includes the No Cash 500 adit (KV-20), which is free draining. In June of 2015, a V-notch weir to gather continuous data was installed on No Cash Creek; however, the station was unsuccessful due to significant glaciation and channel braiding in winter and high sedimentation in the summer, as such the continuous monitoring was discontinued and only the discrete measurements maintained. A new hydrometric station was installed further downstream in August 2021; however, the datalogger had technical issues and was not functional until fall 2022.

Average flows for each month for KV-21 were originally established from the monthly discrete discharge measurements using data that was filtered to have less than 15% relative percent difference during field data collection measurements. The mean monthly values have been updated since using a new synthetic, continuous dataset for KV-21 which covers the period from June 2014 to October 2022. The continuous KV-21 synthetic dataset was derived by reviewing and selecting instantaneous discharge measurements with good quality assurance/quality control values collected at KV-21 between June 2014 to October 2022. A relationship between these KV-21 field discharge measurements and the KV-9 continuous discharge dataset was established. The KV-9 continuous data was used as this station has open water year-round and has a reliable continuous discharge dataset from June 2014 to October 2022. The relationship established between the KV-21 field discharge measurements and the KV-9 continuous discharge data was then applied to the entire KV-9 continuous dataset to create a synthetic KV-21 continuous discharge record. The revised monthly values are shown in Table 4-4.

**Table 4-4: KV-21 Mean Monthly Discharge (m$^3$/s) of Synthetic Dataset**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2014 | 0.0042 | 0.0034 | 0.0028 | 0.0031 | 0.0322 | 0.0210 | 0.0137 | 0.0214 | 0.0176 | 0.0154 | 0.0067 | 0.0059 |
| 2015 | 0.0047 | 0.0037 | 0.0036 | 0.0049 | 0.0511 | 0.0234 | 0.0184 | 0.0210 | 0.0282 | 0.0188 | 0.0086 | 0.0071 |
| 2016 | 0.0057 | 0.0053 | 0.0053 | 0.0103 | 0.0423 | 0.0320 | 0.0214 | 0.0274 | 0.0208 | 0.0083 | 0.0073 | 0.0059 |
| 2017 | 0.0046 | 0.0038 | 0.0036 | 0.0049 | 0.0393 | 0.0207 | 0.0131 | 0.0093 | 0.0186 | 0.0200 | 0.0072 | 0.0055 |
| 2018 | 0.0026 | 0.0037 | 0.0029 | 0.0044 | 0.0574 | 0.0233 | 0.0118 | 0.0171 | 0.0100 | 0.0043 | 0.0022 | 0.0023 |
| 2019 | 0.0024 | 0.0023 | 0.0024 | 0.0049 | 0.0148 | 0.0065 | 0.0022 | 0.0022 | 0.0029 | 0.0029 | 0.0020 | 0.0014 |
| 2020 | 0.0017 | 0.0013 | 0.0012 | 0.0072 | 0.1017 | 0.0378 | 0.0265 | 0.0236 | 0.0217 | 0.0134 | 0.0094 | 0.0097 |
| 2021 | 0.0097 | 0.0094 | 0.0093 | 0.0097 | 0.0688 | 0.0126 | 0.0054 | 0.0033 | 0.0036 | 0.0083 | 0.0039 | 0.0036 |
| 2022 | 0.0044 | 0.0050 | 0.0056 | 0.0059 | 0.0781 | 0.0249 | 0.0099 | 0.0085 | 0.0117 | 0.0292 | [1] | [1] |
| Average | 0.0044 | 0.0042 | 0.0041 | 0.0061 | 0.0540 | 0.0225 | 0.0136 | 0.0149 | 0.0150 | 0.0134 | 0.0059 | 0.0052 |
| Standard Deviation | 0.0024 | 0.0023 | 0.0024 | 0.0025 | 0.0261 | 0.0093 | 0.0076 | 0.0093 | 0.0086 | 0.0085 | 0.0029 | 0.0027 |
| 95% Confidence Limit | 0.0015 | 0.0015 | 0.0016 | 0.0016 | 0.0171 | 0.0061 | 0.0050 | 0.0060 | 0.0056 | 0.0055 | 0.0020 | 0.0019 |

[1] *KV-9 is a quarterly visited site, because the data has not been downloaded since October 2022, no synthetic data could be extrapolated for KV-21 in November and December 2022.*

#### 4.1.2.2 KV-6 CHRISTAL CREEK ABOVE SILVER TRAIL HIGHWAY

The hydrometric station on Christal Creek at KV-6 is above the Silver Trail Highway and several hundred meters downstream of Christal Lake. That catchment area is 6.1 $km^2$ with a median elevation of 1,002 masl.

A Solinst water level recorder was deployed at KV-6 in a stilling well on July 20, 2011 and retrieved on October 23, 2011. Instantaneous discharge measurements have been collected since June 2008 on a monthly basis as often as possible. There was one discharge measurement taken during the continuous water level record, but no staff gauge was installed at that time.

The 2012 Solinst Level Logger record begins May 1 and extends until mid-October. Ice begins to affect the pressure readings on October 10 making water levels following that unreliable. A staff gauge was installed along with the Level Logger on May 1 with a corresponding BaroLogger (barometric pressure data logger). After mid-July the record becomes unreliable due to a ponding effect.

In 2013 the KV-6 station was moved upstream due to the ponding encountered from the road culvert in 2012; however, due to infrequent measurements a continuous record could not be produced. The station was moved again in September 2013 to a more stable reach with a better control section more favourable to measuring flow. The current location remains relatively stable and free of backwater effects.

Reliable stage records began at the new location in late May 2014 and a derived discharge record has been produced continuously since that time. In March 2018, there was an error with the barologger causing it to stop logging. A new Solinst M5 logger was installed in September 2018, as the old logger data was showing signs of drift and needing calibration. On July 16, 2021, the staff gauge ruler was changed as the previous ruler was worn out and, therefore, it was unable to be read accurately.

Winter records are approximated by drawing a line through discrete measurements as appropriate or manipulation of the record relative to the discrete measurements. The peak annual discharge from 2015 to 2022 is presented below in Table 4-5.

**Table 4-5: Peak Annual Discharge at KV-6**

| Year | Date | Peak Annual Discharge ($m^3/s$) | Peak Annual Discharge ($m^3/d$) |
|---|---|---|---|
| 2015 | 11-May-2015 | 0.343 | 29,635 |
| 2016 | 27-Apr-2016 | 0.280 | 24,192 |
| 2017 | 13-May-2017 | 0.264 | 22,810 |
| 2018 | 10-May-2018 | 0.608 | 52,531 |
| 2019 | 11-May-2019 | 0.144 | 12,442 |
| 2020 | 10-May-2020 | 0.897 | 77,501 |
| 2021 | 7-May-2021 | 0.582 | 50,285 |
| 2022 | 15-May-2022 | 0.246 | 21,254 |

##### *4.1.2.2.1 Mean Monthly Flow*

The mean measured discharge at KV-6 is 7,957.2 $m^3/d$ (0.092 $m^3/s$) or 15.1 $L/s/km^2$ and yields a MAR of 476 mm (Table 4-6). The highest flows tend to be in May and September as a result of snowmelt and late summer rainstorms, respectively. May is assumed to be the least representative of the true monthly mean since discharge fluctuates the greatest in this month. Based on other sites in the region these numbers are not in line with a catchment of the calculated size and median elevation. It is possible that additional water is being delivered by adits within the catchment or simply that the record is not representative of the true mean. Figure 4-3 shows the mean monthly flow distribution based on the discrete measurement record.

**Table 4-6: Mean Monthly Discharge at KV-6, Christal Creek Below Christal Lake, for Months Where Continuous Data are Available ($m^3/d$)**

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2012 | | | | | 10,721 | 7,679 | 8,802 | | | | | |
| 2013 | | | | | | | | | | | | |
| 2014 | | | | | 5,422 | 8,314 | 6,299 | 10,112 | 9,967 | 9,258 | 6,977 | 6,675 |
| 2015 | 7,937 | 6,697 | 5,733 | 7,242 | 15,977 | 9,519 | 10,275 | 10,594 | 11,051 | 9,990 | 9,920 | 9,256 |
| 2016 | 8,728 | 7,808 | 6,263 | 9,977 | 10,933 | 9,471 | 11,718 | 13,338 | 10,854 | 9,761 | 8,851 | 8,026 |
| 2017 | 7,266 | 6,639 | 6,098 | 6,102 | 12,872 | 9,025 | 9,675 | 5,853 | 6,654 | 6,182 | 5,147 | 6,059 |
| 2018 | 5,691 | 4,297 | 3,738 | 6,325 | 23,224 | 12,785 | 9,981 | 13,151 | 10,631 | 7,881 | 7,327 | 6,771 |
| 2019 | 6,283 | 5,853 | 5,452 | 5,067 | 7,018 | 6,312 | 5,734 | 5,348 | 4,800 | 3,381 | 2,692 | 1,971 |
| 2020 | 1,237 | 528 | 838 | 2,216 | 20,594 | 8,973 | 11,774 | 12,867 | 12,974 | 7,843 | 4,006 | 3,833 |
| 2021 | 3,657 | 3,489 | 3,322 | 6,998 | 20,896 | 7,755 | 6,588 | 7,804 | 7,466 | 6,924 | 5,217 | 5,547 |
| 2022 | 5,650 | 5,094 | 4,665 | 4,957 | 11,462 | 9,580 | 9,186 | 8,884 | 8,980 | | | |
| Mean | 5,806 | 5,051 | 4,514 | 6,110 | 13,912 | 8,941 | 9,003 | 9,772 | 9,264 | 7,653 | 6,267 | 6,017 |
| Standard Deviation | 2,419 | 2,297 | 1,832 | 2,225 | 6,057 | 1,703 | 2,160 | 3,043 | 2,547 | 2,188 | 2,447 | 2,296 |
| 95% Confidence Limit | 1,676 | 1,592 | 1,269 | 1,542 | 3,754 | 1,056 | 1,339 | 1,988 | 1,664 | 1,516 | 1,695 | 1,591 |

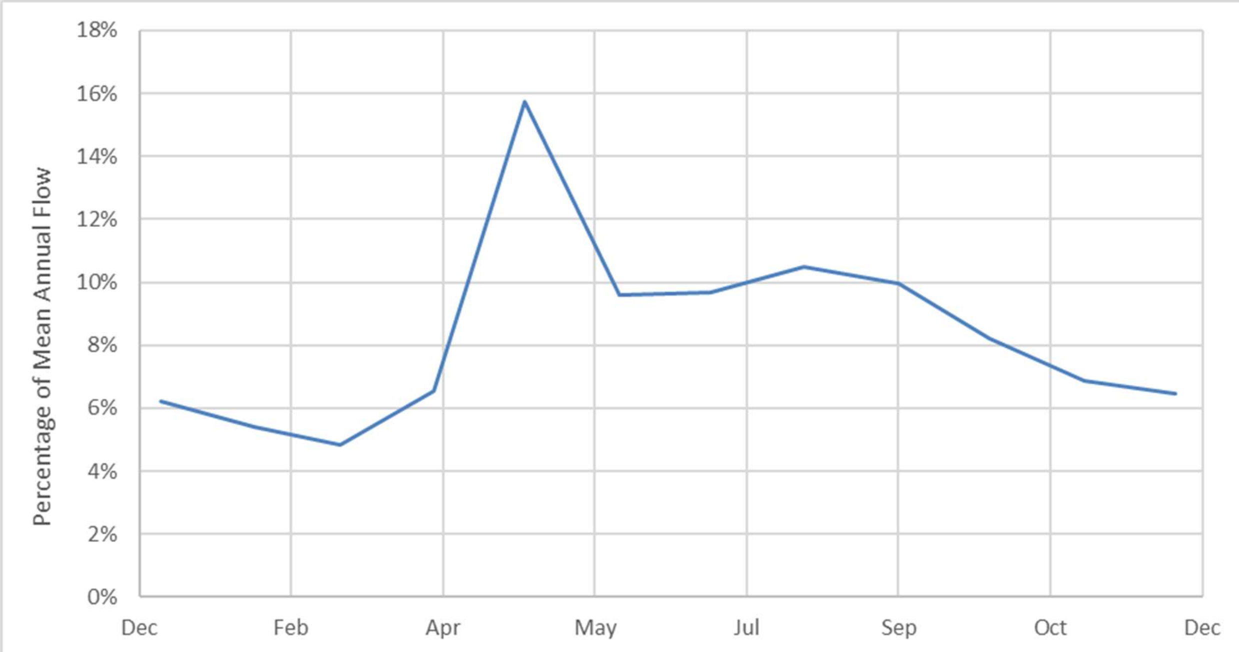



**Figure 4-3: Annual Flow Distribution at KV-6 Christal Creek**

*KV-6 flow data available from 2014 to 2022.*

Although some continuous data were obtained in 2012, the station was unsuccessful until its establishment at the current location in 2014. Since that time reliable continuous data have been obtained with winter data filled in by extrapolation between discrete winter measurements. The MAR for the continuous data is 7,907.3 $m^3/d$ (0.0915 $m^3/s$), which is equivalent to 473 mm.

###### *4.1.2.2.2 Winter Low Flows*

The lake and bog area may have the effect of creating a more stable annual flow regime so that winter low flows do not drop nearly as low as a catchment of similar size due to the lake storage. Typically, base flows slowly drop over the winter and the lowest flows occur in March or April. Since 2012 April discrete measurements have been relatively consistent ranging from 4,493 $m^3$/d (0.052 $m^3$/s) to 6,480 $m^3$/d (0.075 $m^3$/s) with a mean of 5,443 $m^3$/d (0.063 $m^3$/s) or 10.3 L/s/$km^2$. As such 6,110 $m^3$/d (0.070 $m^3$/s) is considered a good estimate of mean winter low flow, and it does appear that the lake allows KV-6 to maintain a much higher unit runoff baseflow than KV-7.

###### *4.1.2.2.3 Peak Flow*

Given that KV-6 is the outlet of the lake and wetland area with little long-term data it is not possible to produce a proxy record with which to conduct a return period analysis. May 2018 has the highest measured peak discharge to date at 31,622 $m^3$/d (0.366 $m^3$/s) for the discrete measurement with a derived continuous record peak of 52,531 $m^3$/d (0.608 $m^3$/s). It is worth noting, the derived peak flow in May 2020 was 77,501 $m^3$/d (0.897 $m^3$/s), but the instantaneous measurement was collected later in May 2020, when freshet was decreasing.

#### 4.1.2.3 KV-7 CHRISTAL CREEK AT HANSON-MCQUESTEN LAKES ROAD BRIDGE

Christal Creek at KV-7 is located at the Hanson and McQuesten Lakes Road Bridge approximately 7 km downstream of KV-6. KV-7 drains an area of 35.8 $km^2$ with a median elevation of 970 m and includes KV-6 and Christal Lake. Ice-free continuous water level data typically extends from early May 1 to late September/early October. There are a number of old workings within the watershed including Galkeno 300, Galkeno 900, Brewis Red Lake (aka Shepard), Lucky Queen, Klondike Keno and, at least partially, Onek 400. Additionally, the District Mill, the Silver Trail Highway, and parts of Keno City including the Keno City dump are at least partially within the watershed. It includes both a major east facing slope of Galena Hill and west facing aspects of Sourdough Hill. The MAR at KV-7 is 252.9 mm or 24,812 $m^3$/d (0.287 $m^3$/s; 8.0 L/s/$km^2$) using the available continuous data and discrete measurements as a measure of mean monthly for winter months. MAR calculated in 2008 was 221 mm and 26,300 $m^3$/d (0.304 $m^3$/s; CCL, 2008), based on a different catchment area. Recalculating for our new catchment area that would be 268 mm. The MAR estimates in the initial hydrology study found in UKM/96/01 (Access Mining Consultants, 1996) was 230 mm. The continuous data show that the original estimates were appropriate, but the new mean is considered the best estimate.

###### *4.1.2.3.1 Mean Monthly Flow*

CCL summarized the data for 2004 to 2009 (CCL, 2008 and 2009). Data for 2010 and 2011 were processed by Ensero following the same methodology as CCL. Ensero has processed data at this site using Aquarius time series software since 2012. Mean monthly discharge calculated from the continuous record (unless otherwise noted) is shown since 2003 at KV-7 in Table 4-7.

**Table 4-7: Mean Monthly Discharge at KV-7, Christal Creek at Hanson-McQuesten Road Bridge ($m^3$/d)**

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2003 | | | | | | | | 36,000 | 44,000 | | | |

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| 2004 | | | 13,000 | 14,000 | 100,000 | 27,000 | 10,000 | 9,700 | 14,000 | 12,000 | 8,900 | 8,700 |
| 2005 | | 11,000 | 9,700 | 34,000 | 130,000 | 23,000 | 25,000 | 34,000 | 29,000 | 22,000 | 16,000 | 13,000 |
| 2006 | | | | | 103,026 | 44,813 | 34,332 | 24,033 | 35,812 | 33,375 | 16,147 | 12,264 |
| 2007 | 13,039 | 10,326 | | 73,654 | 65,410 | 28,136 | 46,757 | 18,815 | 28,969 | 13,460 | | |
| 2008 | | | | | | | | 37,000 | 29,000 | 30,000 | | 12,000 |
| 2009 | 6,800 | 5,900 | 4,100 | 6,400 | 97,000 | 29,000 | 8,800 | 16,000 | 32,000 | | | |
| 2010 | | | | | 27,000 | 21,000 | 31,000 | 20,000 | 20,000 | 16,000 | | |
| 2011 | | | | | 110,000 | 12,000 | 43,000 | 36,000 | 23,000 | 15,000 | 11,000 | |
| 2012 | 13,000 | 6,700 | | | 62,946 | 22,280 | 34,598 | 18,712 | 23,100 | 17,317 | | |
| 2013 | 6,500 | 5,700 | | | | 25,563 | 10,900 | 6,917 | 28,763 | 19,586 | 12,121 | 9,502 |
| 2014 | 8,355 | 8,870 | 7,428 | 6,628 | 63,896 | 37,177 | 16,889 | 49,543 | 30,305 | 18,977 | 15,244 | 12,357 |
| 2015 | 11,110 | 9,074 | 7,260 | 14,170 | 90,038 | 14,884 | 28,882 | 40,811 | 48,518 | 21,100 | 15,261 | 14,484 |
| 2016 | 12,590 | 11,048 | 8,699 | 21,804 | 45,779 | 20,687 | 44,566 | 54,872 | 41,383 | 20,922 | 13,462 | 11,814 |
| 2017 | 10,538 | 10,414 | 7,663 | 10,211 | 53,741 | 21,111 | 13,876 | 10,730 | 28,986 | 11,694 | 8,532 | 7,131 |
| 2018 | 6,027 | 7,961 | 6,777 | 5,114 | 99,205 | 55,674 | 23,640 | 37,194 | 23,180 | 13,238 | 12,788 | 13,369 |
| 2019 | 9,449 | 7,534 | 6,428 | 7,266 | 19,806 | 13,580 | 11,024 | 7,977 | 10,150 | 10,665 | 9,709 | 8,831 |
| 2020 | 9,246 | 8,631 | 8,059 | 7,515 | 74,876 | 46,586 | 47,189 | 38,241 | 39,443 | 27,680 | 13,320 | 13,089 |
| 2021 | 12,853 | 12,630 | 12,406 | 14,206 | 59,659 | 26,296 | 16,188 | 31,700 | 26,084 | 23,574 | 16,602 | |
| 2022 | | | | 45,464 | 88,561 | 52,716 | 26,256 | | | | | |
| Mean | 10,001 | 9,399 | 8,320 | 20,033 | 75,938 | 28,972 | 26,272 | 27,802 | 29,247 | 19,329 | 13,007 | 11,378 |
| Standard Deviation | 2,477 | 1,907 | 2,585 | 20,061 | 29,977 | 13,121 | 13,341 | 14,280 | 9,715 | 6,833 | 2,810 | 2,270 |
| 95% Confidence Limit | 1,535 | 1,127 | 1,528 | 10,905 | 14,250 | 6,061 | 6,163 | 6,421 | 4,368 | 3,348 | 1,528 | 1,285 |

*Note: Grey numbers are discrete discharge measurements and are not used in the statistical analyses.*
*Grey cells are discharge measurements obtained from the Clearwater Consultants Ltd. reports.*

Figure 4-4 shows the distribution of flow annually by month. The distribution is dominated by the snow melt driven high flows occurring in May, with flow throughout the rest of the open water season driven by precipitation events and a slow decline through the winter with lows typically reached in February or March. However, the lowest winter flows could also result in early April. It is likely then that the April mean flows are overestimated by discrete measurements late in the month.

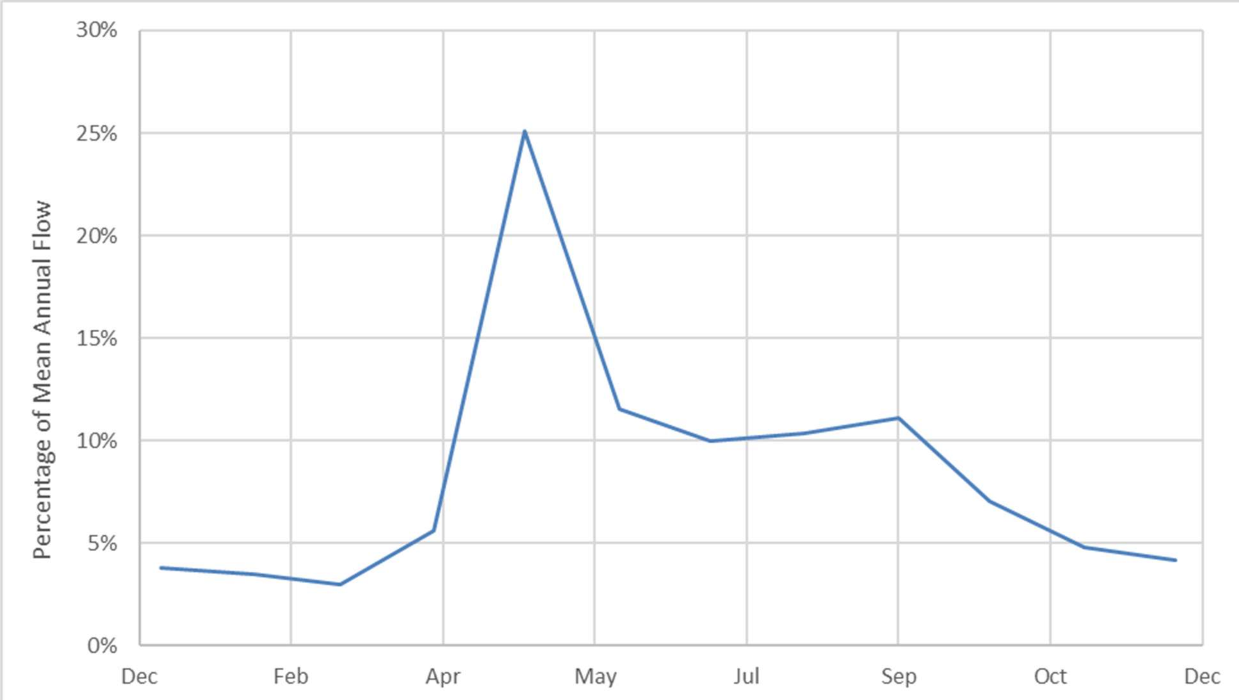



**Figure 4-4: Annual Flow Distribution at KV-7 Christal Creek**

*KV-7 flow data available from 2005 to 2022.*

### *4.1.2.3.2 Winter Low Flows*

Typically, runoff decreases steadily over the winter months assuming there is no major thaw, rain, or snow event. Thus, discharge typically reaches the lowest volume in March or early April and begins to rise as temperatures warm near the end of the month. More recent data gathered since 2017 shows an average winter low flow (March) of 8,266 $m^3$/d (0.096 $m^3$/s) while the long-term mean is 8,090 $m^3$/d (0.094 $m^3$/s), suggesting that the last five years are representative of the overall average discharge observed.

### *4.1.2.3.3 Peak Flow*

There are thirteen years of flow data at KV-7 from which peak flows can be taken; however, it is important to note that since peak flows can occur when ice is still impacting the water level it is possible that the true peak may not have been captured in the continuous record for some years. Nonetheless, a frequency analysis was carried out on peak instantaneous and daily flows using the Log Pearson Type III distribution to predict L-moments and yielded the results in Table 4-8. The maximum daily calculation yields higher discharge rates as the instantaneous flows don't always capture the annual peak discharge rate.

**Table 4-8: Peak Instantaneous and Daily Flows for Various Return Periods (Tp) at KV-7, Christal Creek**

| | Instantaneous | | | Max Daily | | |
|---|---|---|---|---|---|---|
| $T_p$[1] | $m^3$/d | $m^3$/s | L/s/$km^2$ | $m^3$/d | $m^3$/s | L/s/$km^2$ |
| 2 | 52,156 | 0.604 | 16.9 | 134,015 | 1.551 | 43.23 |

| | Instantaneous | | | Max Daily | | |
|---|---|---|---|---|---|---|
| 10 | 137,817 | 1.595 | 44.6 | 237,166 | 2.745 | 76.7 |
| 25 | 200,647 | 2.322 | 64.9 | 284,224 | 3.290 | 91.9 |
| 50 | 257,001 | 2.975 | 83.1 | 317,071 | 3.670 | 102.5 |

[1] *Return period ($T_p$) are in years.*

#### 4.1.2.4 KV-51 CHRISTAL CREEK DOWNSTREAM OF HINTON CREEK

In 2015, a new hydrometric station was commissioned above Christal Lake to better quantify the water balance of Christal Lake. The 2015 hydrograph begins in early June when the station was established and shows similar event peaks to lower Christal Creek sites. Unfortunately, the KV-51 station is subject to heavy icing in winter months causing data loss in low flow conditions and late freshet peak flows. Table 4-9 summarizes the continuous data collected to date as mean monthly discharge. This station data indicates backwater effects through the spring, which would affect the spring data. The monitoring at this site was changed from monthly to quarterly in 2021. As such, fewer data points are contributing to the rating curve development which contributes to the variation in observed discharge.

**Table 4-9: Mean Monthly Discharge at KV-51, Christal Creek Downstream of Hinton Creek ($m^3/d$)**

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2015 | | | | | | 2,059 | 2,481 | 2,946 | 3,909 | 3,285 | 3,061 | 2,933 |
| 2016 | 2,823 | 2,680 | 2,643 | 3,114 | 4,553 | 3,730 | 4,454 | 5,794 | 4,416 | | | |
| 2017 | 1,358 | 1,254 | 1,156 | 1,060 | 6,971 | 2,005 | 1,883 | 1,336 | 1,290 | | | |
| 2018 | | | | 346 | 17,794 | 7,497 | 3,175 | 5,181 | 5,019 | | | |
| 2019 | 1,268 | 1,238 | 1,206 | 1,173 | 2,719 | 1,533 | 1,538 | 1,339 | 1,533 | 1,313 | 1,236 | 3,503 |
| 2020 | 14,670 | 26,311 | 37,952 | 49,787 | 61,622 | 24,936 | 2,810 | 2,903 | 2,881 | 2,029 | 1,386 | 893 |
| 2021 | 1,736 | 2,486 | | 1,811 | 4,896 | 2,887 | 2,818 | 3,852 | 3,677 | 2,807 | | |
| 2022 | | | | 5,494 | 5,711 | 4,086 | 3,068 | 2,715 | | | | |
| Mean | 4,371 | 6,794 | 10,739 | 8,969 | 14,895 | 6,092 | 2,778 | 3,258 | 3,246 | 2,359 | 1,894 | 2,443 |
| Standard Deviation | 5,790 | 10,931 | 18,155 | 18,080 | 21,190 | 7,844 | 885 | 1,620 | 1,416 | 868 | 1,013 | 1,372 |
| 95% Confidence limit | 5,075 | 9,581 | 17,792 | 13,394 | 15,698 | 5,436 | 613 | 1,123 | 1,049 | 851 | 1,146 | 1,553 |

#### 4.1.2.5 KV-41 LIGHTNING CREEK AT KENO CITY BRIDGE

Lightning Creek at KV-41 has a catchment area of 59 $km^2$ and a median catchment elevation of approximately 1,400 masl. Lightning Creek originates to the east of Keno City and drains the southern flank of Keno Hill and the northern flank of Mount Hinton. Lightning Creek flows to the south of Galena hill into Duncan Creek. Within the Lightning Creek watershed are multiple adits including Keno 200 and 700, multiple old surface workings, active mining at Bellekeno East and placer mining on Thunder Gulch.

Hydrometric station KV-41 is located on Lightning Creek above the Keno City Bridge and downstream of the Bellekeno mine and local placer mining activity. Ice-free continuous water level data typically extends from late May to late September/early October after which ice begins to affect water level readings and the stage-discharge relationship.

MAR at KV-41 is 338 mm, 54,576 $m^3/d$ (0.632 $m^3/s$), or 10.7 $L/s/km^2$. This is similar to earlier estimates by CCL of 344 mm or 55,700 $m^3/d$ (0.645 $m^3/s$). Unit runoff is much higher on Lightning Creek as compared to Christal Creek. This is likely due to less vegetative cover compared to Christal Creek owing to the higher elevations and steeper rocky terrain characterising Lightning Creek.

#### *4.1.2.5.1 Mean Monthly Flow*

Table 4-10 shows the mean monthly discharge record with some winter months estimated with discrete measurements. Data from 2013 was lost due to a failure with the logger and while discrete measurements are shown they are not used to calculate the means in summer months. Monthly means are used to calculate a percentage of total annual flow by month (Figure 4-5). Peak flows occur slightly later at this site than in Christal Creek, presumably due to the higher median elevation delivering a more temporally spread-out spring snowmelt and holding high elevation snowpack longer. Flows then decrease throughout the summer and into winter with low flows occurring March or early April.

**Table 4-10: Mean Monthly Discharge at KV-41, Lightning Creek Above Keno City Bridge ($m^3/d$)**

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| 2004 | | | | | | | | 37,000 | 27,000 | 21,000 | 13,000 | 11,000 |
| 2005 | 8,500 | 5,800 | 4,800 | 11,000 | 160,000 | 120,000 | 85,000 | 96,000 | 83,000 | 55,000 | 39,000 | 26,000 |
| 2006 | 19,000 | 17,000 | 17,000 | 24,000 | 69,000 | 170,000 | 110,000 | 80,000 | 94,000 | 77,000 | 48,000 | 39,000 |
| 2007 | | | | | 110,000 | 170,000 | 100,000 | | | | | |
| 2008 | | | | | | | | 98,000 | 67,000 | 89,000 | | |
| 2009 | | 9,500 | 11,000 | 6,000 | 140,000 | 140,000 | | | | | | |
| 2010 | | | | | 100,000 | 120,000 | 87,000 | 66,000 | 49,000 | 39,000 | | |
| 2011 | | | | | | 62,004 | 92,291 | 78,682 | 54,083 | | | 23,000 |
| 2012 | 21,686 | 13,738 | 15,725 | | 74,823 | 102,157 | 69,623 | 35,954 | 43,899 | 32,081 | | |
| 2013 | | | | | | 164,160 | 61,344 | 37,757 | 47,174 | 66,182 | 36,374 | 15,034 |
| 2014 | 12,874 | 10,886 | 8,277 | 44,842 | 91,626 | 85,729 | 35,727 | 62,766 | 43,001 | 29,360 | 21,883 | 19,968 |
| 2015 | 18,099 | 16,395 | 14,766 | 13,160 | 179,539 | 97,523 | 82,490 | 95,163 | 98,315 | 48,648 | 14,126 | 7,498 |
| 2016 | 3,541 | 3,215 | 2,450 | 6,331 | 62,526 | 134,234 | 85,439 | 106,918 | 79,057 | 47,012 | 22,417 | 21,106 |
| 2017 | 16,571 | 13,930 | 12,949 | 11,920 | 88,692 | 107,048 | 53,088 | 39,921 | 74,424 | 56,616 | 40,037 | 32,276 |
| 2018 | 17,037 | 20,812 | 23,999 | 23,028 | 143,712 | 221,603 | 97,903 | 125,159 | 82,347 | 40,543 | 33,878 | 26,973 |
| 2019 | 20,682 | 15,473 | 15,103 | 15,599 | 93,236 | 51,010 | 27,049 | 25,303 | 25,012 | 19,759 | 12,020 | 9,936 |
| 2020 | 8,928 | 8,934 | 8,941 | 8,948 | 98,614 | 185,371 | 82,936 | 118,554 | 119,798 | 48,184 | 25,934 | 27,047 |
| 2021 | 28,200 | 29,317 | 30,456 | 32,538 | 80,235 | 128,463 | 69,337 | 88,609 | 75,536 | 60,756 | 29,829 | 23,588 |
| 2022 | 22,686 | 20,715 | 18,524 | 16,665 | 44,233 | 169,132 | 97,762 | 91,442 | 89,544 | 95,533 | 73,107 | |

| Year | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Mean | 16,324 | 14,645 | 14,544 | 15,381 | 102,416 | 129,017 | 78,376 | 77,842 | 69,064 | 50,633 | 31,103 | 22,282 |
| Standard Deviation | 7,384 | 7,536 | 8,078 | 8,223 | 36,692 | 44,492 | 22,914 | 29,657 | 25,819 | 21,953 | 16,755 | 8,875 |
| 95% Confidence Limit | 4,577 | 4,453 | 4,774 | 4,859 | 18,569 | 21,801 | 11,596 | 14,532 | 12,651 | 11,109 | 9,480 | 5,021 |

*Note: Grey numbers are discrete discharge measurements and are not used in the statistical analyses.*
*Grey cells are discharge measurements obtained from the Clearwater Reports.*


**Figure 4-5: Annual Flow Distribution at KV-41 Lightning Creek**

*KV-41 flow data available from 2004 to 2022.*

### *4.1.2.5.2 Winter Low Flows*

The lowest mean monthly measured flow on record was in March 2016 at 2449.9 $m^3$/d (0.028 $m^3$/s) or 0.48 L/s/$km^2$ followed by February 2016 at 3,215 $m^3$/d (0.037 $m^3$/s) or 0.630 L/s/$km^2$. The lowest flows are generally observed in the January to April period.

### *4.1.2.5.3 Peak Flow*

There are twelve years of continuous flow data from which peak flows can be taken at KV-41; however, it is important to note that since peak flows can occur when ice is still impacting the water level it is possible that the true peak may not have been captured in the continuous record for some years. Nonetheless, a frequency analysis was carried out on peak instantaneous and daily flows using the Log Pearson Type III distribution to predict moments and yielded the results in Table 4-11.

### Table 4-11: Peak Instantaneous and Daily Flows for Various Return Periods (Tp) at KV-41, Lightning Creek

| | Instantaneous | | | Daily | | |
|---|---|---|---|---|---|---|
| $T_p$[1] | $m^3/d$ | $m^3/s$ | $L/s/km^2$ | $m^3/d$ | $m^3/s$ | $L/s/km^2$ |
| 2 | 148,595 | 1.7 | 29.2 | 261,145 | 3.0 | 84.4 |
| 10 | 224,320 | 2.6 | 44.0 | 385,261 | 4.5 | 124.6 |
| 25 | 236,784 | 2.7 | 46.5 | 436,544 | 5.1 | 141.1 |
| 50 | 241,588 | 2.8 | 47.4 | 470,981 | 5.5 | 152.3 |

[1] *Return period ($T_p$) are in years.*

The unit runoff of peak flows is similar between KV-7, KV-41, and McQuesten River at the mouth for the 2-year mean daily peak flow which may also be considered the mean annual discharge. The value at Lightning Creek is highest followed by Christal Creek and then McQuesten River. This is the expected trend as we move to lower median catchment elevations. The size of the McQuesten River watershed will also dampen peak flows. As return period increases so too does the gap between the estimates at the McQuesten River and the smaller Christal and Lightning Creeks. This may be explained by the smaller watersheds having more distinct physiography and shorter lag times to event responses. In other words, less storage means a proportionally larger (flashier) response to melt and precipitation events of combinations of in smaller catchments.

## 4.2 WATER QUALITY

The KHSD lies along the broad McQuesten River valley with three prominent hills to the south of the valley, Galena Hill, Sourdough Hill, and Keno Hill. It is surrounded by three major watersheds: the McQuesten River watershed, the Mayo River watershed, and the Keno Ladue Watershed. For this report, surface water quality results are discussed, focussing on those watercourses potentially impacted by KHSD Mining Operations, including the South McQuesten River, No Cash Bog/Creek, and Christal Creek within the McQuesten Watershed, and the Lightning Creek catchment within the Mayo River watershed. Water quality stations are shown in Figure 4-6.

Water quality for watercourses in the KHSD have been thoroughly assessed over the last fifteen years (Minnow, 2008; 2011; 2013; 2014; 2015; 2017; 2018; 2020). These reports provided: a data quality review, identified contaminants of concern (COCs), potential contaminants of concern (PCOCs), and characterized water quality for stations in the KHSD. Reports were prepared as part of district closure studies and the long-term monitoring plan and included assessments for background stations, Lightning Creek, Christal Creek, No Cash Creek, Flat Creek and the South McQuesten River. The following PCOCs were identified as being elevated above recommended water quality guidelines and potentially hazardous to aquatic life: aluminum, arsenic, cyanide, chromium, copper, iron, lead, manganese, mercury, nitrate, nitrite, phosphorus, selenium, silver, sulphate, total Kjeldahl nitrogen, and uranium. For many of the total metal parameters, the maximum values tended to occur when the total suspended solids (TSS) were also elevated (such as during spring freshet), suggesting that concentrations were associated with particulate matter in water samples. Comparison of filtered metal (dissolved) values at the same sites were confirmed to be below guidelines and less bioavailable (and less harmful) to aquatic life. Many constituents that exceeded guidelines showed concentrations that had either stabilized or decreased over time and were therefore not considered future COCs. Final COCs flagged for the project sites were cadmium and zinc which form the focus of the following sections. Unless otherwise noted, only total cadmium and dissolved zinc are discussed since these reflect the fractions that have Canadian Council of Ministers of the Environment (CCME) cadmium and zinc long-term guidelines for the protection of aquatic life (PAL).

The following sections describe an overview of results of the KHSD water quality sampling program from 2007 to 2022, including the surface water quality monitoring stations at Lightning Creek, Christal Creek, No Cash Creek and the South McQuesten River, and the relevant KHSD adits and wastewater treatment plants within their respective catchments. Monitoring locations for each catchment are presented on Figure 4-6 and in Table 4-12 and Table 4-13.

**Table 4-12: Keno Hill Silver District Surface Water Quality Monitoring Stations**

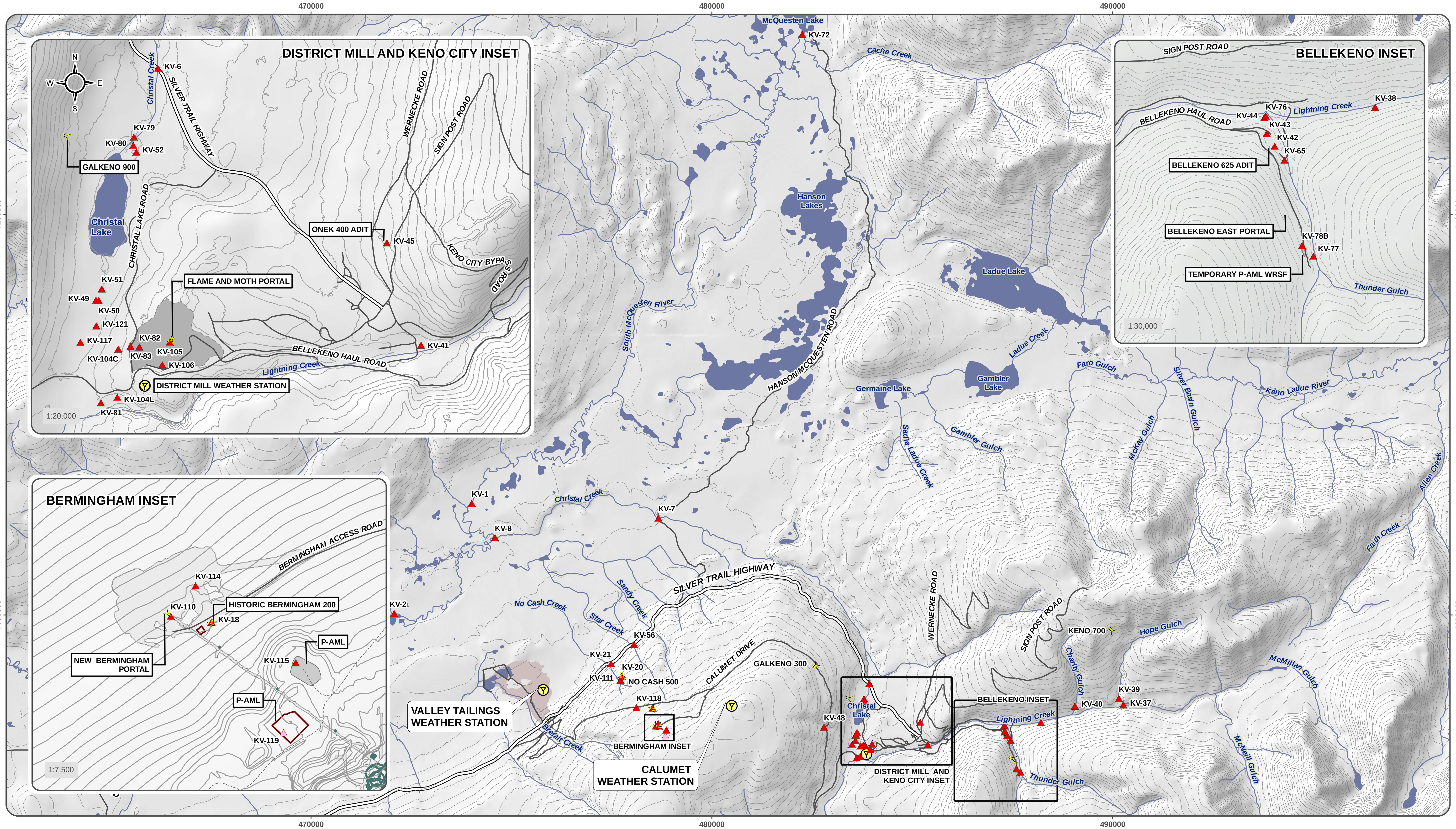
| Site* | Description |
|---|---|
| **Mayo River Watershed** | |
| **Lightning Creek** | |
| KV-37 | Lightning Creek upstream of Hope Gulch |
| KV-38 | Lightning Creek upstream of Thunder Gulch |
| KV-41 | Lightning Creek upstream of bridge at Keno City |
| KV-65 | Thunder Gulch upstream of Bellekeno East Portal |
| KV-76 | Thunder Gulch downstream of Bellekeno 625 Adit |
| KV-81 | Lightning Creek southwest of Mill Site |
| **McQuesten River Watershed** | |
| **Christal Creek** | |
| KV-6 | Christal Creek at Silver Trail Highway |
| KV-7 | Christal Creek at Hanson Road |
| KV-8 | Christal Creek at mouth |
| KV-49 | Hinton Creek upstream of Christal Creek |
| KV-50 | Christal Creek upstream of Hinton Creek |
| KV-51 | Christal Creek downstream of Hinton Creek |
| **No Cash Creek** | |
| KV-21 | No Cash Creek upstream of Silver Trail Highway |
| KC-111 | Upper No Cash Creek above No Cash 500 Adit |
| KV-118 | Upper No Cash Creek at Calumet Drive |
| **South McQuesten River** | |
| KV-1 | South McQuesten River upstream of Christal Creek |
| KV-2 | South McQuesten River at pump house downstream of Christal Creek |

** CCME-PAL is applied to the above monitoring sites*

### Table 4-13: Keno Hill Silver District Adits and Wastewater Treatment Plants Locations

| Site | Description |
|---|---|
| **Mayo River Watershed** | |
| **Lightning Creek** | |
| KV-33 | Keno 700 Adit |
| KV-42 | Bellekeno 625 Adit |
| KV-43* | Bellekeno 625 Treatment Pond Decant |
| KV-104L* | Flame & Moth effluent discharged to Lightning Creek |
| KV-105 | Flame & Moth Adit discharge |
| **McQuesten River Watershed** | |
| **Christal Creek** | |
| KV-27 | Galkeno 300 Adit |
| KV-28** | Galkeno 300 Treatment Pond Decant |
| KV-31 | Galkeno 900 Adit |
| KV-32** | Galkeno 900 Treatment Pond Decant |
| KV-34 | Lucky Queen Adit |
| KV-45 | Onek 400 Adit |
| KV-104C | Flame & Moth effluent discharged to Christal Creek |
| KV-95** | Onek 400 Treatment Pond Decant |
| **No Cash Creek** | |
| KV-18 | Historical Bermingham 200 Adit |
| KV-19 | Ruby 400 Adit |
| KV-20 | No Cash 500 Adit |
| KV-110 | New Bermingham Portal discharge |
| KV-114* | New Bermingham Treatment Pond Decant |

** Effluent Quality Standard (EQS) is applied under Type A Water Licence QZ18-044*
*** EQS is applied under Type B Water Licence QZ17-076*

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Datum: NAD 83; Map Projection: UTM Zone 8N

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1:90,000 (when printed on 11 x17 inch paper)

0 1 2 3 4 5 Kilometers

- Active Surface Water Quality Station
- Pending/Proposed Water Quality Station
- Weather Station
- Adit
- As Built Mine Feature
- Valley Tailings
- Silver Trail Highway
- Other Road
- Watercourse
- Waterbody

Hecla KENO HILL

HECLA KENO HILL

**FIGURE 4-6**
**SURFACE WATER QUALITY STATION LOCATIONS**

DECEMBER 2022

O:\Projects\ALEX-05-01\gis\mxd\Overview_Maps\WQ\02-SURFACEWATER\Specific_Topic\Licenses\SWMonitoring_KenoHill_QZ09-092_Hecla_20221129.mxd
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### 4.2.1 SOUTH MCQUESTEN RIVER DRAINAGE

The South McQuesten River is a large watercourse that drains much of the western portion of the KHSD. It receives drainage from Christal and Flat Creeks; the Flat Creek catchment is not discussed further since there are no KHSD Mining Operations within this catchment. No Cash Creek also drains towards the South McQuesten River but infiltrates to ground approximately 2 km south of the South McQuesten River.

#### 4.2.1.1 SOUTH MCQUESTEN RIVER

Water quality stations installed along the South McQuesten River have been monitored by AKHM (2008 to 2022) to evaluate any potential impact on water quality related to mining activities at the project site.

Water quality in the South McQuesten River downstream of all mining related activities has improved over the years as management practices and interim Care and Maintenance activities at the historic environmental liabilities by ERDC have reduced the overall loading of metals into the receiving environment. However, since 2006 an unrelated source (Cache Creek) upstream of the KHSD's influence on the South McQuesten River has affected downstream water quality, resulting in increasing concentrations of metals, particularly cadmium and zinc. Station KV-1 is located on the South McQuesten River upstream of any loading sources from AKHM activities or historical mine contributions being managed by ERDC within the KHSD. Samples collected at KV-1 between 1994 and 2006 yielded a median total zinc concentration of 0.031 mg/L (n = 72), whereas samples collected between 2007 and 2016 returned a median total zinc concentration of 0.12 mg/L (n = 108). An investigation into the source of the elevated metals indicated that a scree field in the upper headwater region of Cache Creek was responsible for the increase in metal concentrations in the South McQuesten River (ITL, 2011; EDI, 2005). This area is also located upstream of AKHM and ERDC historical KHSD claims and although the Cache Creek drainage has had some minimal surface exploration, no substantial mining activity has taken place in this area.

Total cadmium and dissolved zinc concentrations in the South McQuesten River were generally higher at KV-1 located upstream of Christal Creek than those downstream at KV-2 (Figure 4-7). Approximately 91% of samples at station KV-1 had exceedances of CCME-PAL total cadmium guideline and 88% at station KV-2. Similarly, 67% of samples at KV-2 and 87% of samples at KV-1 exceeded the CCME-PAL dissolved zinc guideline. As such, the AKHM and historical metal loading captured by Christal Creek do not have a significant effect on the existing cadmium and zinc levels in the South McQuesten River. Seasonal patterns of dissolved zinc concentrations were similar at the South McQuesten River sites in which minima normally occurred in September and October and peak concentrations were observed in the spring. Similar seasonality was observed for total cadmium concentrations.

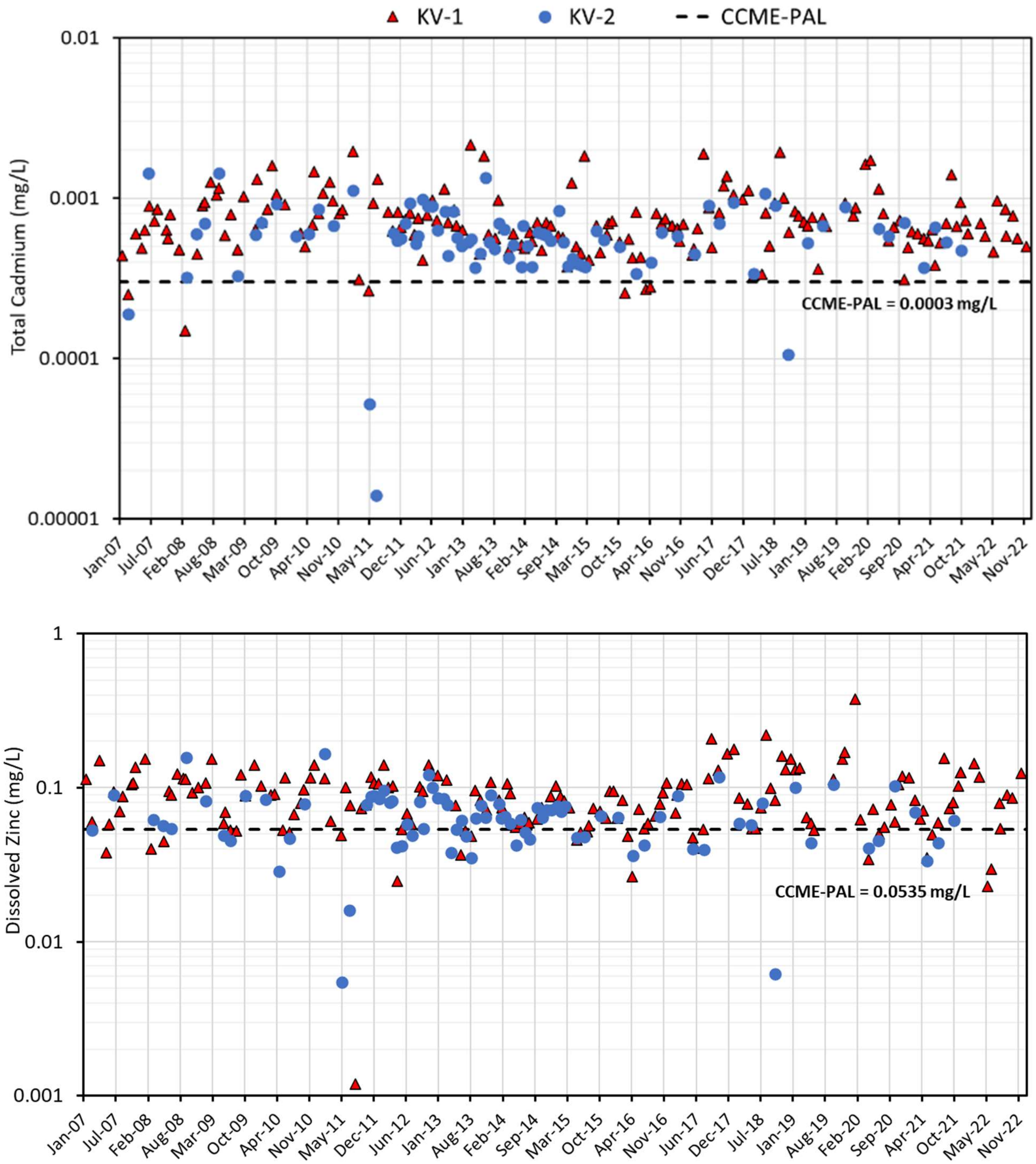



**Figure 4-7: Total Cadmium and Dissolved Zinc Concentrations at Stations KV-1 and KV-2 in the South McQuesten River**

#### 4.2.1.2 CHRISTAL CREEK CATCHMENT

Christal Creek originates on the south side of Galena Hill, flows into Christal Lake, and discharges at the north end of the lake, where it meanders north and west until it discharges into the South McQuesten River approximately 10 km downstream of the lake. The stream is predominately high gradient with erosional habitat through most of the upper reaches, but near the mouth of the creek, it becomes a low gradient meandering watercourse.

Major sources of metal load to Christal Creek include the Galkeno 300 and Galkeno 900 adits, both of which are treated under care and maintenance as part of the Type B Water Licence (QZ17-076). Historically, the Onek 400 adit discharge infiltrated to ground within a few hundred metres of the portal; however, since October 2020 it has been piped to a water treatment plant which discharges treated water at Wernecke Road. Tailings from the historical Mackeno mill, which are deposited at the mouth of Christal Lake and dispersed downstream within Christal Creek, are additional sources of metal load. ERDC manages these historic environmental liabilities.

Of the KHSD Mining Operations components, the Flame & Moth water treatment plant (WTP) and District Mill pond represent the primary sources of water discharge to the Christal Creek catchment.

##### *4.2.1.2.1 Flame & Moth Water Treatment Plant*

The Flame & Moth WTP can discharge to Christal Creek or Lightning Creek. The EQS for each watershed are further defined by the discharge rate, with four ranges identified in Part G, Clause 65 and 66 of Water Licence QZ18-044. Discharge from the Flame & Moth to Christal Creek has only occurred from April 30 to May 7 and May 15 to 16 of 2021 (station KV-104C); otherwise discharge has been directed to Lightning Creek (station KV-104L). Discharge may also be stopped and samples during non-discharge periods are referred to as KV-104ND.

##### *4.2.1.2.2 District Mill Pond*

Construction and placement of the DSTF was initiated in December 2010 during the commissioning of the District Mill. The District Mill Pond and DSTF are located south of Christal Lake, and immediately north of Lightning Creek. Until August 2015, the mill had not produced a discharge to the receiving environment. On August 24, 2015 water was released from the District Mill pond with decanting discontinued by October 17, 2015 to lower the level within the mill pond. Water was discharged from the pond at about 0.5 L/s intermittently over 50 or so days with a total effluent volume of 2,025 $m^3$ released in 2015.

Water was again released from the sedimentation pond starting June 26, 2016 with periodic discharges occurring through July to August 20, 2016. During September 10 to 20, 2016 additional water was pumped from the District Mill pond for a total of 1,675 $m^3$ released in 2016.

No water was released from the district mill pond in 2017.

On June 18 2018, water started being discharged from the District Mill pond with periodic discharges occurring in July, August, October, and November. No discharge from the District Mill Pond to the environment occurred in 2019 to 2022. Approximately 10% and 18% of non-discharge samples from the District Mill Pond (station KV-82) had exceedances of total cadmium and zinc EQS from 2015 to 2021, while no samples had exceedances of cadmium and zinc in 2022. Only one sample had exceedance of zinc EQS at the District Mill Pond discharge (station KV-83) from

2015 to 2018 (Figure 4-8); no subsequent samples have been collected at KV-83 due to lack of discharge from the District Mill Pond.

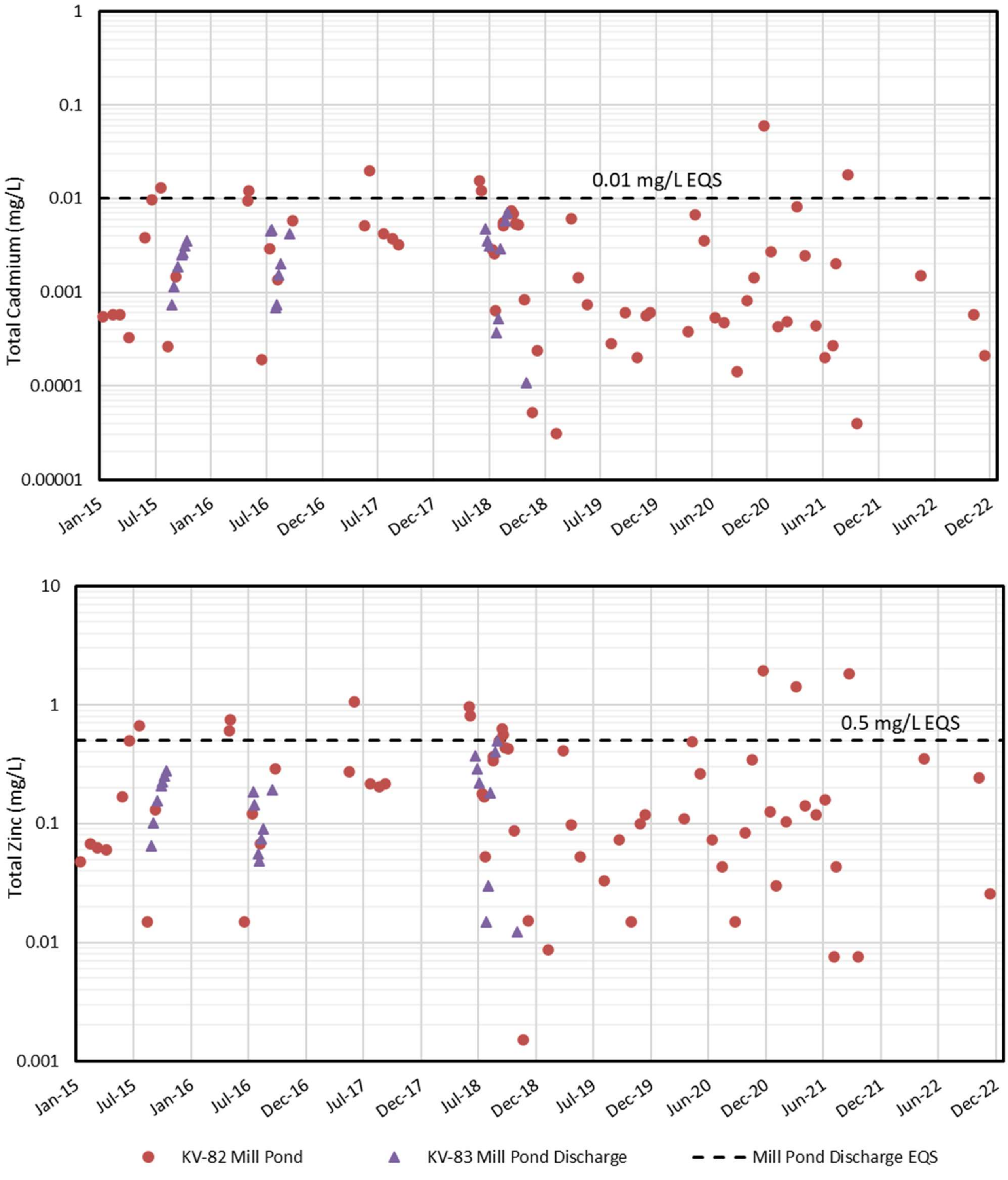



**Figure 4-8: Total Cadmium and Zinc Concentrations in the District Mill Pond**

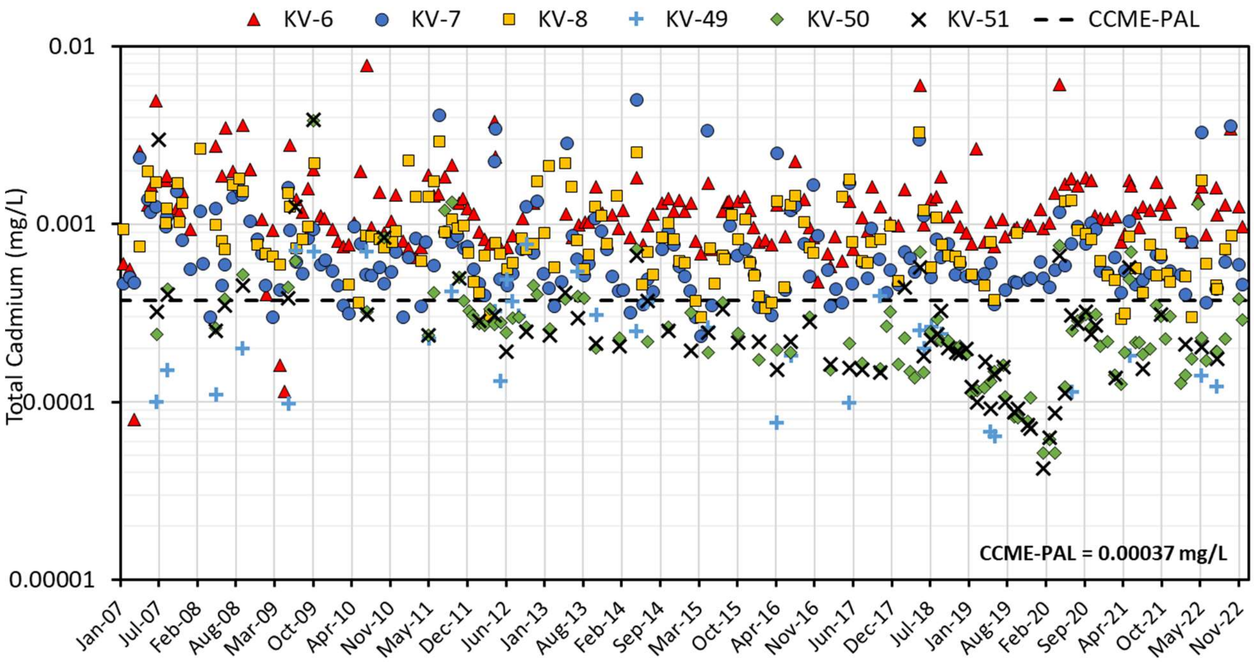
##### *4.2.1.2.3 Christal Creek*

Water quality in Christal Creek is monitored at upstream stations KV-49, KV-50, and KV-51, and downstream along the creek at KV-6, KV-7, KV-8. Stations KV-7 and KV-8 are downstream of all mine sources and integrate effects from the main load sources in the catchment (treated discharge from the Galkeno 300 and Galkeno 900 adits, untreated and treated [since October 2020] discharge from the Onek 400 adit, and the Mackeno Tailings that are adjacent to and partially within Christal Lake and upper Christal Creek). These sites also capture effects of contributions from the UN and Lucky Queen adits, dispersed tailings within Christal Creek, and drainage from Erickson Gulch.

Christal Creek waters are circumneutral to mildly alkaline pH and have high hardness. Time series of total cadmium and dissolved zinc concentrations at each station in the Christal Creek catchment are shown in Figure 4-9. The CCME cadmium guideline is hardness-dependent; for reference, the CCME guideline displayed in Figure 4-9 is calculated based on the median hardness for all samples (KV-6, KV-7, KV-8, KV-49, KV-50, KV-51) collected in the Christal Creek catchment (420 mg/L). Similarly, the CCME dissolved zinc guideline is hardness, pH, and dissolved organic carbon (DOC) dependent; for reference, the CCME guideline displayed in Figure 4-9 is calculated based on the median hardness, pH, and DOC for all samples (KV-6, KV-7, KV-8, KV-49, KV-50, KV-51) collected in the Christal Creek catchment (420 mg/L, pH 7.40, and 1.83 mg/L, respectively).

Cadmium and zinc concentrations have remained relatively steady within seasonal bounds, typically peaking during spring freshet and again in the late fall. The concentrations of both metals typically exceeded their CCME guidelines during spring freshet, due to the markedly lower hardness (and therefore, lower CCME guidelines) present at this time owing to dilution by snowmelt. Total cadmium concentrations at Christal Creek were higher in downstream locations (stations KV-6, KV-7, and KV-8) and lower in upstream locations (stations KV-49, KV-50, and KV-51). In upper Christal Creek, total cadmium concentrations were above the CCME-PAL guideline in 22% of samples at KV-50, 21% at KV-51, and 49% at KV-49. On the other hand, in lower Christal Creek, 94%, 85%, and 89% of samples at KV-6, KV-7, KV-8 had exceedances of the total cadmium CCME-PAL guideline, respectively. Station KV-6 had the highest median total cadmium concentration of all sites within the catchment. These downstream sites generally show total cadmium concentrations peaking from May to July (during freshet).

No evident spatial pattern was identified for dissolved zinc concentrations at Christal Creek. Seasonal fluctuations are likely related to dilution from spring snowmelt. No seasonal variation for dissolved zinc was observed at KV-49. In upper Christal Creek, dissolved zinc concentrations exceeded the guideline in approximately 90% of samples at KV-50 and 83% of samples at KV-51. However, dissolved zinc concentrations were relatively low at station KV-49, showing 20% of samples with exceedances of CCME-PAL dissolved zinc guideline. In lower Christal Creek, dissolved zinc concentrations were above the guideline in 91% of samples at KV-6, 86% at KV-7, and 85% at KV-8. The trends in the lower Christal Creek stations (KV-7 and KV-8) are similar to those observed at the mouth of Christal Creek (KV-6) with higher levels of dissolved zinc concentrations observed during May to September.



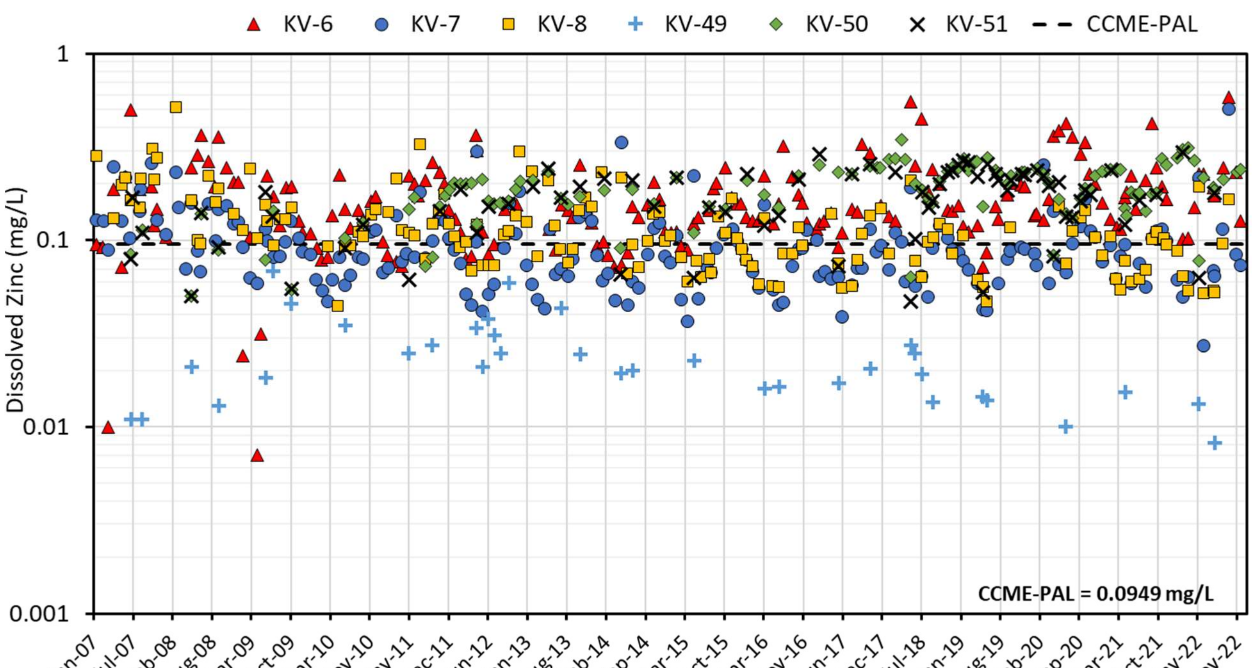




**Figure 4-9: Total Cadmium and Dissolved Zinc Concentrations in Christal Creek**

#### 4.2.1.3 NO CASH CREEK CATCHMENT

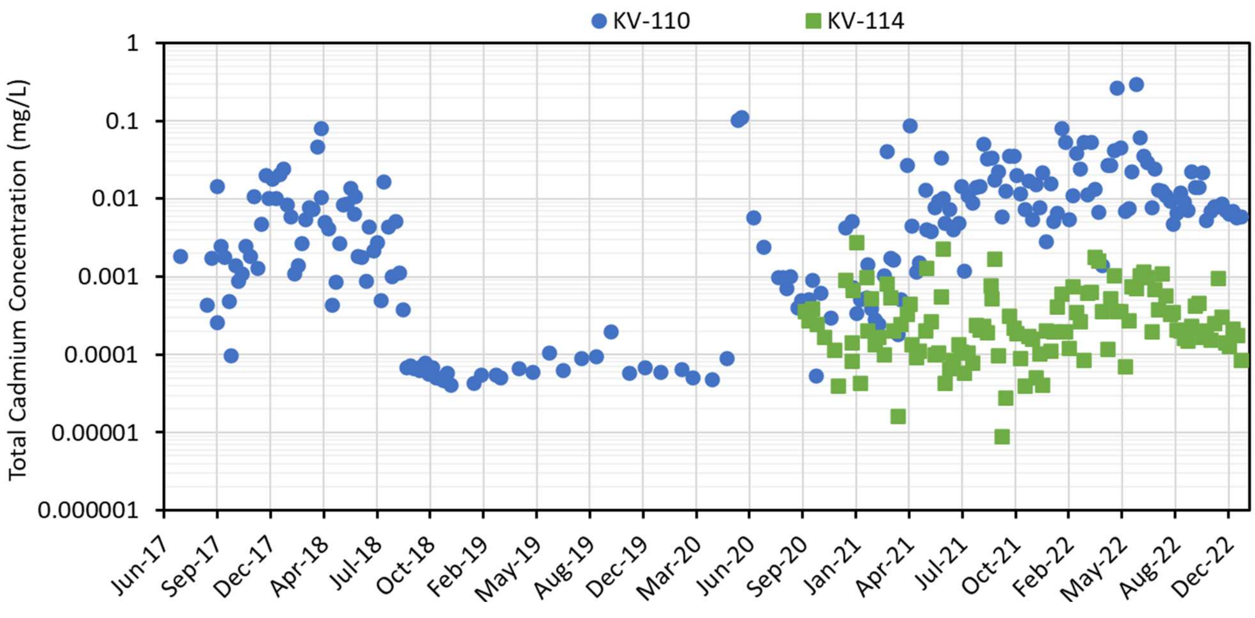
No Cash Creek is located on the northwest side of Galena Hill. The No Cash Creek headwaters are located upstream of the No Cash 500 adit, although the majority of flow in No Cash Creek is supplied by discharge from No Cash 500. The Ruby 400 and historical Bermingham 200 adits are located farther up the hillside; discharge from these adits infiltrates to ground such that there is typically no surface connection to No Cash Creek, although one may form in winter when ground is frozen. Below the Silver Trail Highway, No Cash Creek intersects the No Cash Diversion Ditch and then runs through a poorly drained valley containing extensive areas of heavily vegetated peat bog/marsh. No Cash Creek is not a direct tributary of any other streams but instead terminates in a small pond in a low-lying boggy area of the valley approximately 2 km south of the South McQuesten River.

Discharge of untreated wastewater from No Cash 500, Ruby 400, and Bermingham 200 adits is authorized under the ERDC Type B Water Licence (QZ17-076 and draft Water Licence QZ21-012). No EQS is specified for these adits under the ERDC or AKHM water licences. The New Bermingham mine portal is located adjacent to the historical Bermingham 200 adit.

##### *4.2.1.3.1 New Bermingham*

Discharge from the New Bermingham mine commenced in mid-2017. Mine dewatering was required during development activities at the New Bermingham mine and with issuance of QZ18-044 discharge commenced from the water management pond decant (KV-114) in September 2020. The New Bermingham WTP was installed in November 2020. The water discharged from the New Bermingham mine is treated through the New Bermingham WTP and discharged to ground in the upper No Cash Creek catchment. There is no overland connection with downstream watercourses such as No Cash Creek.

Total cadmium and dissolved zinc concentrations in the New Bermingham portal discharge (station KV-110) were relatively high from November 2017 to June 2018 (Figure 4-10) as water was pumped from the historical Bermingham 200 adit for decline excavation purposes. Concentrations decreased markedly in the fall of 2018 as portal development was suspended during that time. Between September 2018 and May 2020, total cadmium (median 0.000063 mg/L) and dissolved zinc (median 0.010 mg/L) concentrations were between one and two orders of magnitude lower, reflecting local groundwater baseline concentrations. The total cadmium and dissolved zinc concentrations increased from May 2020 to December 2022. Total cadmium and dissolved zinc concentrations in the New Bermingham WTP Pond Decant (KV-114) were one to two orders of magnitude lower than those in the portal discharge (KV-110), ranging from 0.000009 to 0.00275 mg/L (median 0.0002 mg/L) for total cadmium and from less than 0.001 to 0.0965 mg/L (median 0.001 mg/L) for dissolved zinc.



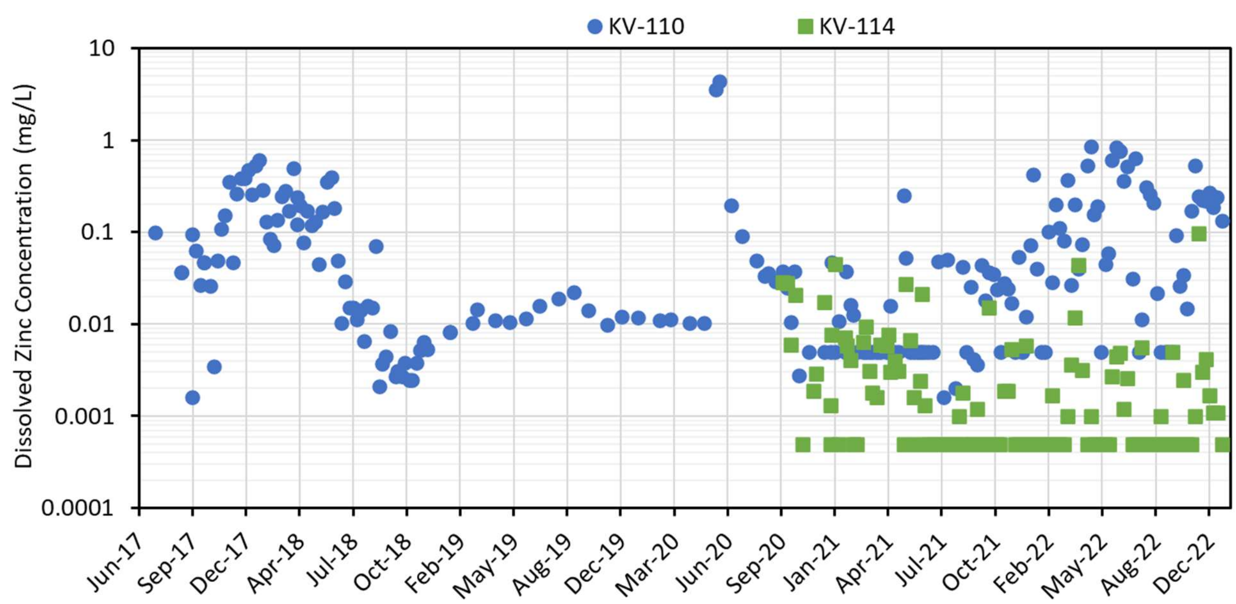




**Figure 4-10**: **Total Cadmium and Dissolved Zinc Concentrations in New Bermingham Portal Discharge (KV-110) and New Bermingham Pond Decant (KV-114)**

##### *4.2.1.3.2 No Cash Creek*

Water quality in No Cash Creek is monitored at stations:

- KV-21, located at the Silver Trail Highway, 500 m downstream of No Cash 500 adit;
- KV-111, located immediately upstream of the No Cash 500 adit; and
- KV-118, located upper No Cash Creek at Calumet Drive and upstream of KV-111

Water at stations KV-118 and KV-111 only flows seasonally and is typically dry/frozen to ground between October and March. Station KV-21 has the longest water quality data record (regular monitoring since 2008), whereas monitoring at KV-111 and KV-117 was initiated more recently, beginning September 2017 and July 2018, respectively.

All samples exceeded the CCME-PAL guidelines for total cadmium and dissolved zinc at both KV-21 and KV-118, whereas 11% and 25% of samples exceeded the guideline for total cadmium and dissolved zinc at KV-111, respectively. Cadmium and zinc concentrations displayed little seasonality at station KV-118, although the highest concentrations tended to occur in late fall or winter (Figure 4-11), likely due to contributions from the historical Bermingham 200 and/or Ruby 400 adit flow that travels farther over frozen ground. Changes in total cadmium and dissolved zinc concentrations at KV-118 did not correlate with those at KV-111. At KV-111, total cadmium and dissolved zinc concentrations were relatively higher in April and May, then declined through the year. Total cadmium and dissolved zinc concentrations at KV-111 were approximately two orders of magnitude lower than those at downstream station KV-21, reflecting the contribution of the No Cash 500 adit discharge to KV-21. Peak concentrations of total cadmium were normally observed in May and October at KV-21. The highest dissolved zinc concentrations were generally observed in the fall at KV-21.

Natural attenuation of cadmium and zinc via co-precipitation with and sorption on iron and manganese (oxyhydr)oxides along the reach of No Cash Creek serves to lower concentrations of cadmium and zinc such that they approach their respective CCME-PAL guidelines towards the terminus of No Cash Creek (ITL, 2013).

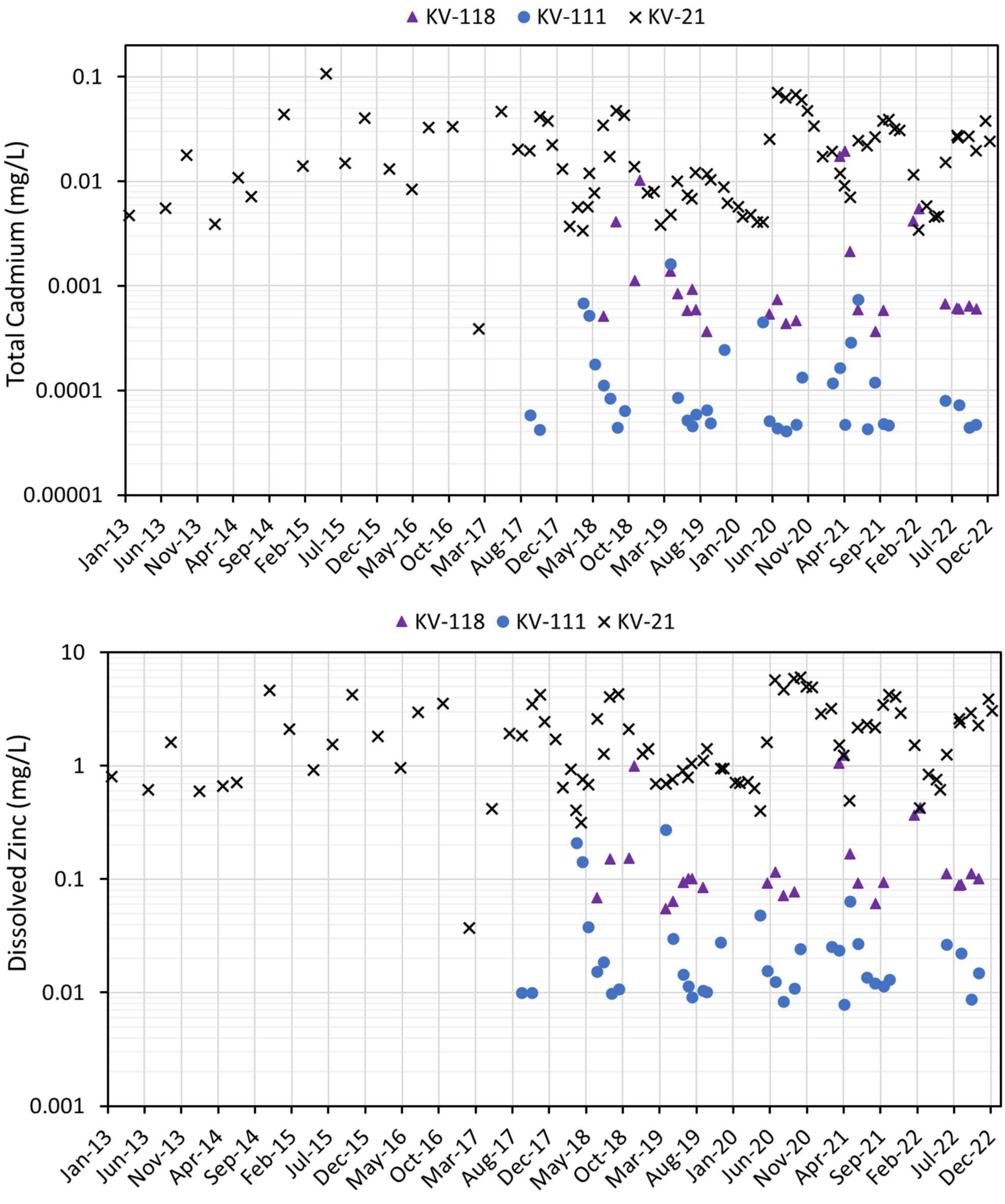



**Figure 4-11**: **Total Cadmium and Dissolved Zinc Concentrations at stations KV-118, KV-111, and KV-21 in No Cash Creek**

### 4.2.2 MAYO RIVER DRAINAGE

#### 4.2.2.1 LIGHTNING CREEK CATCHMENT

Lightning Creek is a mountainous alpine stream flowing within a narrow valley with a steep gradient from the north side of Sourdough Hill into Duncan Creek, which drains into the Mayo River. Historically several mines have been in operation in the Lightning Creek catchment of which the Keno 700 adit is the primary source of metal load. Habitat within Lightning Creek is heavily impacted by historical and ongoing placer mining activities that have been active on the stream and its tributary, Thunder Gulch, since the 1960s. Placer mining operations have had a significant effect on water quality with respect to suspended solids.

Of the KHSD Mining Operations components, the Bellekeno 625 WTP pond decant (KV-43) and Flame & Moth WTP effluent discharged to Lightning Creek (KV-104L) are currently regulated under the Type A Water Licence (QZ18-044).

##### *4.2.2.1.1 Bellekeno Water Treatment Plant*

The Bellekeno mine site is near the confluence of Thunder Gulch with Lightning Creek, on the north side of Sourdough Hill. Thunder Gulch flows into Lightning Creek roughly 300 m down the hill from the Bellekeno Treatment Facility. Bellekeno 625 WTP decant water is discharged east of the treatment facility and reports to ground, eventually flowing via a diffuse surface pathway into Lightning Creek, downstream of Thunder Gulch.

In the fall of 2015 infrastructure was removed from the 900 level of the Bellekeno mine to allow the 900 level working to flood up to the 800 level. Flooding of the 900 level workings began in November 2015, therefore, no discharge from the mine occurred for several months. In early July 2016, groundwater reached the 800 level and water was once again pumped to surface and treated as required, with treated effluent discharge starting up again July 8, 2016.

Discharge at the Bellekeno 625 adit has been monitored since at least 1984. Discharges occurred from August 2010 to October 2021 (with exception of time in 2015 and 2016 when part of the mine was allowed to flood) and no discharge from Bellekeno 625 adit has occurred since October 2021 when the mine was allowed to flood when put into temporary closure. Discharge from Bellekeno 625 adit is expected to resume in by May 2023. The trends in total zinc and cadmium concentrations are similar in the Bellekeno 625 adit discharge (Figure 4-12), reflecting a common source such as sphalerite. Of the EQS-regulated parameters, total zinc concentrations were constantly above the EQS of 0.5 mg/L throughout the monitoring period, ranging from 0.03 to 547 mg/L (median 2.9 mg/L). Over the same period, total cadmium concentrations typically remained comparable with or below the EQS of 0.01 mg/L (median 0.011 mg/L; Figure 4-12).

Total zinc concentrations and pH of the treated decant water at Bellekeno are shown in Figure 4-12. Total zinc concentrations in the treated decant typically remained well below the EQS (0.5 mg/L) with median concentrations being around 0.06 mg/L. Occasional marginal exceedances (e.g., November 24, 2015, January 17, 2017, October 31, 2019, September 8, 2020) were related to elevated particulates in the sample or power outages resulting in the suspension of lime addition.

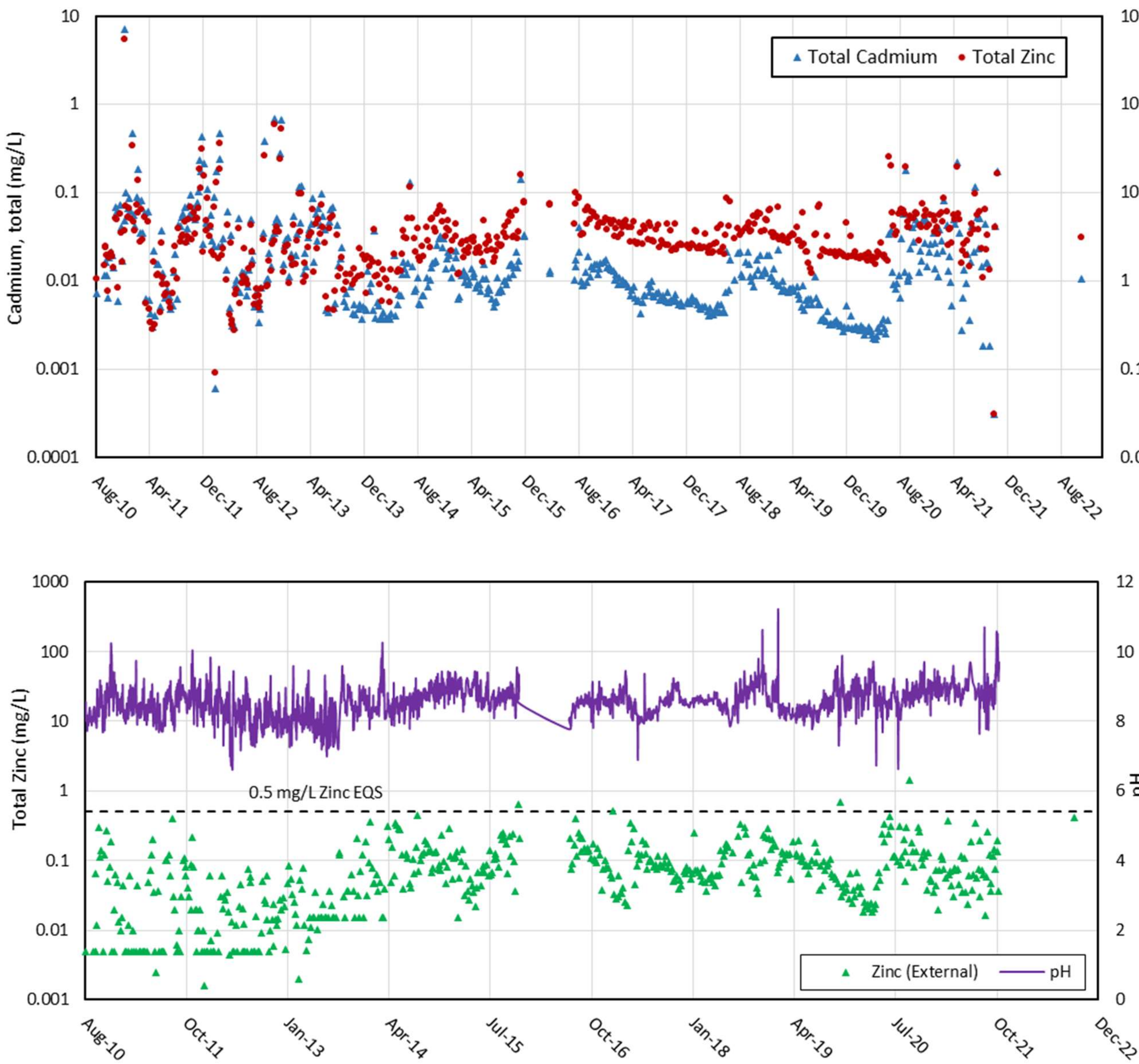



**Figure 4-12: Total Cadmium and Zinc Concentrations in the Untreated Bellekeno 625 Adit Discharge (top) and Treated Bellekeno 625 WTP Decant pH and Zinc Concentrations (bottom)**

#### *4.2.2.1.2 Flame & Moth Water Treatment Plant*

The Flame & Moth water treatment system can discharge to Christal Creek or Lightning Creek. The EQS for each watershed are further defined by the discharge rate, with four ranges identified in Part G, Clause 65 and 66 of Water Licence QZ18-044.

Continuous water sampling was conducted at the Flame & Moth adit (KV-105) from July 2018 to December 2022, with discharge going to the WTP. Effluent discharge occurred periodically to the Lightning Creek watershed (<10 L/s); discharge to Christal Creek was limited to 9 days in 2021 (Section 4.2.1.2.1). Water samples were collected at the Flame & Moth WTP effluent to Lightning Creek (KV-104L) from October 2018 to December 2022. Discharge to KV-104L or KV-104C is manually controlled and non-discharge from the Flame & Moth WTP is station KV-104ND,

Monitoring from 2018 to 2022 show cadmium and zinc concentrations in the Flame & Moth adit (KV-105) typically below EQS prior to treatment (Figure 4-13). Dissolved cadmium concentrations at the Flame & Moth adit (KV-105) and WTP effluent to Lightning Creek (KV-104L) were below the EQS at all time points, ranging from less than 0.000005 to 0.001 mg/L. All water samples at the Flame & Moth WTP discharge (KV-104L) had dissolved zinc concentrations below the EQS, ranging from less than 0.001 to 0.08 mg/L.

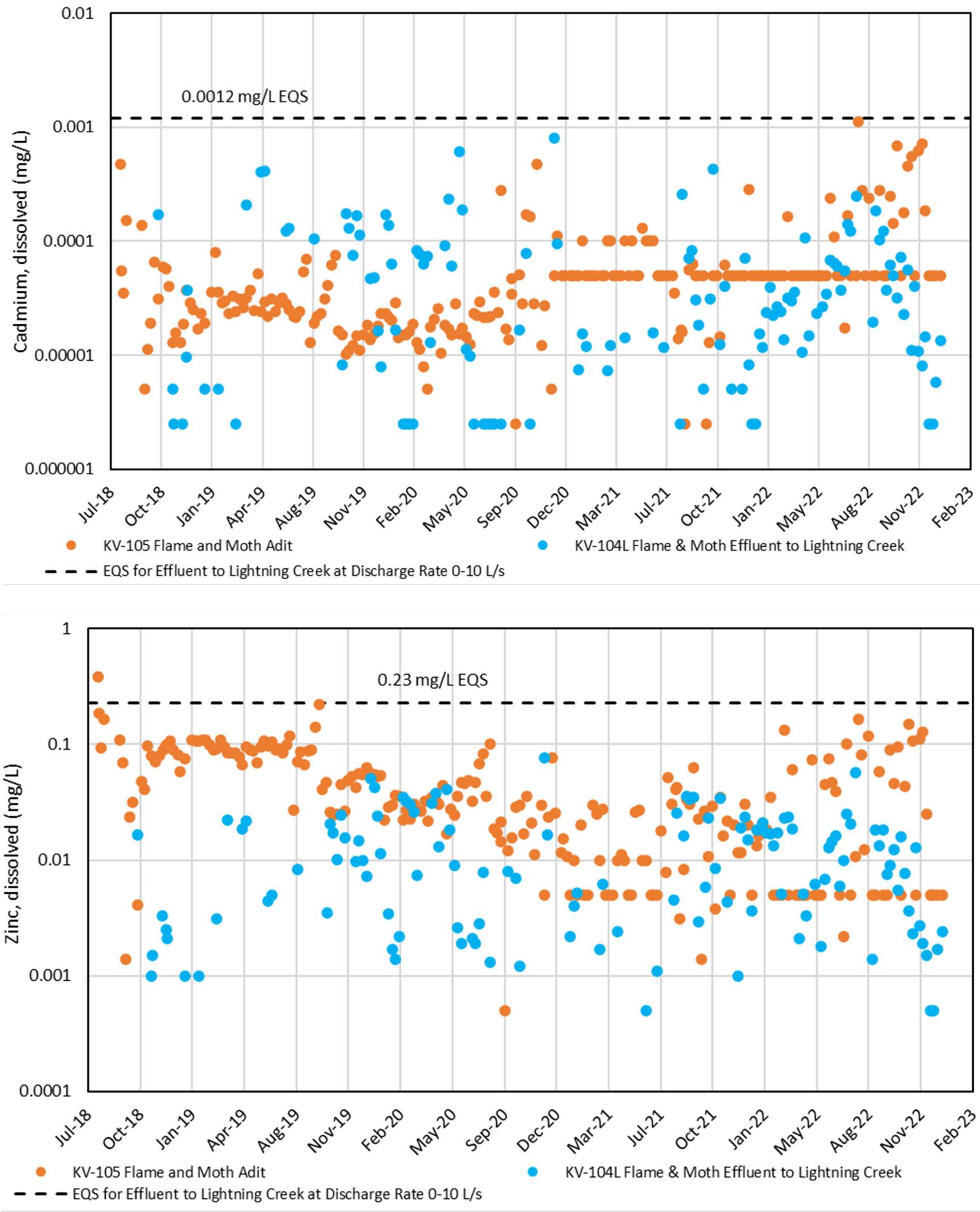



**Figure 4-13: Dissolved Cadmium and Zinc Concentrations in Flame & Moth Discharge**

#### *4.2.2.1.3 Lightning Creek*

There are nine regularly monitored sites under AKHM Water Licence QZ18-044 within the Lightning Creek catchment, of which the cadmium and zinc concentrations in samples collected from stations located on Lightning Creek and Thunder Gulch are discussed herein:

- KV-37, located upstream of KHSD Mining Operations and historical mine inputs and represent background concentrations (although placer mining has occurred upstream in recent years);
- KV-38 located on Lightning Creek downstream of input from the historical Keno 700 adit and upstream of the Bellekeno and Flame & Moth WTP discharges;
- KV-41 located on Lightning Creek downstream of the Bellekeno WTP discharge and upstream of the Flame & Moth WTP discharge; and
- KV-81 located on Lightning Creek downstream of both the Bellekeno and Flame & Moth WTP discharges.

Time series of total cadmium and dissolved zinc concentrations at each site in the Lightning Creek catchment are shown in Figure 4-14. The CCME cadmium guideline is hardness-dependent; for reference, the CCME guideline displayed in Figure 4-14 is calculated based on the median hardness for all samples (KV-37, KV-38, KV-41, KV-65, KV-76, KV-81) collected in the Lightning Creek catchment (106 mg/L). Similarly, the CCME dissolved zinc guideline is hardness, pH, and DOC dependent. For reference, the CCME guideline displayed in Figure 4-14 is calculated based on the median hardness, pH and DOC for all samples (KV-37, KV-38, KV-41, KV-65, KV-76, KV-81) collected in the Lightning Creek catchment.

The median total cadmium concentration was lowest at the sites upstream of mine inputs (i.e., KV-37, 0.000018 mg/L and KV-65, 0.00006 mg/L). The highest median cadmium concentrations were observed at KV-76 (0.00013 mg/L) and KV-38 (0.00012 mg/L). KV-38 had the second highest median total cadmium concentration within the Lightning Creek catchment due to load contributions from the upstream untreated Keno 700 adit. Of the samples collected at KV-38, 42% exceeded the CCME-PAL cadmium guideline compared to 12% at KV-37, located upstream of the Keno 700 adit contribution in lower Lightning Creek. Similarly, the median dissolved zinc concentration observed at KV-38 (0.0111 mg/L; 37% samples exceeded CCME-PAL) was highest, whereas the median dissolved zinc concentration observed farther upstream at KV-37 (0.002 mg/L; 9% samples exceeded CCME-PAL) was the lowest within the entire catchment. CCME PAL exceedances were normally observed in May during freshet, coincident with the lowest hardness levels and therefore lower hardness dependent calculated CCME-PAL guideline. That KV-38 generally returned the highest dissolved zinc concentrations is due to the Keno 700 adit discharge, which contains elevated zinc (median 1.6 mg/L) and flows into Hope Gulch, which in turn discharges to Lightning Creek just upstream of KV-38.

At Thunder Gulch, the median total cadmium concentration at KV-76 (0.00013 mg/L) was approximately double that observed at KV-65 (0.00006 mg/L). CCME-PAL exceedances for total cadmium were commensurately higher at KV-76 (44% of samples) than KV-65 (25%). The total cadmium concentrations gradually increased at both sites from 2008 to 2014, then fluctuated from 2015 to 2022, exhibiting a seasonal variability in which higher concentrations occurred in spring/summer and lower concentrations in winter, likely due to freshet. Over the monitoring period from 2008 to 2022, total cadmium concentrations at KV-65 ranged from lower than 0.00001 to 0.00795 mg/L (median 0.00006 mg/L). Total cadmium concentrations at station KV-76 ranged from 0.00002 to 0.011 mg/L (median

0.00013 mg/L) over the 2008 to 2022 period. Most of the CCME-PAL exceedances at the Thunder Gulch sampling locations occurred through May to July, which coincides with spring freshet and periods when placer mining is active on Thunder Gulch.

Over the monitoring period from 2008 to 2022, the dissolved zinc concentration at KV-65 ranged from less than 0.001 to 0.019 mg/L (median 0.0021 mg/L). Approximately 3% samples from KV-65 collected during the monitoring period exceeded the CCME-PAL guideline for dissolved zinc. Dissolved zinc concentrations were slightly higher at the station KV-76 downstream of KV-65, ranging from less than 0.001 to 0.0235 mg/L (median 0.0052 mg/L). Approximately 13% of samples from KV-76 exceeded the CCME-PAL guideline. Most of the exceedances occurred May to August. Seasonal variations also occurred with peak concentrations observed during the same period.

KV-41 and KV-81 had 29% and 25% of samples that exceeded the cadmium CCME-PAL guideline, respectively. Total cadmium concentrations at KV-41 and KV-81 were generally similar with exceedances and annual peaks occurring May to September. At lower Lightning Creek, KV-81 had the second highest median dissolved zinc concentration (0.0085 mg/L) of the catchment and 10% of samples exceeded the CCME-PAL dissolved zinc guideline. The dissolved zinc concentrations were slightly decreased at KV-41, farther upstream of KV-81, with a median of 0.0076 mg/L. KV-41 had 10% of samples that exceeded the CCME-PAL dissolved zinc guideline. Dissolved zinc concentration at KV-41 and KV-81 were similar with annual peaks normally occurring in May (during freshet). Overall, concentrations have not shown much change since the start of the Flame & Moth WTP discharge to Lightning Creek from 2018 to 2022, suggesting that it has not had a material effect on Lightning Creek water quality.

It should be noted that the median dissolved cadmium concentrations were generally lower than the median total cadmium concentrations within the Lightning Creek catchment, suggesting that the cadmium in this catchment had a significant particulate component. This reflects the influence of placer mining activities and associated raised TSS levels, which in turn result in elevated total cadmium concentrations. The number of dissolved cadmium samples that exceeded the CCME-PAL cadmium guideline was much lower at each site (i.e., 2.5% of samples exceeded the guideline at KV-65, 28% at KV-76, 9% at KV-37, 37% at KV-38, 10% at KV-41, and 13% at KV-81 respectively).

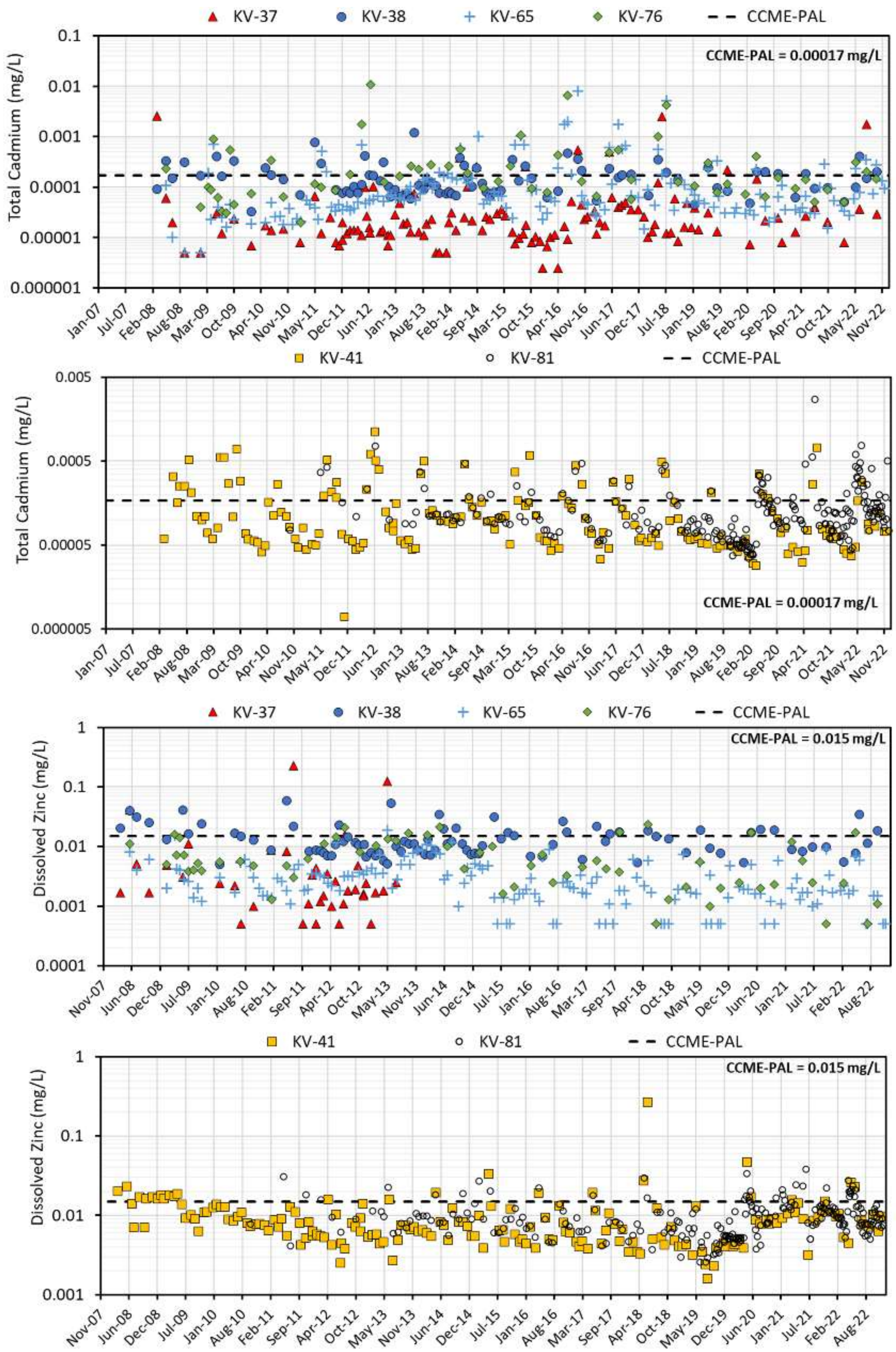



**Figure 4-14: Cadmium and Zinc Concentrations in Lightning Creek (KV-37, KV-38, KV-41, and KV-81) and Thunder Gulch (KV-65 and KV-76)**

# 5 GROUNDWATER

## 5.1 GROUNDWATER CONDITIONS

Extensive groundwater studies have been conducted throughout the KHSD, which include mapping of the geology and historic mine development in the KHSD, hydrogeological investigations, and ongoing monitoring. A Conceptual Model and Preliminary 3D Groundwater Model (Piteau, 2016) was also developed that includes particle tracking to map the potential groundwater flow paths from historical mine workings.

Regionally, the KHSD groundwater flow regime is controlled by (1) topography, (2) hydraulic characteristics of the local geologic units, and (3) natural infiltration of meteoric water (recharge), particularly in the three prominent hills that comprise the KHSD, Galena Hill, Sourdough Hill and Keno Hill. The water table is generally a muted image of the overlying topography so that groundwater flow directions are similar to the regional ground slopes. Groundwater flow divides are interpreted to coincide with the major watershed divides. Groundwater migrates from highland areas (where most recharge occurs) towards lowland areas where groundwater discharges to perennial streams (primarily Flat Creek, Christal Creek, Lightning Creek). Groundwater flow is concentrated in higher permeability geologic materials, which include overburden (where present) and shallow bedrock (which tends to be more fractured).

Locally, the regional groundwater flow characteristics can be altered by the presence of higher permeability rock discontinuities (faults, fracture zones, mineralized veins) and underground mine workings. It is common for underground mine workings to operate as hydraulic sinks so that groundwater inflows are conveyed through the workings to adit portals where the collected groundwater is discharged to surface water (Piteau, 2016). Adit discharges can be significant for underground workings that intersect permeable faults or are located below open mine pits that collect surface runoff/snowmelt and convey this water into the subsurface. Some underground workings collect groundwater at upgradient locations, convey this water through the workings, and then recharge the groundwater system at downgradient locations without adit discharges.

The regional groundwater flow system results in perennial streams that are gaining (receiving groundwater discharge) along most of their lengths. An exception to this occurs along Lightning Creek south and west of Keno City. Along this reach, Lightning Creek is a losing stream that recharges the groundwater system north of the Creek.

Groundwater flow is concentrated in higher permeability geologic materials, which include overburden (where present) and shallow bedrock (which tends to be more fractured).

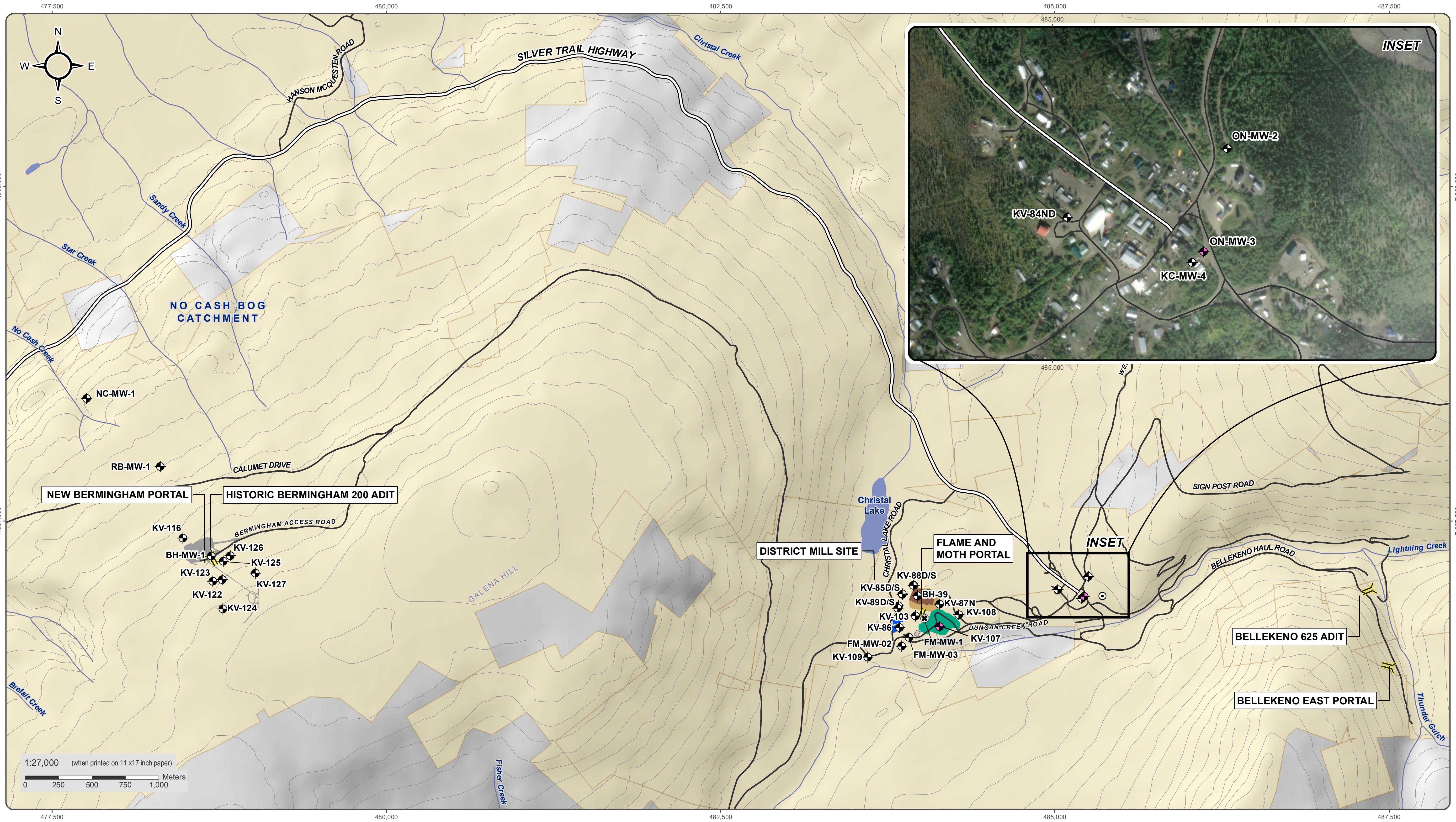
The groundwater monitoring well locations for the proposed and existing KHSD Mining Operations are described by catchment in Table 5-1, and the locations of the wells are shown on Figure 5-1 to Figure 5-3.

### Table 5-1: Keno Hill Silver District Groundwater Monitoring Well Network

| Site | Description | Total Depth (m) | Screen Length (m) | Geology/lithology of screened interval | Monitoring Date Range |
|---|---|---|---|---|---|
| BH-MW-1[1] | Well d/g of the historical Bermingham 200 Adit | 21.34 | 3.0 | Graphitic Schist/Quartzite | September 2013 – Present |
| RB-MW-1 | Well d/g of the Ruby 400 Adit and WRSA | 13.41 | 3.0 | Gravel, Sand, Silt and Cobble/Graphitic Schist | September 2013 – Present |
| NC-MW-1 | Well u/g of the NC 500 Adit | 35.7 | 12.0 | Bedrock | December 2020 – Present |
| KV-116 | New Bermingham Waste Rock Disposal Area | 12.9 | 6.0 | Bedrock | November 2020 – Present |
| KV-122 | New Bermingham Waste Rock Disposal Area | 26.70 | 6.0 | Bedrock | November 2020-Present |
| KV-123 | New Bermingham Waste Rock Disposal Area | 44.56 | 6.0 | Bedrock | November 2020-Present |
| KV-124 | New Bermingham Waste Rock Disposal Area | 15.83 | 6.0 | Bedrock | November 2020-Present |
| KV-125 | New Bermingham Waste Rock Disposal Area | 59.16 | 6.0 | Bedrock | January 2021-Present |
| KV-126 | New Bermingham Waste Rock Disposal Area | 71.24 | 7.0 | Bedrock | December 2020 - Present |
| KV-127 | New Bermingham Waste Rock Disposal Area | 27.61 | 9.0 | Bedrock | November 2020-Present |
| KV-84ND | Bedrock well on Keno Firehall lot to replace KV-84 | 88.39 | 12.0 | Graphite/Schist/Quartzite/Muscovite/Sericite Schist/Pyrite | 2013 – Present |
| KV-85D[2] | DSTF and Mill Site Groundwater Well #1 (PH2) Deep | 42.7 | 3.0 | Bedrock | 2010 – 2022 |
| KV-85S | DSTF and Mill Site Groundwater Well #1 (Shallow) | 4.03 | 1.5 | Gravel and Silt | October 2011 – Present |
| KV-86[2] | DSTF and Mill Site Groundwater Well #2 (PH5) | 36 | 3.0 | Fine gravel and coarse sand | 2010 – Present |
| KV-87 | DSTF and Mill Site Groundwater Well #3 (PH6) | 57.9 | 3.1 | Bedrock | 2010 – May 2018 |
| KV-87N | New 2020 Flame & Moth Site Groundwater Well #3 | 94.8 | 21.0 | Bedrock | December 2020 – Present |

| Site | Description | Total Depth (m) | Screen Length (m) | Geology/lithology of screened interval | Monitoring Date Range |
|---|---|---|---|---|---|
| KV-88D[2] | DSTF and Site Groundwater Well #4 (Deep) | 50.1 | 15 | Bedrock | October 2011 – Present |
| KV-88S | DSTF and Mill Site Groundwater Well #4 (Shallow) | 4.11 | 1.5 | Sand/Gravel/Silt/Bedrock | October 2011 – Present |
| KV-89D[2] | Flame & Moth Site Groundwater Well #5 (Deep) | 38.3 | 10 | Bedrock | October 2011 – Present |
| KV-89S | DSTD and Mill Site Groundwater Well #5 (Shallow) | 4.8 | 1.5 | overburden | October 2011 – Present |
| KV-103 | Mill Supply Well | 82.3 | n/a | Sand with Gravel/Glitstone (Shale) | November 2015 - Present |
| KV-107 | Proposed DSTF expansion area | TBD | TBD | TBD | TBD |
| KV-108 | Upgradient of DSTF expansion area | 94.3 | 12.0 | Bedrock | December 2020 – Present |
| BH-39 | Phase I of DSTF | 7.5 | 7.5 | Tailings | 2012 – Present |
| FM-MW-1[2,3] | Flame & Moth Well #1 (KAR-01) | 182.3 | 12.2<br>12.2 | Quartzite/Schist/Graphite Schist/Sericite Schist<br>Greenstone/Mineralized Vein | August 2013 – 2020 |
| FM-MW-2[3] | Flame & Moth Well #2 (KAR-02) | 244.4 | 12.2<br>12.2 | Quartzite<br>Quartzite/Stringer Zone | August 2013 – Present |
| FM-MW-3 | Flame & Moth Well #3 (KAR-16) | 195.7 | 12.2 | Quartzite/Graphics Schist | September 2013 – Present |
| KC-MW-4[2] | Well south of Onek 400 Adit | 82.3 | 2.2 | Gravel/Sand/Boulder/Cobble | 2011 – 2014 |
| ON-MW-2 | Onek Monitoring Well #1 d/g Project Facilities | 66.3 | 6.0 | Bedrock/quartzite/graphitic schist | August 2012 – Present |
| ON-MW-3 | Proposed Well south of Onek 400 Adit | TBD | TBD | TBD | TBD |
| KV-109 | Flame & Moth Lightning Creek Discharge area near KV-81 | 27.6 | 3.1 | Schist/Quartzite | July 2018 – Present |

**TBD – To be determined, these wells are proposed.*
*[1] Well has been dry since October 2017.*
*[2] Well is broken. KV-85D – frost jacked; KV-86 – flattened by loader and therefore not monitored in 2022; KV-88D – well kinked at 10 m; KV-89D – logger is stuck in the well; FM-MW-1 – well compromised by on-site equipment; KC-MW-4 – broken.*
*[3] These wells have two sections of screen. Screen lengths and lithology values are presented in order of upper screen and lower screen.*

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Datum: NAD 83; Map Projection: UTM Zone 8N



- Proposed Monitoring Well
- Monitoring Well
- Decomissioned Monitoring Well
- Adit
- As-Built MIne Footprint
- Pond
- DSTF 322k Tonnes Design
- Current DSTF
- To Be Constructed Mine Features
- Alexco/ERDC Quartz Claims
- Silver Trail Highway
- Other Road

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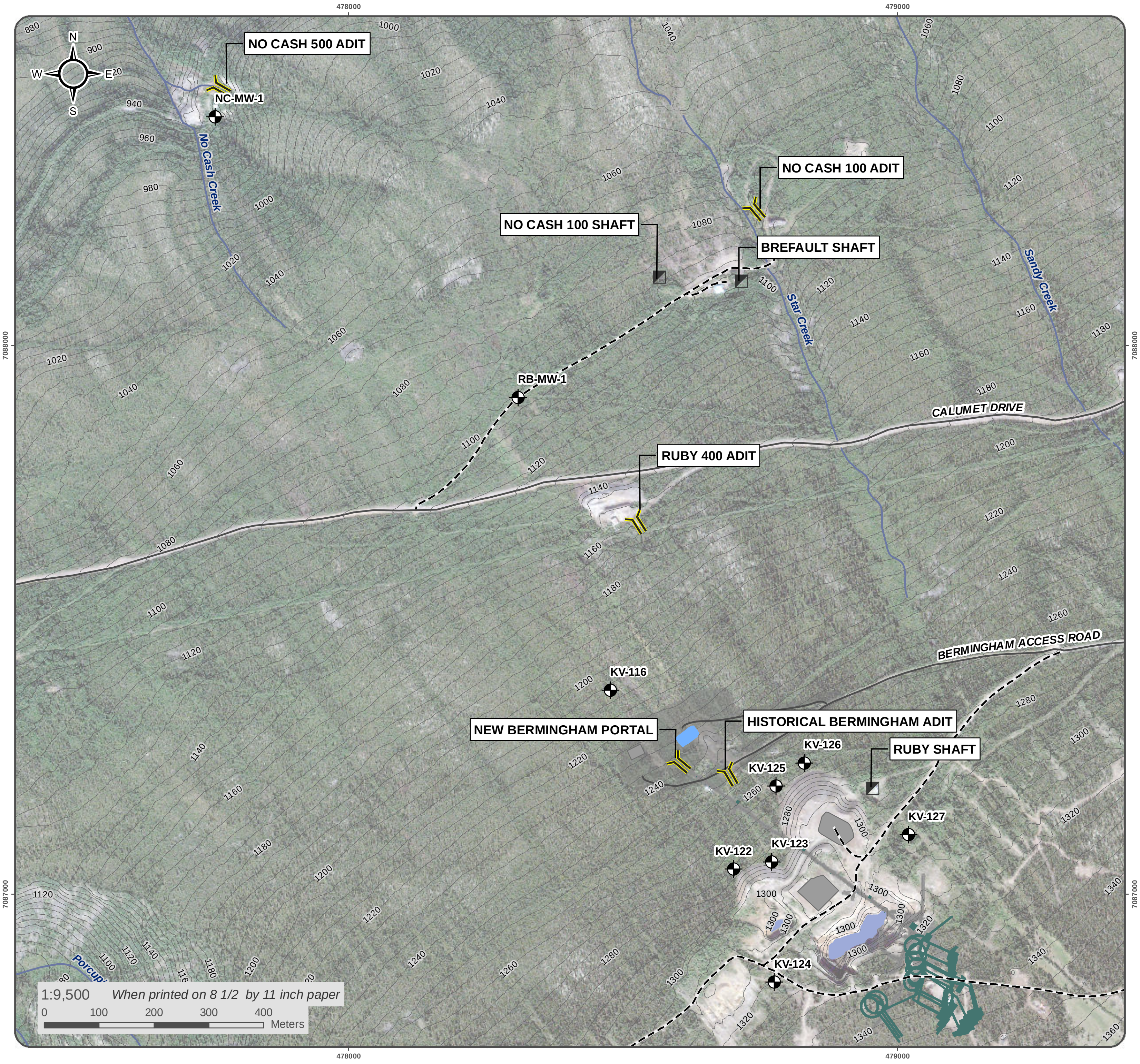
HECLA KENO HILL

**FIGURE 5-1**

**KHSD GROUNDWATER MONITORING LOCATIONS**

FEBRUARY 2023




HECLA KENO HILL

# FIGURE 5-2

## BERMINGHAM GROUNDWATER MONITORING LOCATIONS

FEBRUARY 2023

- Adit/Portal
- Shaft
- Groundwater Quality Monitoring, Existing
- Groundwater Quality Monitoring, Proposed
- Pond
- Proposed Underground Workings
- Road
- Limited-Use Road
- Contour (5m interval)

Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on February 06 2023

Datum: NAD 83; Map Projection: UTM Zone 8N



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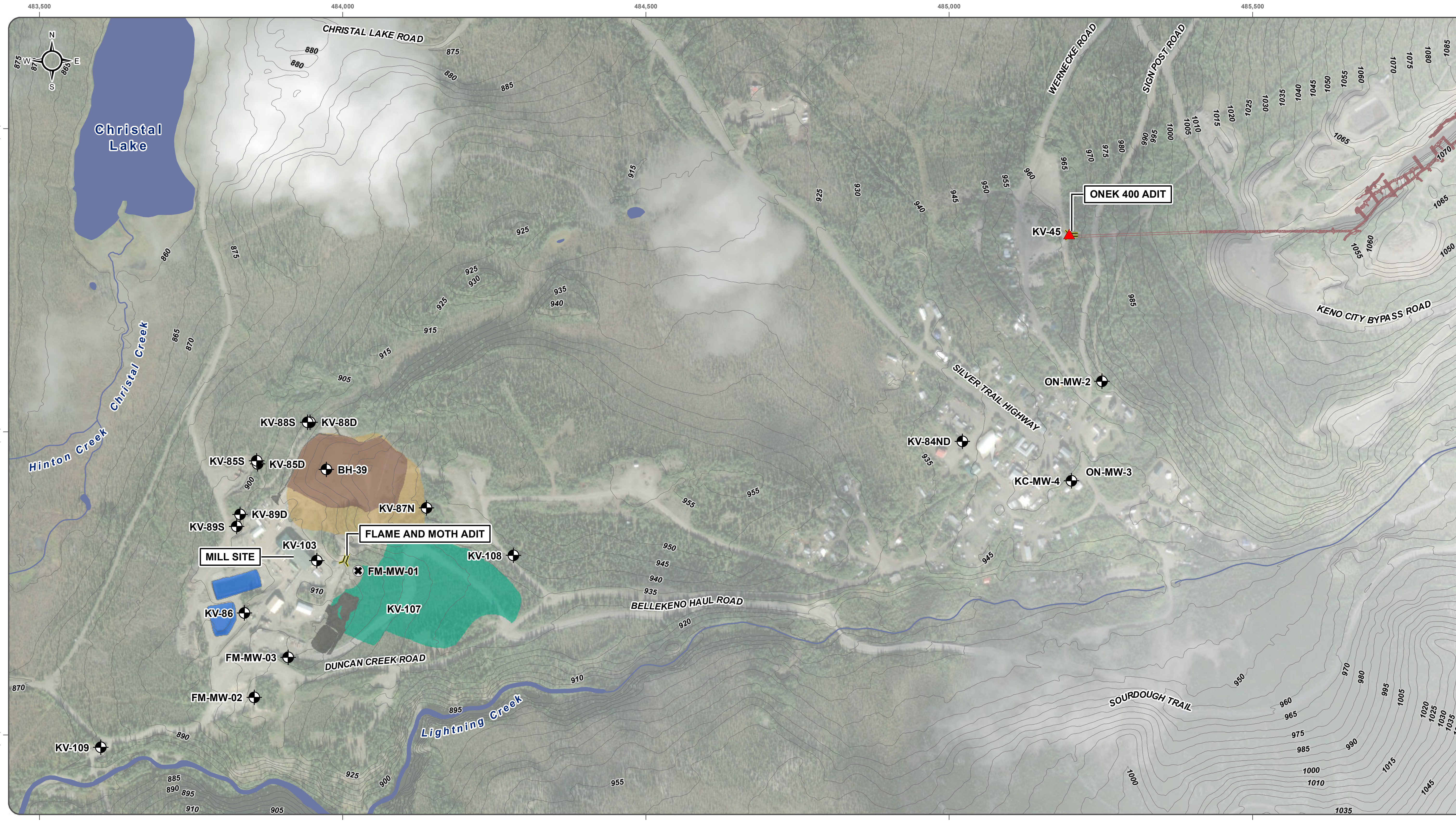


Satelite imagery obtained from ESRI Imagery map service http://goto.arcgisonline.com/maps/World_Imagery on February 2023

Datum: NAD 83; Projection: UTM Zone 8N

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1:6,000 *(when printed on 11 x17 inch paper)*

0 50 100 150 200 250 Meters

- Monitoring Well
- Decomissioned Monitoring Well
- Surface Water Quality Station
- Adit
- Infrastructure Footprint
- Pond
- DSTF 322k Tonnes Design
- Current DSTF
- To Be Constructed Features
- Underground Workings
- Waterbody
- Watercourse
- Contour (5m)

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FIGURE 5-3

GROUNDWATER MONITORING LOCATIONS AT DISTRICT MILL SITE, FLAME AND MOTH, ONEK 990 AND KENO CITY

FEBRUARY 2023

## 5.2 GROUNDWATER HYDROLOGY

Characterization of the KHSD groundwater hydrology has been done conceptually, as well as through physical testing. Pumping tests and slug tests have been conducted on most of the wells installed throughout the KHSD, and water level elevations are tracked manually and through a network of continuous loggers. This field data combined with the mapped geology is used to describe the expected flow paths and seasonal changes to the water table for each mine.

Additional characterization work was done around some mines where mine dewatering rates needed to be estimated. Air lift testing was conducted at the New Bermingham and Flame & Moth mine sites during drilling of new monitoring wells.

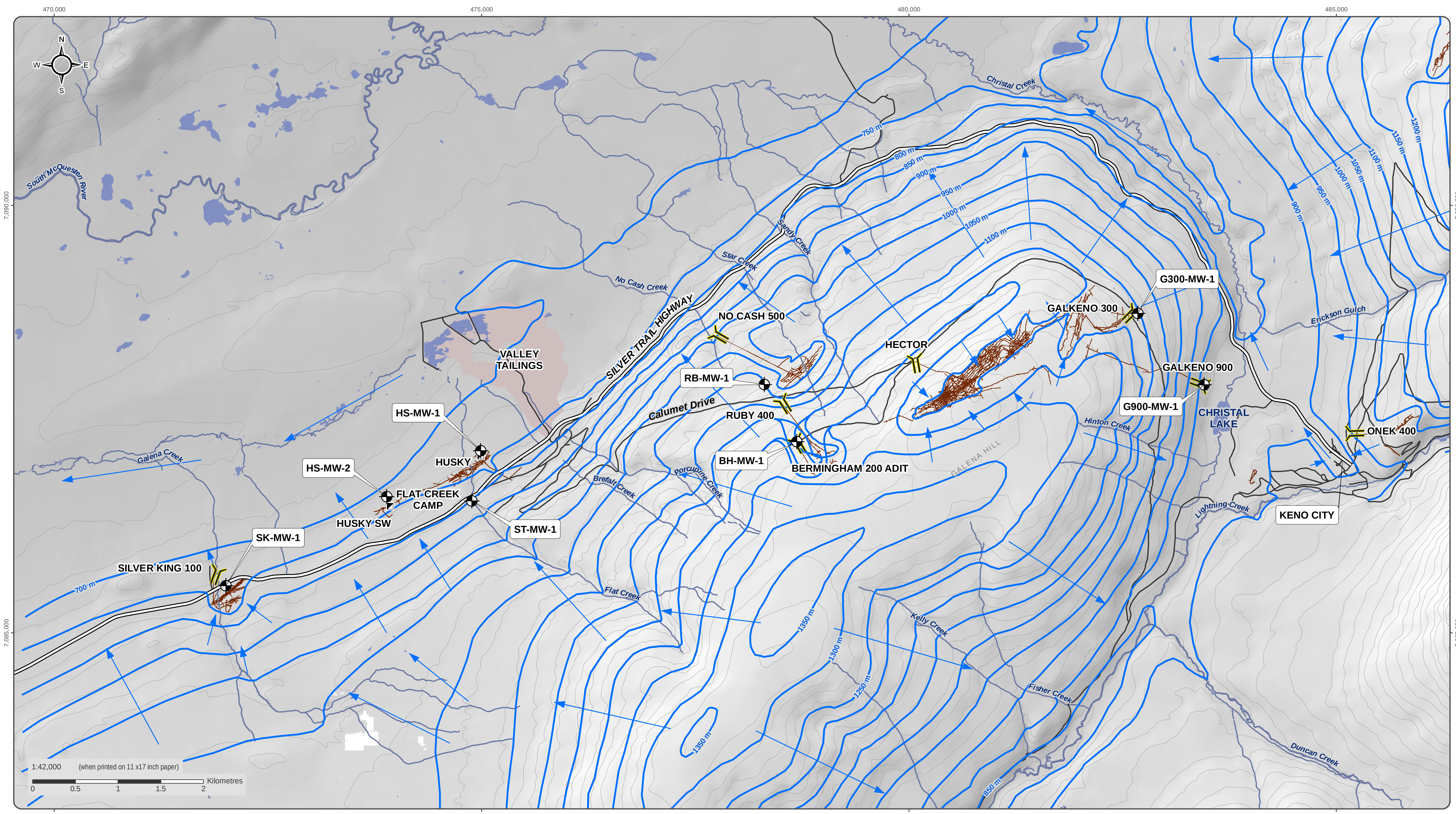
Figure 5-4 presents conceptual groundwater level contours and groundwater flow directions for Galena Hill. The contours were constructed so that water levels were:

- below ground surface;
- at ground surface at streams in gullies;
- consistent with measured water levels; and
- met with mine pool levels.

Although the contours are conceptual in nature, they provide an indication of flow directions and the apparent catchment area of the various mines. The primary discharge areas illustrated are Flat Creek Valley, No Cash Creek, Star Creek, Sandy Creek, Christal Creek Valley, and Lightning Creek Valley.

Based on the contours, the gradients indicated range from 3% to 30%. Much of the groundwater is expected to migrate in the more permeable shallow bedrock and overburden. For this high-level conceptual assessment, inferred velocities on the north and northwest side above an elevation of 950 masl to 1150 masl are estimated to be 10’s to 100’s m/year in the sand and gravel overburden and 1’s m/day to 10’s m/year in the disturbed bedrock.

The groundwater entering the mine workings is sourced from meteoric recharge. This recharge is enhanced in some areas by open-pit workings that overlie underground workings, and waste dumps that reduce evapotranspiration. Some historic mine workings have caused noticeable deviations from natural groundwater flowpaths toward mine discharge areas, including Galkeno and Hector Calumet, Ruby, No Cash, and Silver King.

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- Monitoring Well
- Adit
- Shaft
- Valley Tailings Area
- Underground Mine Workings
- Groundwater Flow Direction
- Groundwater Contour (50m Intervals)
- Waterbodies
- Watercourses
- Silver Trail Highway
- Secondary Road
- Contours (100 ft intervals)

* Only showing mine sites referenced in document

* * Depth to water table displayed in MASL when used for contour interpretation

*** GW Contours provided by Rod Smith

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KENO HILL SILVER DISTRICT

## FIGURE 5-4

## GALENA HILL GROUNDWATER CONTOURS

DECEMBER 2021

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### 5.2.1 NO CASH CREEK

In 2016, Piteau Associates Engineering Ltd. (Piteau) conducted a preliminary groundwater model for the KHSD for Elsa Reclamation and Development Company Ltd. for mine reclamation. The preliminary model included particle tracking to determine probable groundwater flow paths from historical mine workings. The particle tracking indicated that regional groundwater derived from the Ruby, historical Bermingham, and No Cash mine workings discharges downgradient between the lower reaches of Star Creek and Christal Creek (Piteau, 2016).

In October 2016 drilling and testing of two boreholes at New Bermingham were performed. After each hole was drilled, one or two airlift pumping tests were performed. After a period of sustained pumping, the airlift was discontinued, and time was allowed for water-level recovery in the borehole. The best-estimate hydraulic conductivities were calculated for the two boreholes and were found to be similar, providing evidence that the rock mass is relatively homogeneous with regard to hydraulic properties. The average of the calculated hydraulic conductivities was $4.3 \times 10^{-6}$ cm/s, which is taken as the best-estimate of the large-scale (bulk) hydraulic conductivity for rock within the mine area. Based on the average hydraulic conductivities a portal discharge rate during closure was estimated to be 220 $m^3$/d (2.5 L/s).

Water levels are collected during monitoring of the Ruby and New Bermingham groundwater wells and are shown on Figure 5-5. The well BH-MW-1 adjacent to the historical Bermingham 200 adit has not had sufficient water to sample since October 2017, the July 2017 measurement, the lowest recorded since installation, shows the decline of the groundwater elevation due to the development of the New Bermingham decline (Figure 5-5).

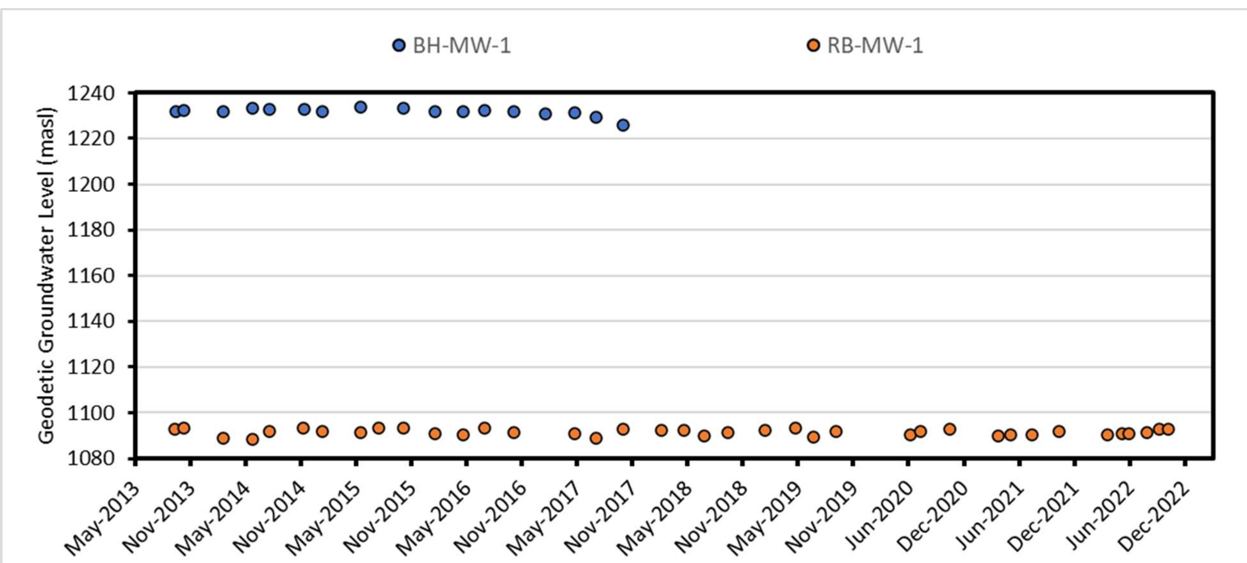


**Figure 5-5: Groundwater Level (masl) in No Cash Creek Catchment Wells**

### 5.2.2 NEW BERMINGHAM

Groundwater flow in the Bermingham area follows topography, so the general flow direction is from southeast to northwest. Construction and continued dewatering of the New Bermingham workings have modified the flow patterns. Figure 5-6 and Figure 5-7 are interpreted groundwater elevation contour maps of the Bermingham area in June and October 2022, respectively. Shown on the maps are interpreted groundwater flowpaths, which are generally drawn perpendicular to the contours. The maps show flow lines converging along the New Bermingham decline, which operates as a groundwater sink. Groundwater inflows in the decline are collected by a sump system and pumped via pipeline to the portal where the mine water is discharged via the water treatment plant. The groundwater effects (drawdowns) are most pronounced at the far end of the portal where the depth of excavation below the natural (preconstruction) water table is the greatest. As one proceeds away from the decline, the effects diminish, and groundwater becomes more similar to the natural regional system characterized by southeast to northwest flow.

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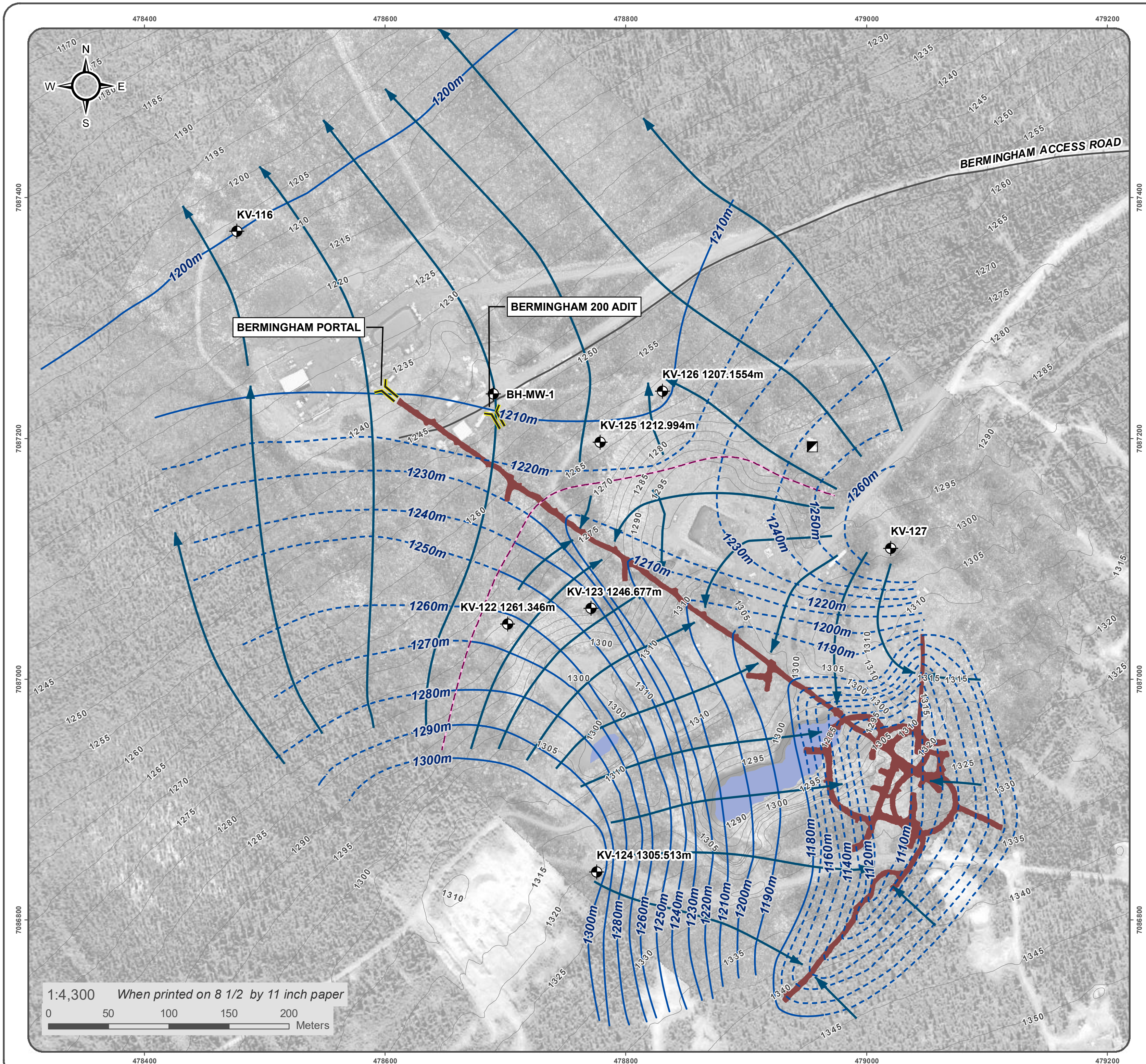
## FIGURE 5-6

## BERMINGHAM MONITORING LOCATIONS AND GROUNDWATER LEVEL CONTOUR MAP, JUNE 2022

JANUARY 2023




Adit/Portal

Shaft

Groundwater Quality Monitoring, Existing

Groundwater Contour

Estimated Groundwater Contour

GW Flow

GW Divide

Contour (5m interval)

*Water Elevations are based on Groundwater Data Collected in June 2022*

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Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on January 2023

Datum: NAD 83; Map Projection: UTM Zone 8N



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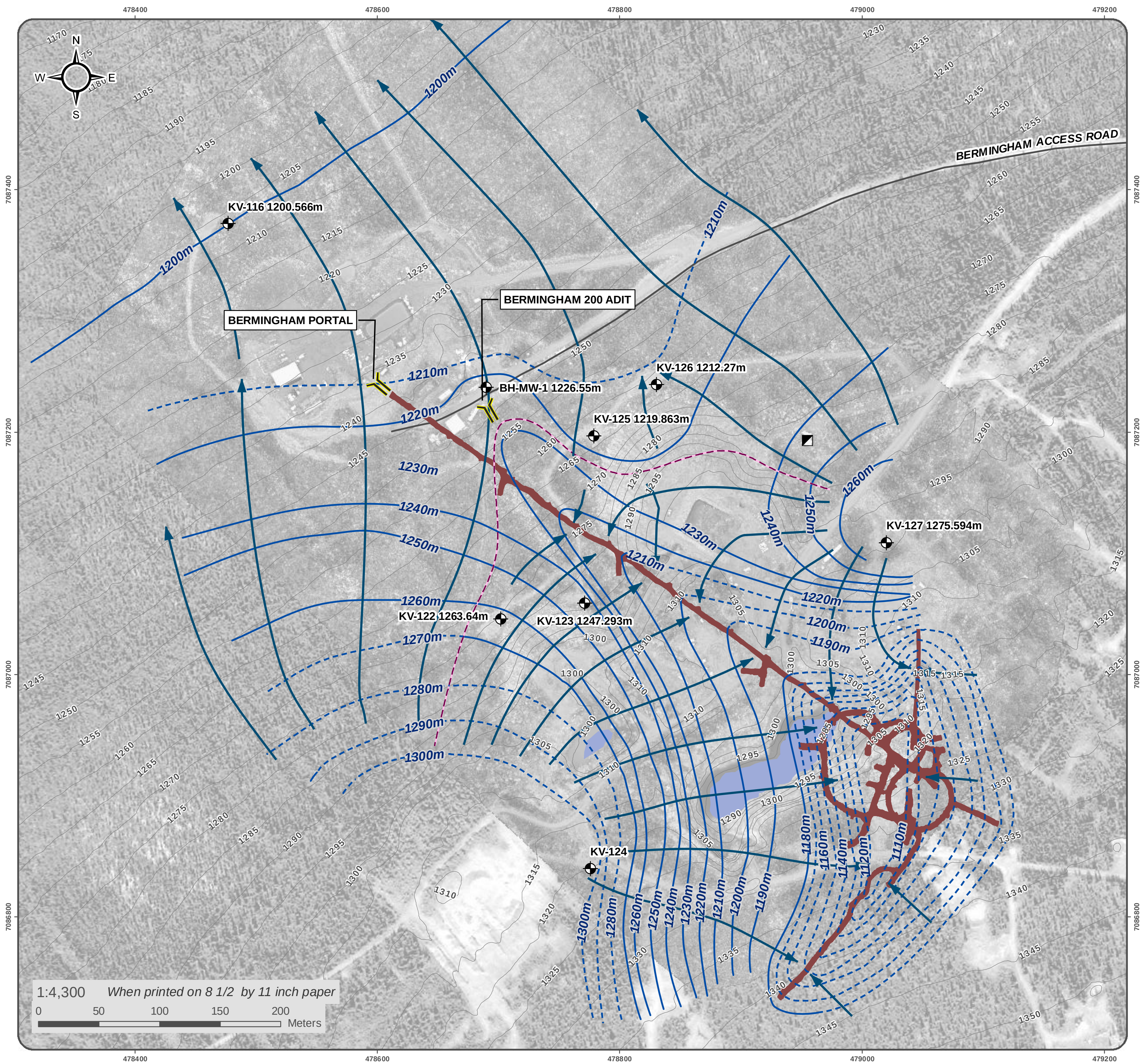
*(Last edited by: amatlashevska; 2023-01-31/08:13 AM)*

HECLA KENO HILL

# FIGURE 5-7

## BERMINGHAM MONITORING LOCATIONS AND GROUNDWATER LEVEL CONTOUR MAP, OCTOBER 2022

FEBRUARY 2023




- Adit/Portal
- Shaft
- Groundwater Quality Monitoring, Existing
- Groundwater Contour
- Estimated Groundwater Contour
- GW Flow
- GW Divide
- Contour (5m interval)

*Water Elevations are based on Groundwater Data Collected in October 2022*

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Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on February 2023

Datum: NAD 83; Map Projection: UTM Zone 8N



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(*Last edited by: amatlashevska;2023-02-01/10:44 AM*)

### 5.2.3 CHRISTAL CREEK

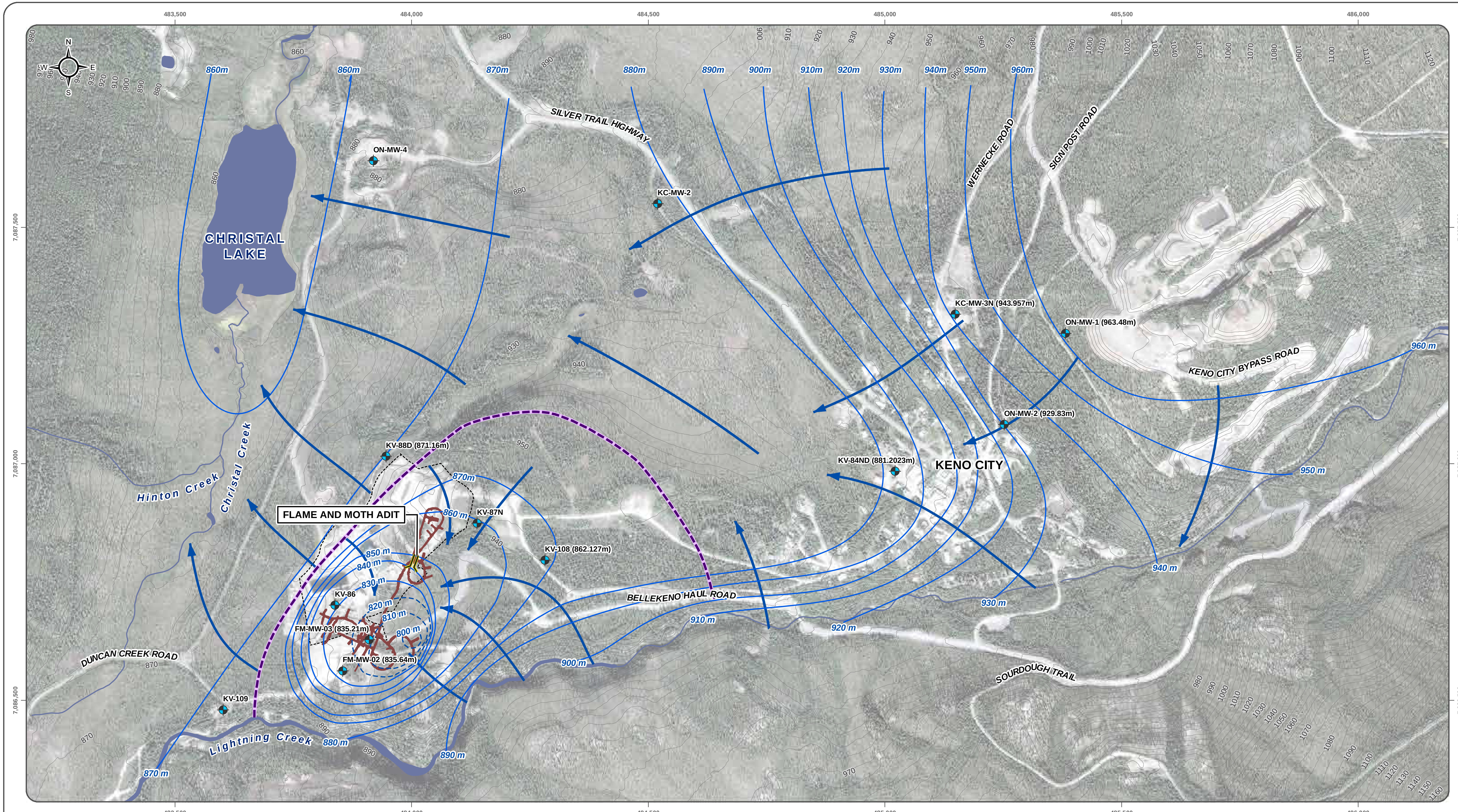
The 2016 preliminary groundwater modelling and particle tracking conducted by Piteau indicated that groundwater from the area of the historical Onek 400 mine workings flows towards the upper reaches of Christal Creek (Piteau, 2016). The Keno City conceptual groundwater model conducted by Interralogic estimated from synoptic water level events that groundwater from Keno City flows northwest towards Christal Lake (Interralogic, 2012). Generally, groundwater flow converges in Keno City and flows to the northwest towards Christal Lake and Christal Creek. Groundwater in the vicinity of the historical Lucky Queen 500 adit is also conceptually understood to flow down towards Christal Creek.

In August and September 2013, three deep monitoring wells (FM-MW-1, FM-MW-2, and FM-MW-3) were drilled and a 72-hr air lift pumping test was completed on FM-MW-1 to calculate the potential mine inflows for the Flame & Moth mine. The maximum predicted flow rate for the Flame & Moth mine was conservatively calculated to be 3.0 x $10^3$ $m^3$/d or 35 L/s. The conclusion of the dewatering estimations and conceptual model is that Flame & Moth mine dewatering will not have a significant impact on surface water flows in Lightning Creek and it is highly unlikely that mine dewatering will have an effect on groundwater levels.

A groundwater flow directional map for Keno City is presented in Figure 5-8 and Figure 5-9. These groundwater contours were created using water level measurements taken in June and October 2022, respectively. Generally, groundwater flows from Keno City to the northwest towards Christal Lake or west towards Christal Creek. The groundwater flow direction for the Flame & Moth mine is towards the northwest in the direction of Christal Lake.

Figure 5-10 presents water level elevations for the bedrock wells in the District Mill area. Water elevations around the District Mill have been recorded between ~835.21 to 963.48 masl. Generally, this equates to being approximately 10 to 56 m below ground surface. The groundwater elevation for the Flame & Moth portal location was estimated to be 840 masl from Figure 5-10, compared to the surface elevation of the portal at 910 masl (a difference of 70 m). The water level elevation at KV-87N is between ~850 to 900 masl while the level at KV-87 is between ~750 and 800 masl. The effects of mine workings development and associated dewatering activities is manifested in the marked water level decline for wells located close to the mine (e.g., FM-MW-2 and FM-MW-3).

The groundwater levels follow a seasonal pattern, which was broadly observed at all sites. It was typically lowest in early May prior to the onset of freshet. Once snowmelt began, the groundwater levels rose due to increased recharge until around November, when progressive freezing over winter likely limited recharge and lowered groundwater levels.




Satelite imagery obtained from ESRI Imagery map service http://goto.arcgisonline.com/maps/World_Imagery on January 2023

Datum: NAD 83; Projection: UTM Zone 8N

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1:7,500 *(when printed on 11 x17 inch paper)*

0 100 200 300 400 Meters

- Well (water levels measured June 2022)
- Adit
- Flame And Moth Underground Workings, As Built End of 2022
- Groundwater Contour (10m)
- Inferred Groundwater Contour (10m)
- Groundwater Flow Direction
- Groundwater Divide
- AKHM District Mill
- Topo Contour (5m)
- Watercourse
- Waterbody

*WATER ELEVATIONS ARE BASED ON GROUNDWATER DATA COLLECTED JUNE 2022*

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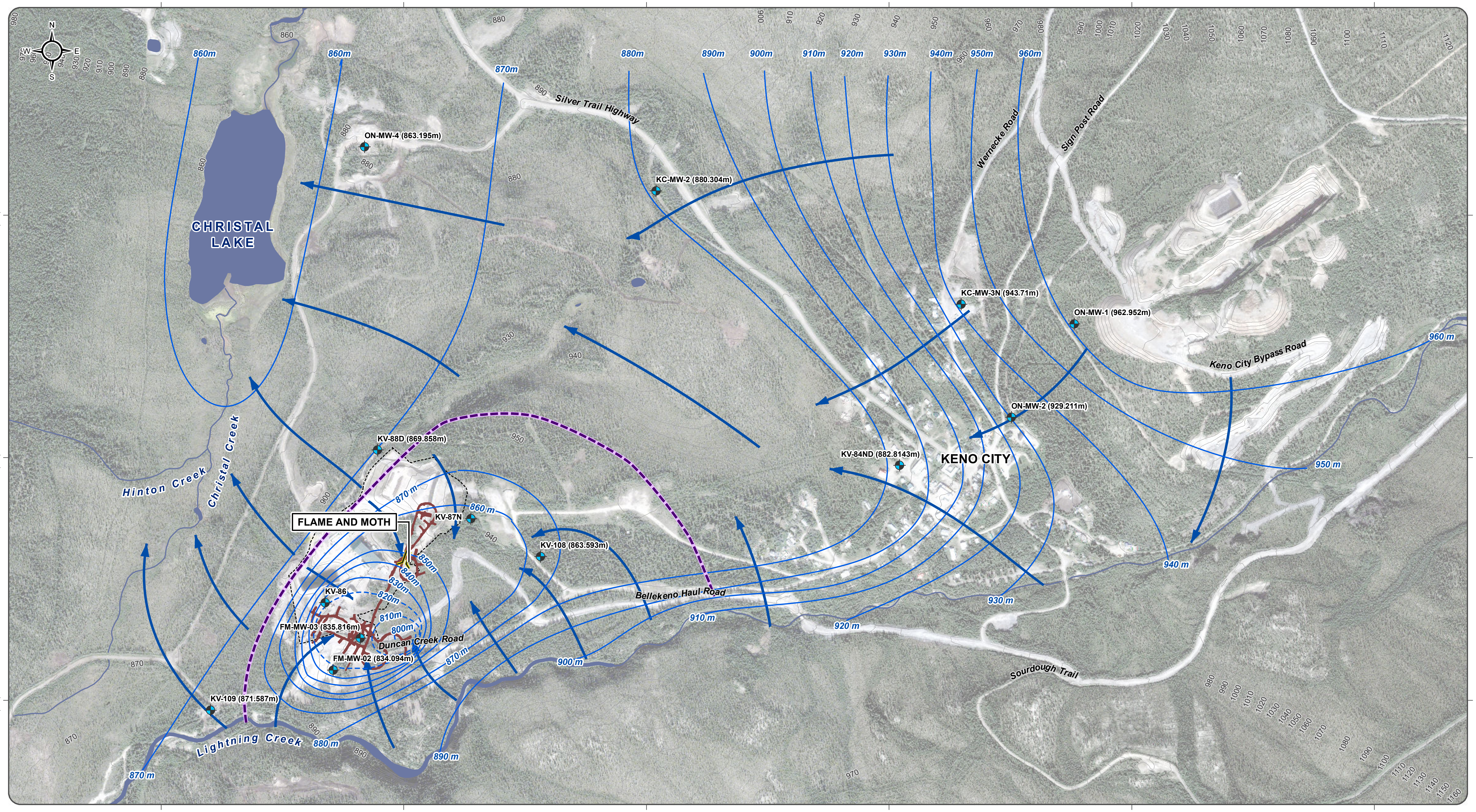
**FIGURE 5-8**
**KENO CITY JUNE 2022 GROUNDWATER LEVEL CONTOUR MAP**

JANUARY 2023

D:\Project\AllProjects\ALEX-05-01\gis\mxd\Overview_Maps\WQ\01-GROUNDWATER\GWContours\Keno_City\2022\Keno_City_GW_Contours_June2022_20230110.mxd
(*Last edited by: amatlashevska;2023-01-31/10:20 AM*)




Satelite imagery obtained from ESRI Imagery map service http://goto.arcgisonline.com/maps/World_Imagery on January 2023

Datum: NAD 83; Projection: UTM Zone 8N

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1:7,500 *(when printed on 11 x17 inch paper)*

0 100 200 300 400 Meters

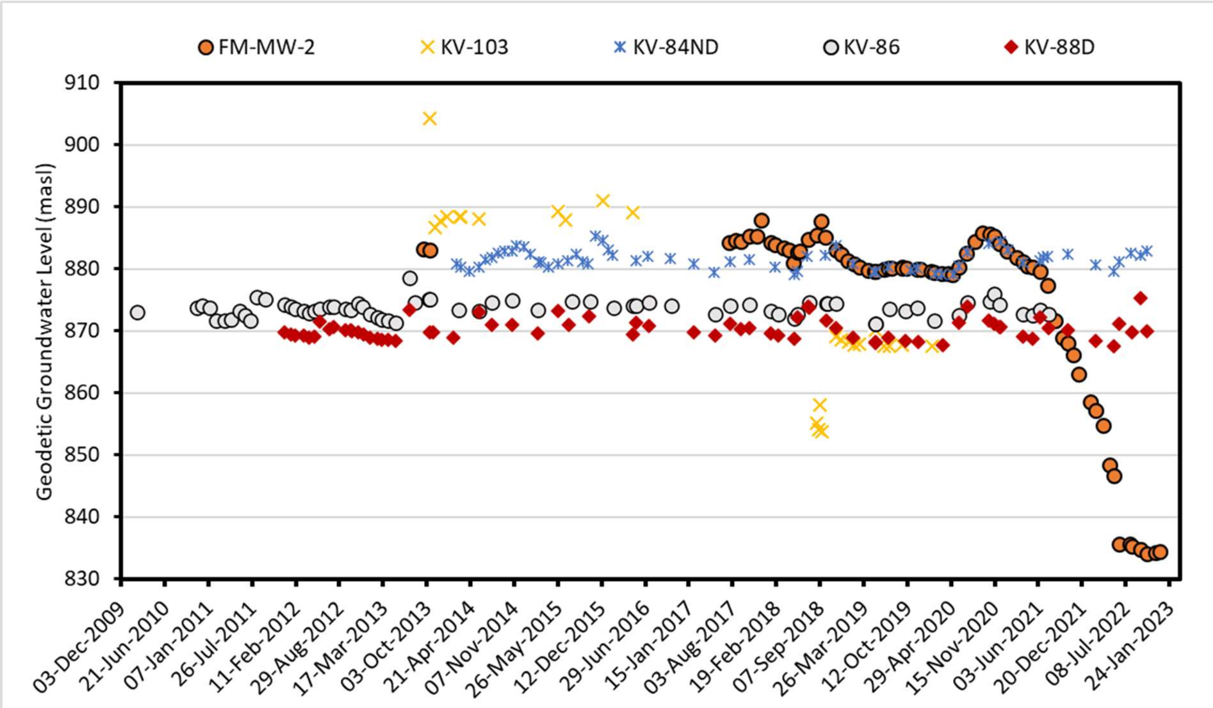
- Well (water levels measured Ocober 2022)
- Adit
- Flame And Moth Underground Workings, As Built End of 2022
- Groundwater Contour (10m)
- Inferred Groundwater Contour (10m)
- Groundwater Flow Direction
- Groundwater Divide
- AKHM District Mill
- Topo Contour (5m)
- Watercourse
- Waterbody

*WATER ELEVATIONS ARE BASED ON GROUNDWATER DATA COLLECTED OCTOBER 2022*

HECLA KENO HILL

**FIGURE 5-9**
**KENO CITY OCTOBER 2022 GROUNDWATER LEVEL CONTOUR MAP**

JANUARY 2023



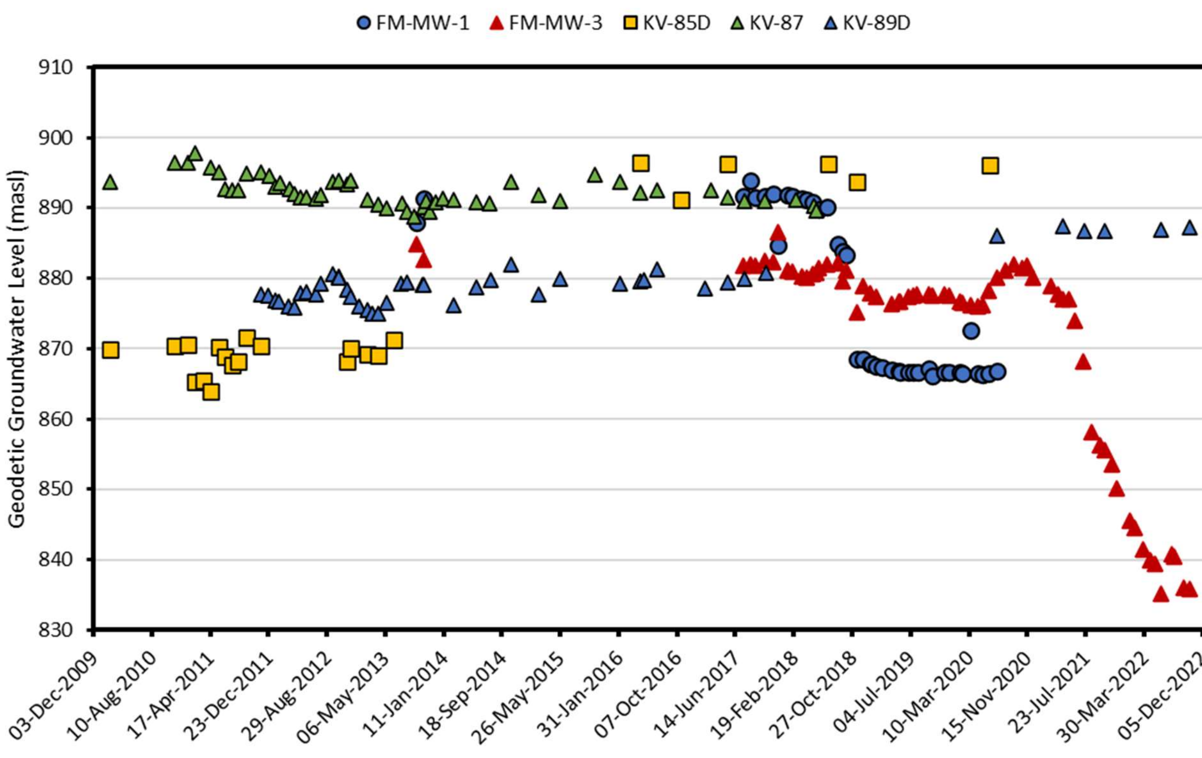




**Figure 5-10: District Mill Area Groundwater Water Levels**

### 5.2.4 LIGHTNING CREEK

In June 2018, a monitoring well (KV-109) was installed between Lightning Creek and the Flame & Moth mine site, to meet Clause 108 (c) of Water License QZ09-92-2. KV-109 was subsequently pump-tested in July 2018 by a two-hour step-test. A best-estimate hydraulic conductivity of 1.3 x $10^{-4}$ cm/s was calculated for the well by relating flow rates to drawdown. Figure 5-11 presents water level elevations for KV-109.

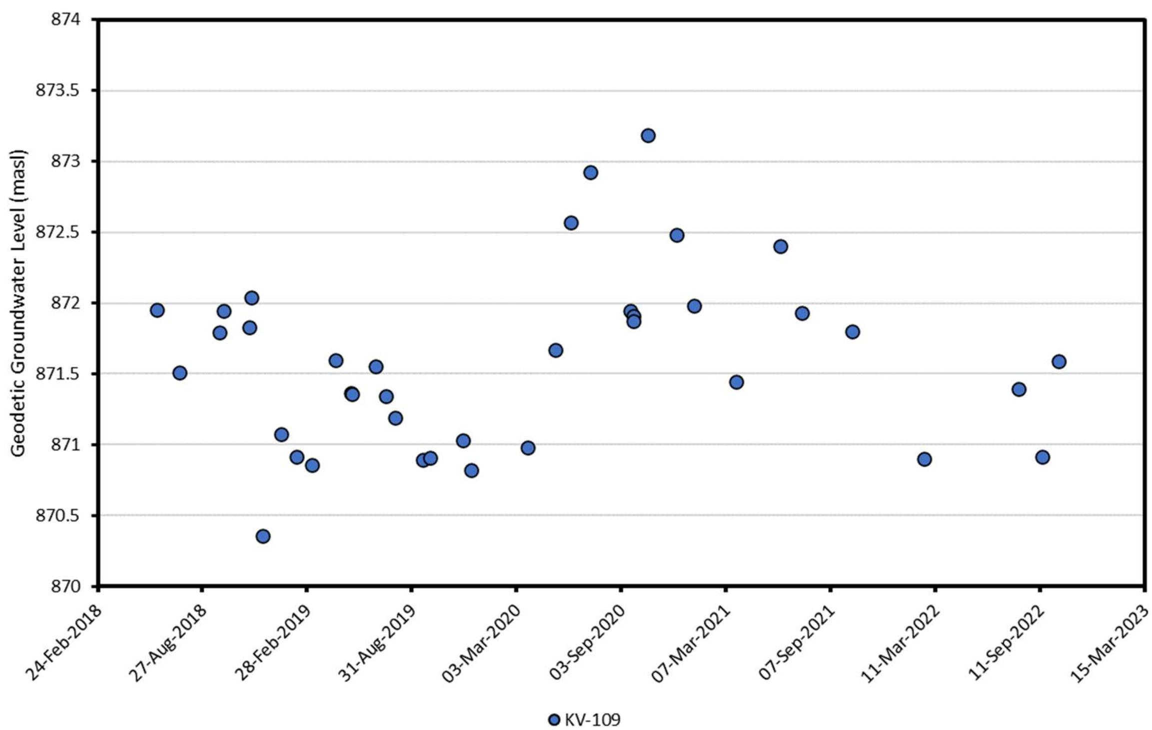



**Figure 5-11: Lightning Creek Groundwater Levels**

## 5.3 GROUNDWATER QUALITY

The groundwater monitoring well network (Table 5-1) is monitored for groundwater levels in addition to groundwater chemistry, with data available since 2010. Generally, the presence and behaviour of the parameters monitored within the KHSD wells are related to:

- The occurrence of natural mineralization in the subsurface; and
- Differences in the prevailing local geochemical regime of the groundwater (e.g., reducing conditions).

Within KHSD, observed elevated concentrations of indicator parameters cadmium and zinc are expected to be controlled by the local mineralization. Sphalerite is the primary source of zinc and cadmium in KHSD waters. As such, both elements showed a correspondence with dissolved sulphate such that elevated levels of dissolved zinc and cadmium typically coincided with high dissolved sulphate concentrations.

### 5.3.1 NO CASH CREEK

Dissolved cadmium and zinc concentrations in monitoring wells RB-MW-1 and BH-MW-1 are presented in Figure 5-12 and Figure 5-13, respectively. Since October 2017 there has not been sufficient water to collect a sample at well BH-MW-1 due to water level drawdown as the New Bermingham mine has advanced. Prior to October 2017 there were no exceedances of dissolved cadmium or zinc relative to the Yukon Contaminated Sites Regulation standards for aquatic life (YCSR-AL). Dissolved cadmium concentrations RB-MW-1 were variable with the maxima observed in July 2014 and 2015. There have been no exceedances of the dissolved zinc YSCR-AL at well RB-MW-1.

Adit discharge from both the historical Bermingham 200 and Ruby adits are documented to infiltrate within a few hundred metres of their respective adit portals; however, there is no evidence that groundwater impacts water quality in No Cash Creek, upstream of the No Cash 500 adit. Indeed, No Cash Creek water sampled at station KV-111 located immediately upstream of the No Cash 500 adit typically has relatively low concentrations of cadmium (median 0.000052 mg/L) and zinc (0.015 mg/L), suggesting that any groundwater metal loading contribution to the upstream reach of No Cash Creek is minimal. Furthermore, extensive natural attenuation of cadmium and zinc concentrations has been documented by monitoring studies in No Cash Creek (ITL, 2013; Kwong et al., 1994; 1997), indicating that any nominal groundwater metal load would likely be sequestered along the reach of No Cash Creek by natural attenuation processes.

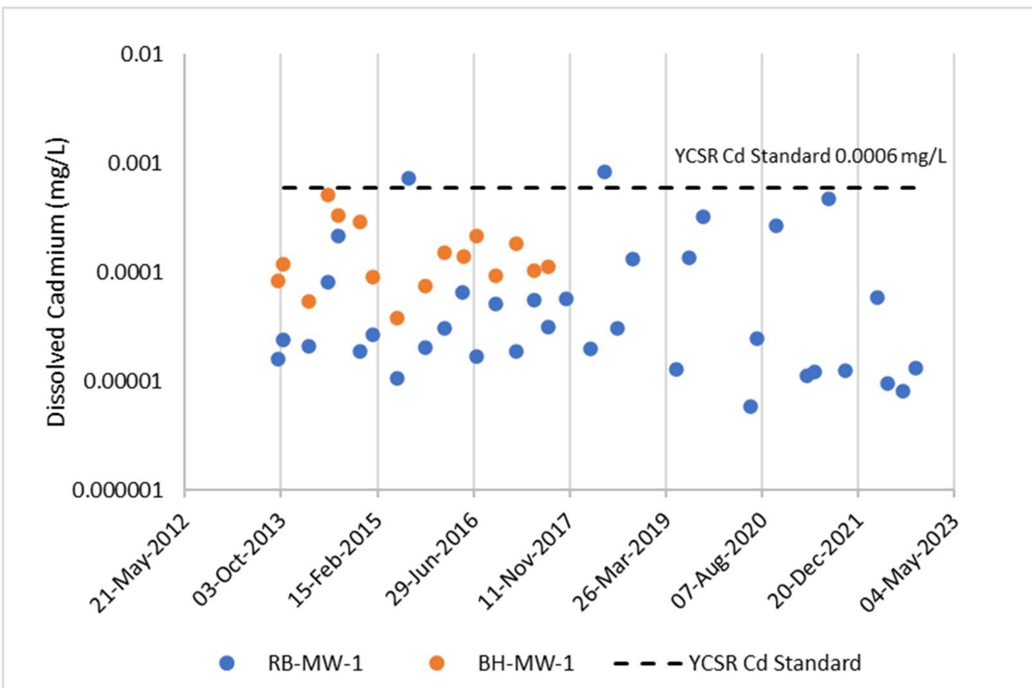



**Figure 5-12: Dissolved Cadmium in No Cash Creek Catchment Wells**

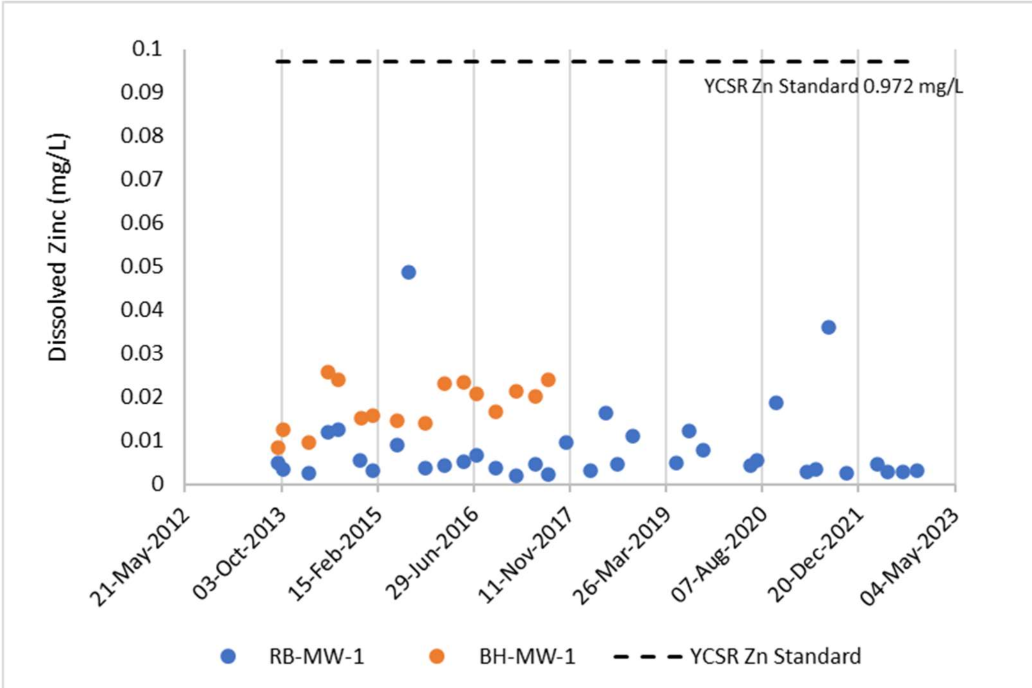



**Figure 5-13: Dissolved Zinc in No Cash Creek Catchment Wells**

### 5.3.2 NEW BERMINGHAM

The New Bermingham monitoring wells were installed in November 2020 to collect baseline information on groundwater conditions, as well as information on the potential impacts of the groundwater quality upgradient and downgradient of the historic Bermingham Southwest open pit, and New Bermingham P-AML (potentially acid generating/metal leaching) waste rock storage facility. The monitoring wells installed in November of 2020 include KV-116, KV-122 through KV-127, and NC-MW-1; all nine wells were completed in the bedrock aquifer. WL QZ18-044 requires new groundwater monitoring wells be sampled on a monthly basis for the first twelve months following installation, after which the frequency can be reduced to quarterly sampling. WL QZ18-044 Clauses 82 and 83 require a comparison of groundwater quality with YCSR-AL. Since no drinking water wells exist within a 1.5 km radius of the Bermingham mine workings and open pits, comparison to YCSR drinking water standards is not required.

P-AML waste rock has been placed in the New Bermingham P-AML waste rock storage facilities since October 22, 2021; water treatment sludge has been placed in the historical Bermingham South West open pit throughout 2021. Analytical results from November 2020 to January 2021 monitoring events can be assumed to provide reference conditions for this area prior to KHSD Mining Operations.

As shown in Figure 5-2, the monitoring wells are:

- KV-124 installed upgradient of Bermingham SW pit.
- KV-122 and KV-123 installed downgradient of Bermingham Southwest pit.
- KV-127 installed upgradient of the New Bermingham P-AML waste rock storage facility.
- KV-125 and KV-126 installed downgradient of the New Bermingham P-AML waste rock storage facility.

- KV-116 installed downgradient of the N-AML waste rock disposal area in order to monitor groundwater downgradient of the N-AML waste rock disposal area and the water treatment discharge location.
- NC-MW-1 was installed to monitor groundwater downgradient of the underground mine workings at New Bermingham.
- KV-108 installed upgradient of DSTF expansion area in 2020.

Monitoring well KV-123 was consistently elevated compared to the YCSR-AL standard for dissolved cadmium (0.0003 mg/L), and exhibited the highest dissolved cadmium concentrations of the Bermingham monitoring wells (median 0.013 mg/L; Figure 5-14). In 2021, KV-122, KV-125, KV-126, and KV-127 had one to two excursions above the YCSR-AL standard, while in 2022 only two excursions were found, both at KV-125 (located downgradient of the New Bermingham P AML waste rock storage facility). KV-124 and NC-MW-1 exhibited the lowest concentrations of dissolved cadmium with median concentrations of 0.000021 mg/L and 0.000014 mg/L, respectively. Monitoring wells KV-116, KV-122, KV-123 (downgradient of Bermingham Southwest pit), and KV-124 (upgradient of Bermingham Southwest pit), exhibited relatively stable concentrations of dissolved cadmium. Three monitoring wells located downgradient of the rock storage facility and underground mine workings, KV-125, KV-126, and NC-MW-1 exhibited marked variability of dissolved cadmium concentration values during which NC-MW-1, KV-108 and KV-126 showed notably low concentrations of dissolved cadmium during the last groundwater monitoring event. Overall, between May 2012 to October 2022 there has been minimal change in dissolved zinc and cadmium concentrations compared to initial concentrations for wells located both up and downgradient of the mine workings.

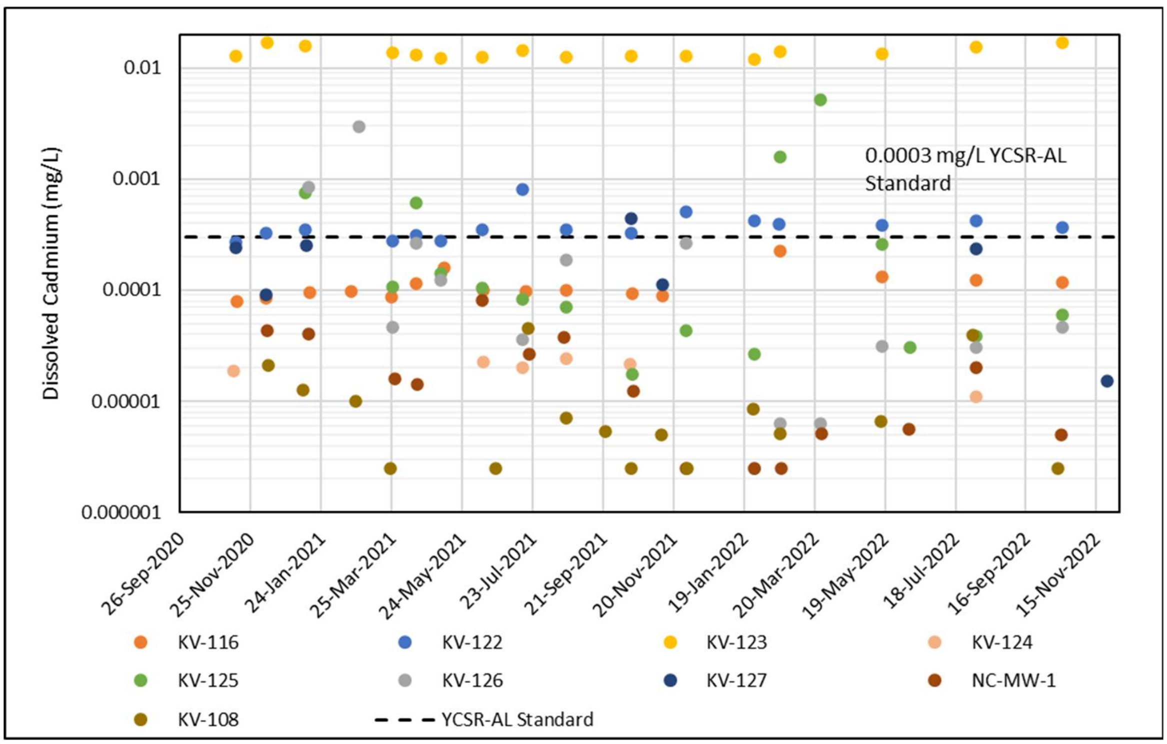



**Figure 5-14: Dissolved Cadmium in Bermingham Groundwater Monitoring Wells**

Monitoring well KV-123 exhibited the highest dissolved zinc concentrations of the Bermingham monitoring wells (median 1.17 mg/L) and was the only well that consistently exceeded the YCSR-AL standard (0.075 mg/L; Figure

5-15). Results from monitoring wells KV-116, KV-124, and KV-125 for dissolved zinc were consistently below the YCSR-AL standard, with KV-116 and KV-124 exhibiting the lowest dissolved zinc concentrations of the Bermingham monitoring wells (median concentrations of 0.0034 mg/L and 0.0013 mg/L respectively). Concentrations of dissolved cadmium and zinc have generally remained the same throughout the monitoring period for wells located downgradient of mine infrastructure (Figure 5-14 and Figure 5-15).

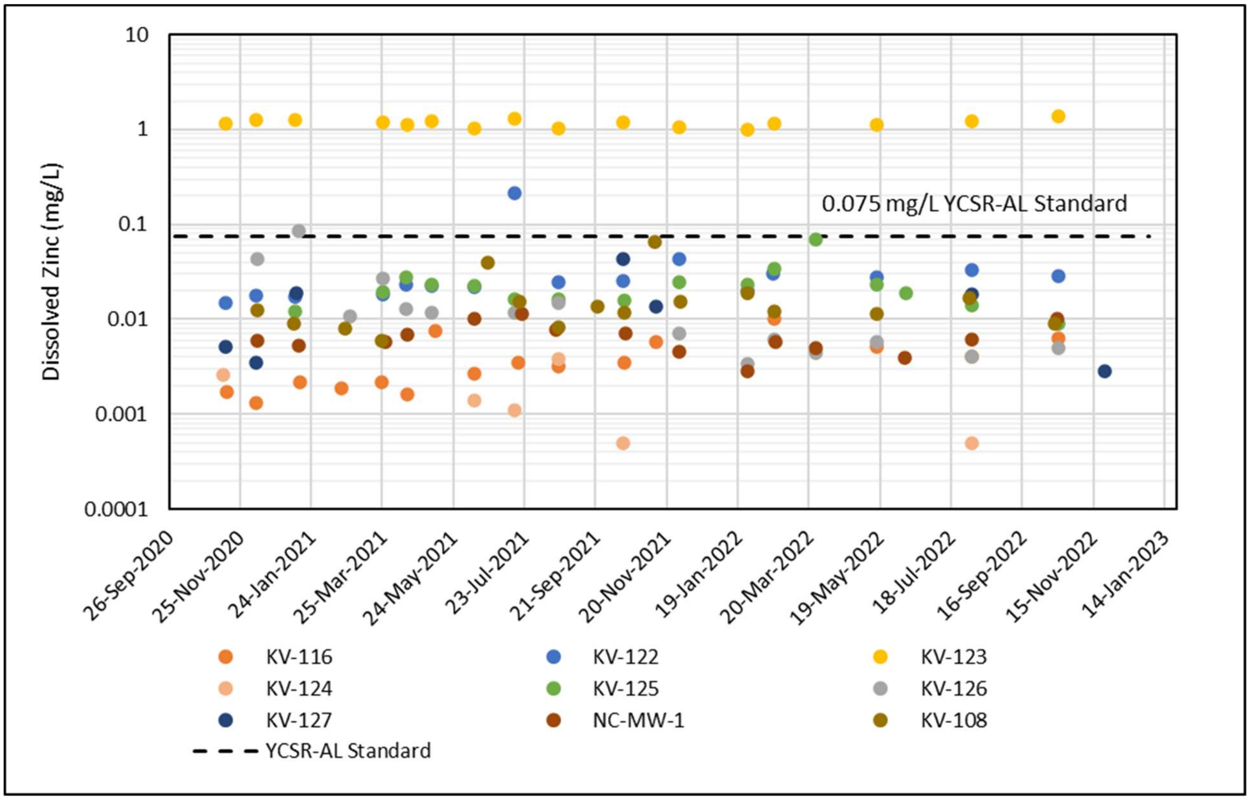



**Figure 5-15: Dissolved Zinc in Bermingham Groundwater Monitoring Wells**

### 5.3.3 CHRISTAL CREEK

Figure 5-16 to Figure 5-19 presents the dissolved cadmium and zinc concentrations, respectively, for the bedrock wells in the Christal Creek catchment.

The deep groundwater boreholes (FM-MW-1, FM-MW-2, and FM-MW-3) were sampled following airlifting 2013. In 2013 the dissolved zinc concentrations in the deep groundwater wells ranged from 0.0026 mg/L to 0.014 mg/L, all below the YCSR-AL standard (2.40 mg/L), and the dissolved cadmium concentrations were below the detection limit (<0.000010 mg/L to <0.000020 mg/L). Dissolved metals concentrations in the deep wells were generally lower than those measured in the shallower groundwater wells around the Mill. It is therefore anticipated that groundwater encountered during the development of the Flame & Moth will not contain significant metals concentrations. The deep groundwater boreholes are not currently monitored for groundwater quality. Monitoring well KV-87 was not monitored past May 2018; however, in December of 2020 monitoring well KV-87N was added to the program to continue the data collection at this location.

Monitoring wells near the District Mill from May 2011 to October 2022 have not exceeded the YCSR-Al standard for dissolved zinc however prior to 2015 dissolved cadmium was found to exceed the YCSR-Al standard (0.0006 mg/L) consistently (Figure 5-16). Since 2015, dissolved cadmium has been exceeded twice, well KV-89D on July 10, 2015 (0.0010 mg/L) and KV-86 on October 2, 2019 (0.000803 mg/L).

Monitoring wells near Keno City from May 2011 to October 2022 were found to be below the YCSR-AL standards except for the following exceedances. Well ON-MW-4 has exceedances of dissolved zinc on February 25, 2018 (2.57 mg/L), May 15, 2021 (2.91 mg/L), February 20, 2022 (2.51 mg/L) and dissolved cadmium on October 13, 2021 (0.00092). KV-84ND exceeded the YCSR-AL standard for dissolved cadmium on June 27, 2014 (0.00062) and KC-MW-4 which consistently exceeded the YCSR-AL standard for dissolved cadmium the years it was sampled (2011 to 2014). The concentrations of dissolved cadmium at wells KV-84ND, ON-MW-2, and KC-MW-4 ranged from <0.000010 to 0.00062 mg/L, <0.000025 to 0.00092 mg/L, and 0.00084 to 0.00495 mg/L, respectively. Dissolved zinc concentrations were higher in the Keno City wells compared to the deep Flame & Moth wells. Monitoring wells ON-MW-2 and KV-84ND had median values of 2.14 and 0.67 mg/L, respectively, while KC-MW-4 between February 2012 and March 2014 had a median value of 0.0515 mg/L. Well KC-MW-4 has not been monitored since 2014.

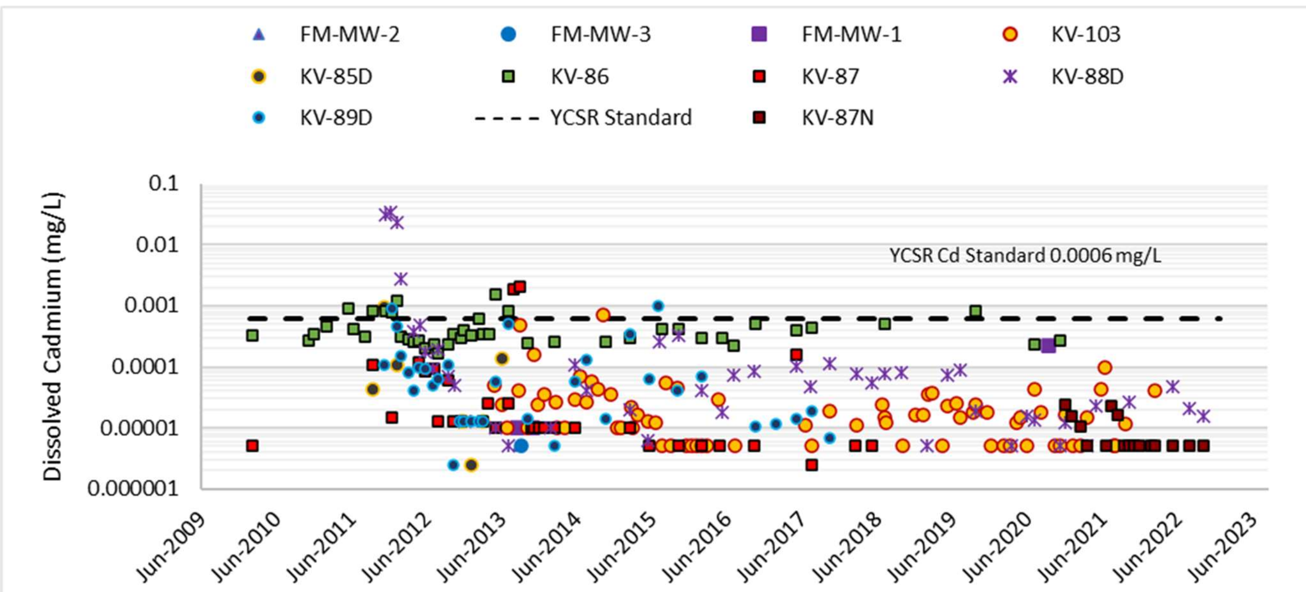



**Figure 5-16: Dissolved Cadmium in Christal Creek Wells near the District Mill**

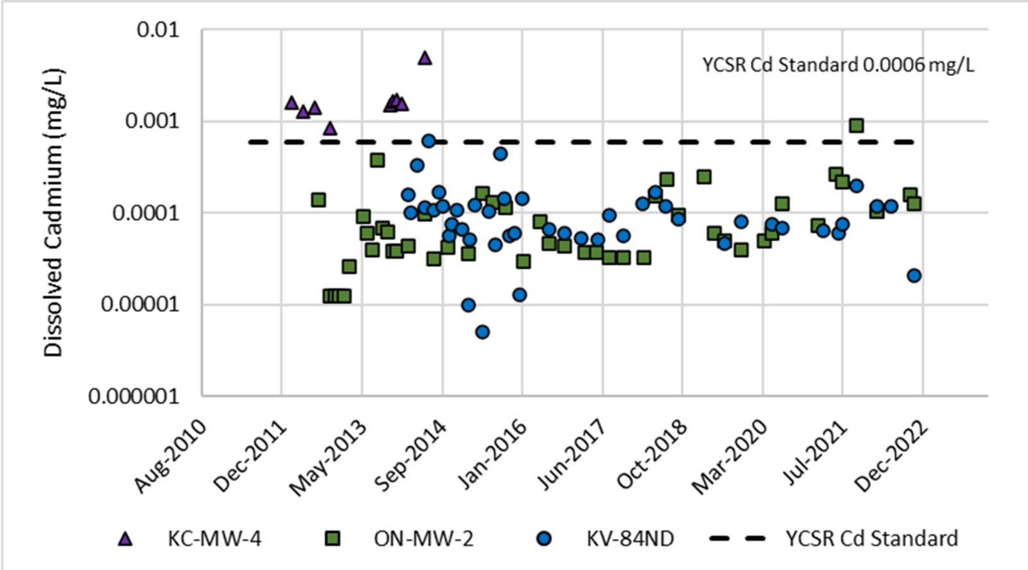



**Figure 5-17: Dissolved Cadmium in Christal Creek Wells near Keno City**

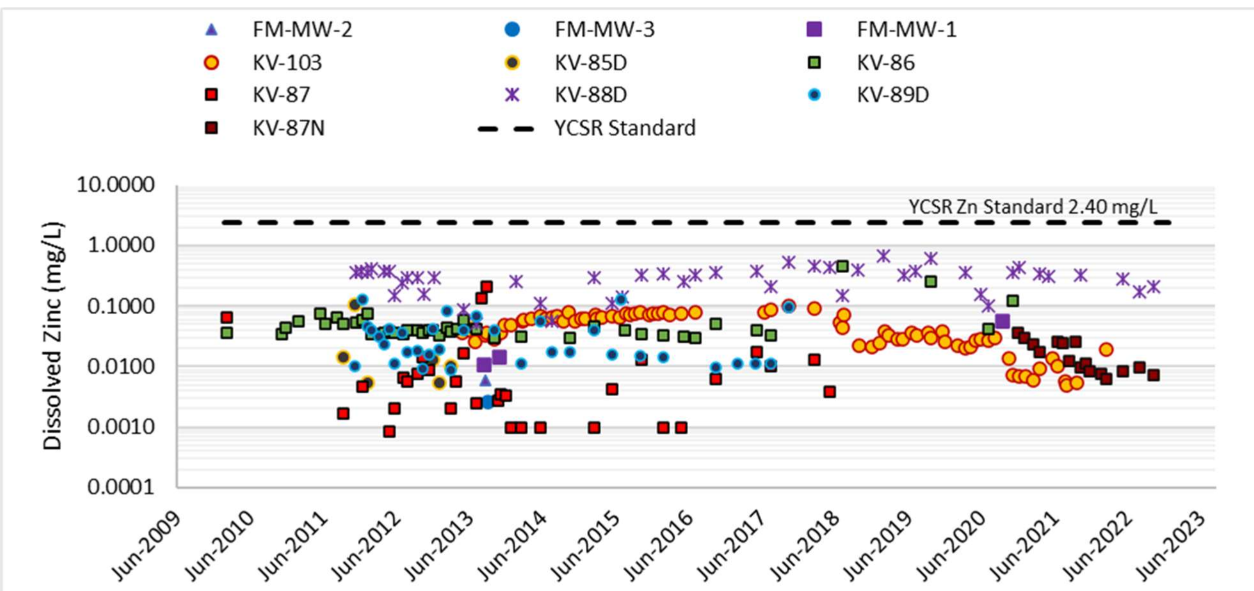



**Figure 5-18: Dissolved Zinc in Christal Creek Wells near the District Mill**

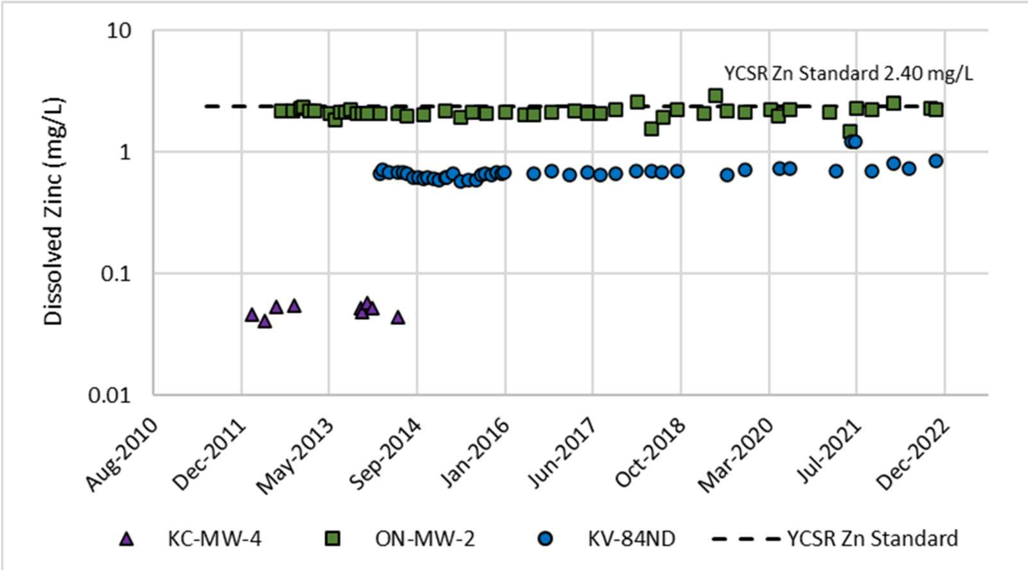



**Figure 5-19: Dissolved Zinc in Christal Creek Wells near Keno City**

### 5.3.4 LIGHTNING CREEK

Following development of the KV-109 monitoring well on June 8, 2018, water quality samples were collected to characterize groundwater chemistry. The concentration of dissolved cadmium ranged from below detection limit (0.000005 to 0.000095 mg/L, and dissolved zinc ranged from 0.017 to 0.039 mg/L, as shown in Figure 5-20 and Figure 5-21, respectively. Neither dissolved zinc or cadmium were found to exceed the YCSR-AL standards and in the case of zinc, results were an order of magnitude below the standard (2.4 mg/L). While there were no defined seasonal trends for these two parameters, the concentration of dissolved cadmium decreased over time whereas dissolved zinc increased.

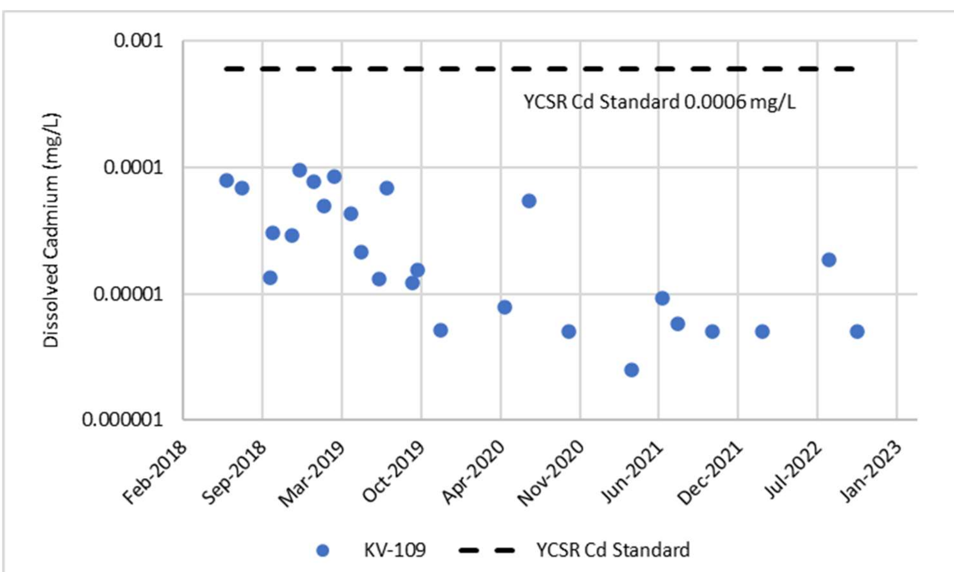



**Figure 5-20: Dissolved Cadmium in Lightning Creek Catchment Wells**

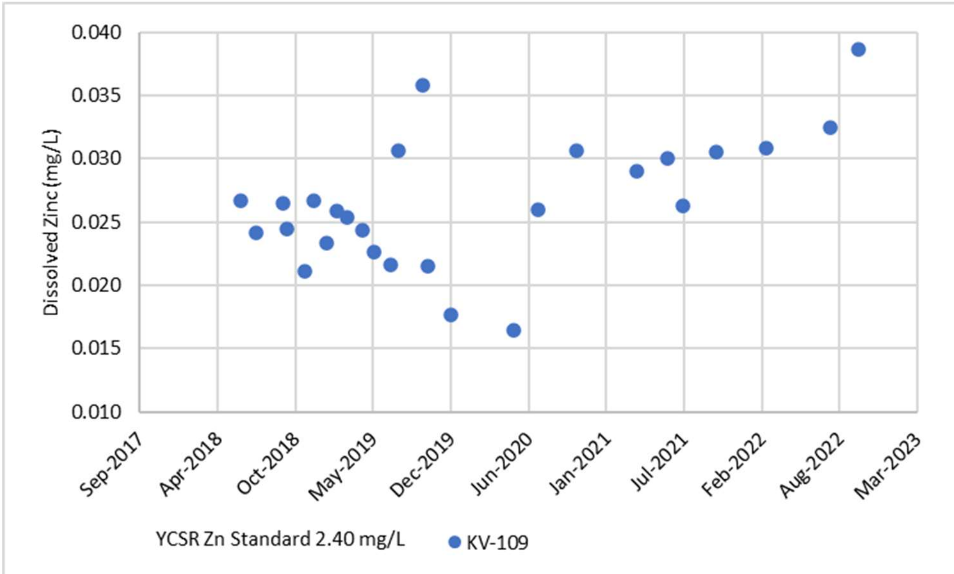



**Figure 5-21: Dissolved Zinc in Lightning Creek Catchment Wells**

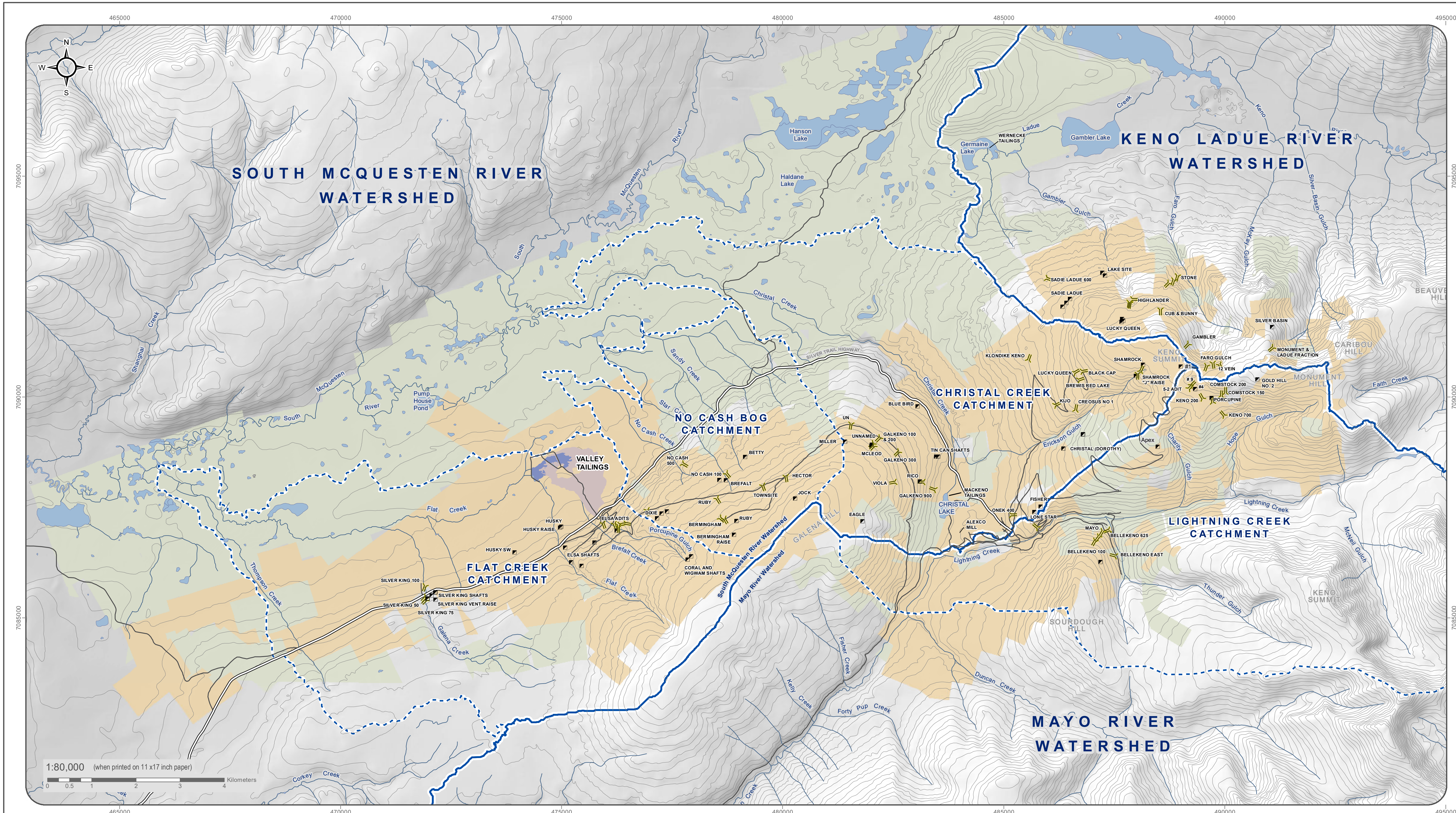
# 6 BIOLOGY

This section provides a summary of components that make up the regional ecosystem that may be affected by mining operations, including fish and fish habitat, wildlife, and vegetation.

## 6.1 AQUATIC RESOURCES

Aquatic resources have been documented in the KHSD through numerous environmental studies conducted over the last two decades. Study methods and results were presented in previous assessments for projects within the KHSD. In general, most of the reports were consistent in their findings with respect to the characterization of the aquatic resources in local watersheds or catchment areas within the KHSD.

The main watercourses in the KHSD potentially affected by the Project (Figure 6-1) are Lightning Creek, downgradient of the Bellekeno adit and Mill and flows west and south into Duncan, ultimately draining into the Mayo River and Stewart River watershed. No Cash and Star Creeks drain the No Cash, Ruby, and Bermingham adits into a bog catchment (approximate 2 km radius) with no surface connection to any rivers. Christal Creek is directly west of the District Mill and DSTF and flows into Christal Lake and eventually into the South McQuesten River and Stewart River watershed. Flat Creek drains the Valley Tailings Facility and flows into the South McQuesten River. The Keno Ladue watershed is located northeast of the Project site and is not discussed in this report.




Topographic Data (CANVEC) data at a scale of 1:50,000 and crown grant (land parcels and mineral survey claims) data compiled by the Department of Natural Resources Canada. Quartz claim boundaries and ownership are current as of March 2017; obtained from Geomatics Yukon, Government of Yukon. Satellite imagery obtained from Yukon Geomatics map service http://mapservices.gov.yk.ca/ArcGIS/services on March 2017

Datum: NAD 83; Map Projection: UTM Zone 8N

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| Legend | | | |
|---|---|---|---|
| Adit | Alexco Keno Hill Mining Corp. Owned Quartz Claims | Tailings | Silver Trail Highway |
| Shaft | ERDC Owned Quartz Claims or Crown Grants | Waterbody | Other Road |
| Watershed | | Watercourse | Contours (100 ft intervals) |
| Catchment | | | |

HECLA KENO HILL

FIGURE 6-1

KENO HILL WATERSHED OVERVIEW

FEBRUARY 2023

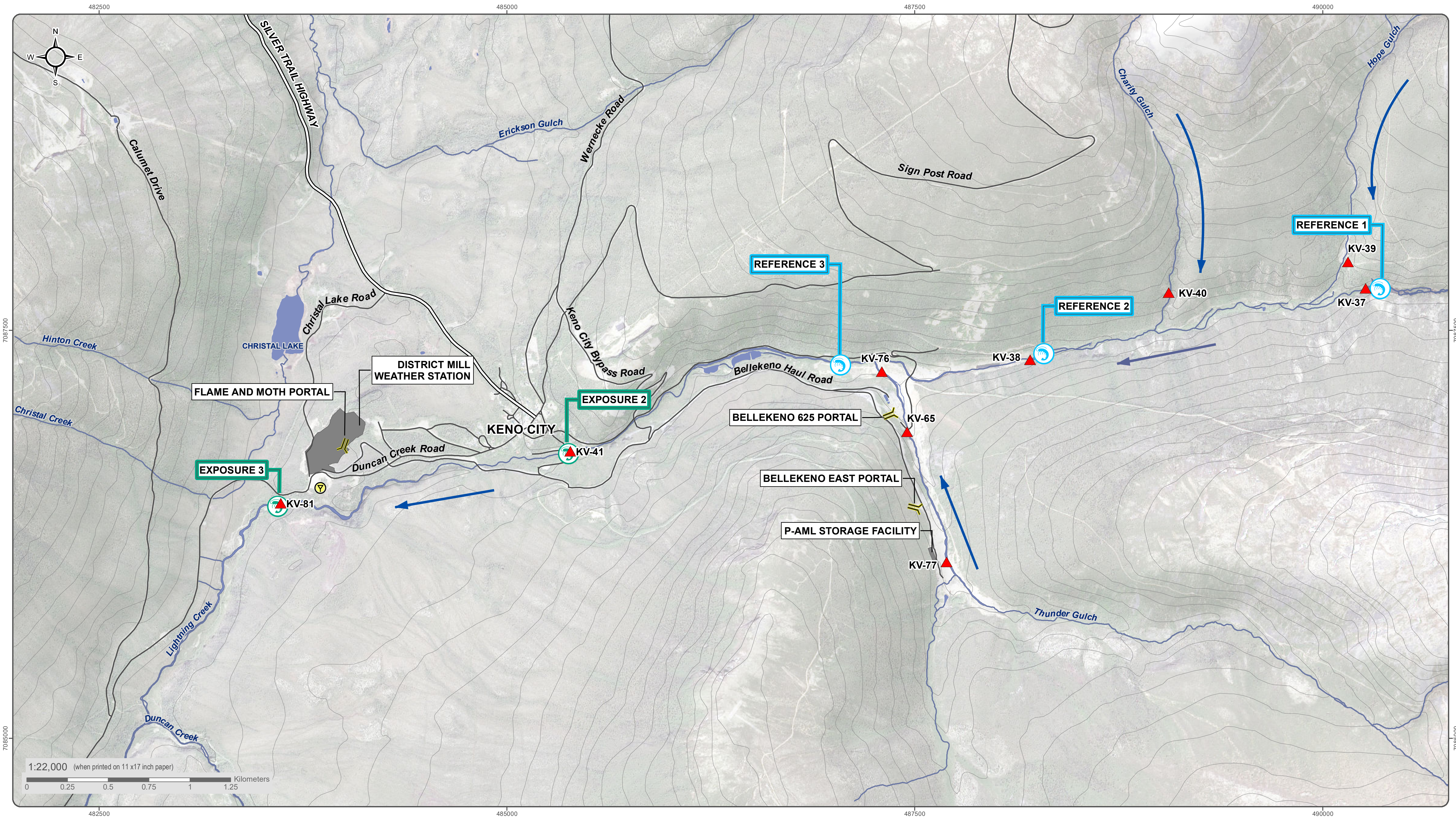
### 6.1.1 FISHERIES

Historical fisheries resource data for Lightning Creek and surrounding drainages (Figure 6-1) is limited to information collected by White Mountain Environmental Consulting (WMEC) in 1995 and 2006, Access Consulting Group (ACG) in September 2008, De Graff and Burns in 2011 and Minnow Environmental in 2012. Investigations of fish and fish habitat were conducted at numerous sites, including two sites on Lightning Creek. More recent investigations have been conducted as part of the Environmental Effects Monitoring (EEM) conducted by Ensero for the Bellekeno mine, with the most recent program completed in 2021 (Ensero, 2022c; Figure 6-2).

Other than No Cash Bog, which is not fish bearing and has no surface connection to fish bearing waters, most of the drainages identified in the KHSD support a diverse fish population. Ten different fish species were identified within the KHSD Including: Arctic Grayling *(Thymallus arcticus)* (most abundant), slimy sculpin *(Cottus cognatus)* (most widely dispersed), round whitefish (*Prosopium cylindraceum*), Northern pike *(Esox lucius),* Arctic lamprey (*Lethenteron camtschaticum*), Chinook salmon (*Oncorhynchus tshawytscha*), burbot (Lota lota), longnose sucker (*Catostomus catostomus*), least cisco (*Coregonus sardinella*), and lake chub (*Couesius plumbeus*).

The fish laboratory exposure study was conducted as part of the EEM Cycle 4 using Kokanee Salmon, allowed for distinguishing potential effects from the Bellekeno mine effluent from those of the Thunder Gulch placer mine discharge, influences that are not possible to isolate *in situ*. The Metal Mining Technical guidance for EEM (Environment Canada, 2012) suggested a critical effect size (CES) of ±10% (of the reference mean) for condition factor and 25% for weight-at-age. Exceeding the effects threshold may indicate potential for impacts to environmental variables. However, since immature fish were used in this study, effects were determined using p-values. When a significant effect was found, the magnitude of difference (%) between the reference and the exposure site was also reported. At the end of the experiment, the reference group significantly differed from at least one of the exposure groups for all endpoints. Since Exposure 2 weight, fork length, and condition were significantly larger at the end of the study compared to the reference group, macronutrients in mine effluent could be stimulating a stronger growth response. When comparing fish endpoints between EEM cycles, similar effects between two consecutive studies were not detected.

The Cycle 5 EEM Study Design was submitted in January 2023, with the biological survey scheduled to be conducted in summer 2023. Specifically, the laboratory-based exposure study with Kokanee salmon will be conducted commencing in August 2023 and will continue for six weeks.




Topographic Data (CANVEC) data at a scale of 1:50,000 and crown grant (land parcels and mineral survey claims) data compiled by the Department of Natural Resources Canada.
Sattellite Imagery obtained from Yukon Geomatics web service http://mapservices.gov.yk.ca/ArcGIS/services on January 2018

Datum: NAD 83; Map Projection: UTM Zone 8N



- Adit
- Surface Water Quality Station of Interest
- District Mill Weather Station
- Exposure Location
- Reference Location
- AKHM District Mill
- Waterbody
- Watercourse
- Silver Trail Highway
- Other Road

Hecla KENO HILL

HECLA KENO HILL
BELLEKENO MINE PROJECT

**FIGURE 6-2**
**EEM AQUATIC SAMPLE LOCATIONS**

JANUARY 2023

### 6.1.2 BENTHIC INVERTEBRATES

Benthic invertebrate sampling has taken place sporadically in the KHSD, dating back to 1975. Environmental Protection Services carried out biological monitoring in the area in 1975, 1985, 1986, 1990, 1994, 2007, and 2011. More recent investigations have been conducted as part of EEM for the Bellekeno mine, completed in 2018 and 2021 (AEG 2019d; Ensero, 2022c), and the Flame & Moth mine, completed in 2021 (data to be submitted as part of the Flame & Moth mine EEM Cycle 1 Interpretive Report in November 2023).

Benthic communities in each watercourse varied based on habitat conditions and historical impacts, but are generally dominated by Plecoptera, Diptera, and Chironomids. Benthic communities in Lighting Creek drainage were found the be robust and represented by a healthy proportion of population-sensitive species. Benthic community metrics in Christal and Flat Creek suggest communities are potentially stressed compared to reference condition. Benthic samples within No Cash and Star Creek are limited to one sampling event in September 2018.

Potential effects to benthic invertebrates were determined during EEM for the Bellekeno mine by comparing reference sites to all downstream exposure sites, as reference sites were upstream of mine effluent discharge and encompassed effects from historical placer and current mine activities. Although some of the metrics assessed for exposure sites showed an effect to benthics, either negatively or positively, this difference was also detected between reference sites located upstream of effluent discharge. This suggests that impairment of the benthic community existed previously and is unrelated to mine effluent. This was supported by water chemistry, as one of the reference sites shared similar water chemistry with the exposure site, for TSS and elevated total metals (aluminum, iron, zinc), chemistry that is often associated with placer activity. As well, sediment chemistry measured metals exceedances in all reference sites, with some parameters far exceeding concentrations measured in downstream exposure sites. This is likely an influence from the placer mining in Thunder Gulch, which may explain some differences in benthic community composition.

During Bellekeno Mine Cycle 4 EEM, a significant effect and direction of effect was detected on the Bray-Curtis (B-C) index when comparing Reference 1 to the exposure groups in past EEM cycles. Therefore, an Investigation of Cause (IOC) study will be conducted during Cycle 5 EEM which will focus on using principal component analysis to compare benthic invertebrate indices with existing water quality data and additional data collected specifically for the study (Ensero, 2022c). If exposure stations tend to separate from reference stations based on mine indicators (i.e., chloride, nitrate, sulphate, zinc, lead, silver, and dissolved metals), then mine effluent may explain the difference in the B-C index between reference and exposure groups. However, if there is no correlation between benthic communities and water quality parameters, then placer mining may explain the difference in the B-C index between reference and exposure groups.

Considering the various lines of evidence in context with the legacy mining that has occurred upstream of the mine, the effects measured are likely caused by historical placer mining activities, rather than by mine effluent. It is suggested that standard monitoring continue for subsequent biological monitoring, in addition to the IOC study noted above for Cycle 5 EEM.

### 6.1.3 STREAM SEDIMENT

Stream sediment sampling was carried out annually or biannually since 2010 in Christal and Lightning Creek. Stream sediment sampling for No Cash Creek was carried out at KV-56 and KV-21 in 2018, then continued at KV-21 in 2020, 2021, and 2022. Sediment quality within each of the affected watercourses has not exhibited obvious increasing or decreasing trends since 1990. Despite several metals that exceeded the Canadian Interim Sediment Quality Guideline (ISQG) and the Sediment Quality Guideline Probable Effects Level (PEL), sediment toxicity tests suggested that elevated metals were not in a form that was biologically available (i.e., dissolved at concentrations that would induce mortalities or sublethal effects), at most sites.

In Lightning Creek, arsenic consistently exceeded the PEL at all sites (KV-37, KV-38, and KV-41; Table 6-1; Table 6-2), while cadmium, lead, and zinc frequently exceeded the ISQG and occasionally the PEL. Copper frequently exceeded the ISQG. In Christal Creek, arsenic, cadmium, lead, and zinc all consistently exceed the PEL at both KV-6 and KV-7 (Table 6-3). In Flat Creek, arsenic, cadmium, lead, and zinc all exceeded the PEL at KV-9 (Table 6-4). Copper exceeded the PEL once and exceeded the ISQG for the remainder of the samples. No Cash drainage measured arsenic exceedance of the PEL at KV-21 and KV-56. Cadmium, lead, and zinc exceeded the PEL and copper exceeded the ISQG at all samples at KV-21. Cadmium and zinc exceeded the ISQG at KV-56. In the South McQuesten sediment, arsenic, cadmium, and zinc all frequently exceed the PEL at KV-1, KV-3, and KV-4 (Table 6-6). Lead exceeded the PEL at KV-3 and KV-4. Copper exceeded the ISQG at KV-3 and KV-4 during all events, and frequently exceeded the ISQG at KV-1.

**Table 6-1: Metal Concentrations in Lightning Creek Sediment at KV-37 and KV-38, 2007-2022**

| Total Metal | Lab MDL | Guideline | | KV-37 | | | | | | KV-38 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concentration mg/kg | | CCME ISQG | CCME PEL | 31-Jul-07 | 23-Sep-11 | 23-Aug-12 | 02-Sep-15 | 13-Sep-18 | 27-Aug-21 | 31-Jul-07 | 30-Aug-13 | 26-Aug-14 | 01-Sep-15 | 22-Sep-16 | 18-Aug-17 | 13-Sep-18 | 23-Sep-20 | 26-Aug-21 | 22-Sep-21 | 17-Sep-22 |
| Aluminum | 50 | - | - | 12533 | 6828 | 8110 | 8940 | 8650 | 8850 | 9023 | 8280 | 6940 | 8510 | 11598 | 10452 | 7502 | 8967 | 6767 | 9088 | 7460 |
| Antimony | 0.1 | - | - | 0.4 | 2.69 | 9.38 | 17.7 | 4.67 | 10.1 | 13.9 | 19.6 | 16.8 | 1.61 | 9.7 | 7.57 | 8.62 | 3.13 | 2.65 | 6.65 | 2.055 |
| Arsenic | 0.1 | 5.9 | 17 | **115.4** | **74.1** | **82.6** | **324** | **95.3** | **170** | **433** | **179** | **277** | **27.1** | **185** | **143** | **135** | **67.1** | **39.6** | **155** | **38** |
| Cadmium | 0.02 | 0.6 | 3.5 | **2.7** | **0.9** | **0.87** | **20.4** | **8.23** | **8.33** | **31.2** | **15.4** | **16.8** | **1.11** | **8.61** | **5.22** | **7.36** | **1.18** | **2.15** | **7.06** | **1.28** |
| Copper | 0.5 | 35.7 | 197 | **41.6** | **39.5** | 26.1 | **46.6** | **41.9** | **46.1** | **56** | **58.7** | **46.7** | 24.1 | **62.5** | **51.1** | **43** | **30.8** | 31.8 | **49** | **28.9** |
| Iron | 50 | - | - | 27633 | 20072 | 18400 | 27000 | 29533 | 25100 | 34833 | 30250 | 23600 | 19200 | 31467 | 23683 | 24333 | 20700 | 19517 | 23583 | 20950 |
| Lead | 2.5 | 35 | 91.3 | **40** | **51.9** | **53.2** | **541** | **130** | **232** | **642** | **352** | **275** | 30.2 | **216** | **173** | **162** | **41.5** | **69.2** | **175** | **36.7** |
| Mercury | 0.005 | 0.17 | 0.486 | 0.084 | <0.05 | 0.033 | 0.135 | 0.02 | 0.08 | **0.228** | 0.079 | 0.106 | 0.0443 | n/a* | 0.0566 | 0.035 | 0.0276 | 0.02 | 0.052 | 0.0291 |
| Nickel | 0.5 | - | - | 29.7 | 21.3 | 20 | 33.3 | 24.9 | 25.6 | 42.3 | 32.7 | 23.9 | 24.5 | 40.2 | 33.9 | 45 | 61.7 | 24.2 | 29.6 | 24.8 |
| Selenium | 0.2 | - | - | 1.4 | <0.5 | 0.67 | 1.37 | 0.32 | 0.63 | 2 | 0.83 | 0.89 | 0.59 | 0.91 | 0.97 | 0.59 | 0.43 | 0.43 | 0.925 | 0.653 |
| Silver | 0.1 | - | - | 0.8 | 0.31 | 0.55 | 16.1 | 1.11 | 5.8 | 15 | 9.95 | 15.5 | 0.49 | 4.52 | 3.72 | 3.57 | 1.63 | 1.24 | 3.22 | 0.725 |
| Zinc | 10 | 123 | 315 | **125** | **137** | **118** | **1260** | **621** | **753** | **1637** | **1259** | **1357** | **127** | **638** | **430** | **539** | **138** | **172** | **545** | **142.3** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

**Table 6-2: Metal Concentrations in Lightning Creek Sediment at KV-41, 2007-2022**

| Total Metal Concentration mg/kg | Lab MDL | Guideline | | KV-41 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CCME ISQG | CCME PEL | 31-Jul-07 | 23-Sep-11 | 22-Aug-12 | 30-Aug-13 | 26-Aug-14 | 01-Sep-15 | 22-Sep-16 | 18-Aug-17 | 12-Sep-18 | 23-Sep-20 | 26-Aug-21 | 21-Sep-21 | 17-Sep-22 |
| Aluminum | 50 | - | - | 8693 | 6625 | 8550 | 7033 | 7530 | 9430 | 10290 | 12067 | 7140 | 9893 | 8685 | 9748 | 7820 |
| Antimony | 0.1 | - | - | 0.5 | 2.67 | 1.67 | 3.05 | 2.7 | 1.98 | 1.63 | 2.18 | 2 | 3.67 | 2.24 | 2.45 | 2.28 |
| Arsenic | 0.1 | 5.9 | 17 | **62.5** | **37.8** | **21.5** | **67** | **50** | **28.3** | **30.6** | **40.7** | **31** | **39.4** | **35** | **43.1** | **42.9** |
| Cadmium | 0.02 | 0.6 | 3.5 | **3.4** | **0.84** | **1** | **2.28** | **1.74** | **1.48** | **1.63** | **2.13** | **1.05** | **1.77** | **1.34** | **1.36** | **1.4** |
| Copper | 0.5 | 35.7 | 197 | 33.8 | 30.6 | 30.9 | **55** | **40** | 34.2 | **35.8** | **55.3** | 26 | 44.4 | 36.2 | 47.9 | 29.2 |
| Iron | 50 | - | - | 26000 | 20072 | 20600 | 21600 | 19233 | 21700 | 22333 | 25083 | 19633 | 24150 | 21750 | 24450 | 21100 |
| Lead | 2.5 | 35 | 91.3 | **82.2** | **40.4** | 31.5 | **138** | **108** | **70.6** | 30.1 | **47.1** | **42.7** | **61.6** | **59.3** | **66** | **83.9** |
| Mercury | 0.005 | 0.17 | 0.486 | 0.055 | <0.05 | 0.037 | 0.055 | 0.029 | 0.032 | n/a* | 0.058 | 0.016 | 0.04 | 0.026 | 0.029 | 0.00487 |
| Nickel | 0.5 | - | - | 30.4 | 22.6 | 26.4 | 34.3 | 28.8 | 27 | 27.5 | 35.1 | 36.5 | 30.2 | 28.1 | 33.4 | 25.3 |
| Selenium | 0.2 | - | - | 0.8 | <0.5 | 0.63 | 0.72 | 0.47 | 0.47 | 0.81 | 0.91 | 0.45 | 0.87 | 0.393 | 0.52 | 0.48 |
| Silver | 0.1 | - | - | 1.9 | 0.35 | 0.91 | 2.38 | 2.35 | 1.09 | 0.51 | 0.92 | 0.87 | 2.48 | 0.64 | 0.97 | 1.68 |
| Zinc | 10 | 123 | 315 | **247** | 121 | 110 | **228** | **196** | **177** | **127** | **200** | **134** | **183** | **156** | **178** | **180** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

**Table 6-3: Metal Concentration in Christal Creek Sediment at KV-6, KV-7, and KV-50, 2007-2022**

| Total Metal | Lab MDL | Guideline | | KV-6 | | | | | | | | | | | KV-7 | | | | | | | KV-50 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concentration mg/kg | | CCME ISQG | CCME PEL | 31-Jul-07 | 8-Aug-09 | 13-Jul-10 | 30-Aug-11 | 21-Aug-12 | 26-Aug-14 | 1-Sep-15 | 23-Sep-16 | 8-Sep-18 | 20-Sep-20 | 17-Sep-22 | 31-Jul-07 | 22-Aug-09 | 13-Jul-10 | 21-Aug-13 | 4-Sep-15 | 8-Sep-18 | 24-Sep-21 | 9-Sep-18 | 23-Sep-20 | 22-Sep-21 |
| Aluminum | 50 | - | - | 9410 | 8420 | 5880 | 7563 | 7130 | 6733 | 7450 | 7470 | 5490 | 5845 | 4675 | 7253 | 9540 | 6000 | 6580 | 6050 | 5043 | 7127 | 8286 | 5413 | 8208 |
| Antimony | 0.1 | - | - | 14.8 | 2 | 96.2 | 37.2 | 66.7 | 37.3 | 0.84 | 5.45 | 44.1 | 102 | 139.7 | 0.25 | 21.8 | 9.5 | 9.12 | 5.89 | 5.65 | 4.39 | 3.39 | 3.52 | 3.94 |
| Arsenic | 0.1 | 5.9 | 17 | **284** | **31.8** | **1030** | **448** | **923** | **544** | **16.5** | **85.2** | **598** | **1257** | **2107** | **34.7** | **194** | **121** | **122** | **66.2** | **85.2** | **76.5** | **597** | **1165** | **645** |
| Cadmium | 0.02 | 0.6 | 3.5 | **28.2** | **2.48** | **91.4** | **33.5** | **95.3** | **43.1** | **0.99** | **6.97** | **50.6** | **122** | **148.2** | **3.7** | **32.4** | **18.8** | **16.1** | **3.83** | **9.92** | **8.28** | **4.72** | **6.84** | **10.58** |
| Copper | 0.5 | 35.7 | 197 | **41.3** | **39** | **67.6** | 35.5 | **69.6** | **54.2** | 21.9 | 33.3 | **49.6** | **79.7** | **86** | 26.6 | **48.5** | 32.2 | 28.1 | 17.3 | 26.0 | 29.9 | 34.3 | 33.8 | **63.0** |
| Iron | 50 | - | - | 27133 | 18400 | 43800 | 28467 | 46900 | 36500 | 15100 | 21867 | 38400 | 48100 | 71600 | 20367 | 32300 | 24200 | 22600 | 16700 | 21567 | 24267 | 124750 | 215167 | 133067 |
| Lead | 2.5 | 35 | 91.3 | **954** | **73.4** | **4130** | **1388** | **3400** | **1533** | 27.5 | **237** | **1980** | **4690** | **8082** | **56.4** | **1040** | **453** | **348** | **227** | **223** | **235** | 34.5 | 28.5 | **42.9** |
| Mercury | 0.005 | 0.17 | 0.486 | 0.102 | 0.06 | **0.18** | 0.07 | 0.164 | 0.096 | 0.036 | n/a* | 0.090 | **0.214** | **0.294** | 0.068 | 0.1 | 0.025 | 0.051 | 0.047 | 0.026 | 0.040 | 0.04 | 0.042 | 0.065 |
| Nickel | 0.5 | - | - | 27.9 | 29.5 | 32.8 | 25.8 | 45.8 | 46 | 25.2 | 29.1 | 99.6 | 43.9 | 47.6 | 22.6 | 59.3 | 38.4 | 36.1 | 18.7 | 55.6 | 34.1 | 65.27 | 77.1 | 67.8 |
| Selenium | 0.2 | - | - | 2.5 | 1.6 | 1.5 | 0.8 | 2.1 | 1.3 | 1 | 1.2 | 1.11 | 1.59 | 1.52 | 1.2 | 1.7 | 1.2 | 1 | 0.4 | 0.62 | 0.68 | 1.43 | 1.72 | 2.36 |
| Silver | 0.1 | - | - | 12.2 | 1.04 | 66.5 | 22.6 | 50.6 | 32.5 | 0.43 | 3.19 | 29.1 | 72.6 | 125 | 0.8 | 14.1 | 5.51 | 3.72 | 3.23 | 2.62 | 2.27 | 0.6 | 0.48 | 0.88 |
| Zinc | 10 | 123 | 315 | **1483** | **237** | **5820** | **2122** | **5270** | **3100** | **132** | **599** | **4154** | **8595** | **10692** | **404** | **4330** | **2010** | **1580** | **362** | **1021** | **876** | **1207** | **2150** | **1800** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

## Table 6-4: Metal Concentrations in Flat Creek Sediment KV-9, 2007-2021

| Total Metal Concentration mg/kg | Lab MDL | Guideline | | KV-9 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CCME ISQG | CCME PEL | 31-Jul-07 | 22-Aug-09 | 31-Aug-11 | 22-Aug-12 | 3-Sep-15 | 7-Sep-18 | 24-Sep-21 |
| Aluminum | 50 | - | - | 7323 | 7520 | 6600 | 6600 | 7630 | 5867 | 6025 |
| Antimony | 0.1 | - | - | 150 | 63.6 | 145 | 58.2 | 106 | 62.9 | 56.2 |
| Arsenic | 0.1 | 5.9 | 17 | **586** | **196** | **413** | **167** | **319** | **217** | **199** |
| Cadmium | 0.02 | 0.6 | 3.5 | **57.1** | **71.4** | **37.4** | **16.1** | **25.4** | **31.1** | **17.6** |
| Copper | 0.5 | 35.7 | 197 | **194** | **285** | **141** | **62.3** | **99.3** | **97.7** | **74.2** |
| Iron | 50 | - | - | 75533 | 31500 | 51000 | 27600 | 43800 | 32983 | 32550 |
| Lead | 2.5 | 35 | 91.3 | **6290** | **5850** | **4760** | **2300** | **3580** | **3305** | **2352** |
| Mercury | 0.005 | 0.17 | 0.486 | **0.589** | 0.150 | **0.340** | 0.156 | **0.309** | 0.140 | 0.103 |
| Nickel | 0.5 | - | - | 31.6 | 47.9 | 26.1 | 19.6 | 27.3 | 34.7 | 24.4 |
| Selenium | 0.2 | - | - | 11 | 0.6 | 1.5 | 0.67 | 1.12 | 0.66 | 0.58 |
| Silver | 0.1 | - | - | 16 | 22.3 | 65.3 | 24.6 | 42.1 | 23.8 | 19.5 |
| Zinc | 10 | 123 | 315 | **3143** | **3360** | **2670** | **1130** | **1680** | **1552** | **1147** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

## Table 6-5: Metal Concentrations in No Cash Sediment at KV-21 and KV-56, 2018-2022

| Total Metal Concentration | Lab MDL | Guideline | | KV-21 | | | | KV-56 |
|---|---|---|---|---|---|---|---|---|
| mg/kg | | CCME ISQG | CCME PEL | 9-Sep-18 | 24-Sep-20 | 22-Sep-21 | 17-Sep-22 | 9-Sep-18 |
| Aluminum | 50 | - | - | 5925 | 6067 | 6637 | 6043 | 7862 |
| Antimony | 0.1 | - | - | 43 | 16.7 | 59.2 | 20.6 | 1.46 |
| Arsenic | 0.1 | 5.9 | 17 | **205** | **61.5** | **471.7** | **88** | **118.6** |
| Cadmium | 0.02 | 0.6 | 3.5 | **150** | **74.2** | **142.7** | **103.6** | **1.59** |
| Copper | 0.5 | 35.7 | 197 | **80.3** | **53.2** | **114.2** | **66** | 32.15 |
| Iron | 50 | - | - | 30283 | 19950 | 38667 | 23517 | 29033 |
| Lead | 2.5 | 35 | 91.3 | **1522** | **389** | **2483** | **860** | 25.98 |
| Mercury | 0.005 | 0.17 | 0.486 | 0.11 | 0.043 | 0.124 | 0.103 | 0.03 |
| Nickel | 0.5 | - | - | 95.5 | 66.9 | 73.7 | 56.4 | 57.2 |
| Selenium | 0.2 | - | - | 1.08 | 0.50 | 2.36 | 0.71 | 0.61 |
| Silver | 0.1 | - | - | 58.6 | 10.9 | 100.7 | 22.0 | 0.34 |
| Zinc | 10 | 123 | 315 | **10363** | **5662** | **13380** | **8035** | **192.7** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

**Table 6-6: Metal Concentration in South McQuesten Sediment at KV-1, KV-3, and KV-4, 2007-2021**

| Total Metal Concentration mg/kg | Lab MDL | Guideline | | KV-1 | | | | | | KV-3 | | | | | | | KV-4 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CCME ISQG | CCME PEL | 31-Jul-07 | 23-Aug-09 | 1-Sep-11 | 21-Aug-12 | 8-Sep-18 | 24-Sep-21 | 31-Jul-07 | 22-Aug-09 | 1-Sep-11 | 22-Aug-12 | 3-Sep-15 | 6-Oct-18 | 24-Sep-21 | 31-Jul-07 | 22-Aug-09 | 31-Aug-11 | 22-Aug-12 | 3-Sep-15 | 7-Sep-18 | 24-Sep-21 |
| Aluminum | 50 | - | - | 8050 | 9570 | 9810 | 12000 | 9440 | 11452 | 8140 | 7640 | 12900 | 10600 | 8750 | 9098 | 8970 | 9557 | 9790 | 8690 | 8470 | 9360 | 7062 | 7882 |
| Antimony | 0.1 | - | - | <0.5 | 0.9 | 0.8 | 1.17 | 0.94 | 0.84 | 15.6 | 29 | 15.1 | 23.2 | 22.4 | 14 | 24.0 | 32.3 | 21.9 | 26.5 | 18.4 | 12.3 | 8.88 | 79.7 |
| Arsenic | 0.1 | 5.9 | 17 | **18.8** | **22.6** | **17.7** | **32.8** | **40.6** | **30.9** | **130** | **128** | **94.1** | **145** | **108** | **113** | **126** | **180** | **109** | **116** | **100** | **68.7** | **45.3** | **284.5** |
| Cadmium | 0.02 | 0.6 | 3.5 | **3.3** | **4.18** | **4.08** | **9.44** | **6.49** | **6.11** | **13.5** | **13.9** | **15.7** | **22.8** | **11.5** | **14.7** | **24.4** | **17** | **16.1** | **14** | **11.8** | **8.57** | **3.57** | **27.53** |
| Copper | 0.5 | 35.7 | 197 | 25.4 | **36.2** | 32.7 | **64.1** | **42.3** | **44.0** | **41.5** | **37.3** | **67** | **67.1** | **42.2** | **45.2** | **53.6** | **59** | **57.1** | **39.9** | **40.7** | **37.6** | 22.6 | **105.0** |
| Iron | 50 | - | - | 17533 | 19900 | 17900 | 24000 | 24367 | 25950 | 25467 | 24000 | 25900 | 25300 | 23900 | 25167 | 26083 | 31800 | 25000 | 24100 | 22600 | 19700 | 15800 | 40967 |
| Lead | 2.5 | 35 | 91.3 | 13.9 | 11.9 | 11.1 | 16.7 | 14.9 | 12.3 | **423** | **463** | **336** | **614** | **342** | **388** | **728** | **985** | **422** | **376** | **372** | **266** | **248** | **3643** |
| Mercury | 0.005 | 0.17 | 0.486 | 0.054 | <0.05 | <0.05 | 0.0716 | 0.0284 | 0.0399 | 0.088 | 0.06 | 0.07 | 0.0856 | 0.0634 | 0.0502 | 0.0896 | **0.173** | 0.07 | <0.05 | 0.0557 | 0.0707 | 0.0311 | **0.2183** |
| Nickel | 0.5 | - | - | 74 | 103 | 102 | 195 | 210 | 192 | 69.4 | 56.1 | 186 | 140 | 96 | 161 | 73.1 | 66.8 | 128 | 93.3 | 101 | 81.6 | 52.1 | 48.2 |
| Selenium | 0.2 | - | - | 1.2 | 1.3 | 1.5 | 3.01 | 1.32 | 1.77 | 2.5 | 1.3 | 2.5 | 2.07 | 1.14 | 1.30 | 2.23 | 3.5 | 1.5 | 1.4 | 1.14 | 1.16 | 0.32 | 1.32 |
| Silver | 0.1 | - | - | 0.2 | 0.21 | 0.14 | 0.3 | 0.19 | 0.5 | 7.1 | 11.6 | 5.77 | 8.78 | 7.32 | 5.14 | 11.43 | 16.2 | 8.87 | 8.47 | 6.61 | 4.85 | 2.81 | 44.47 |
| Zinc | 10 | 123 | 315 | **512** | **800** | **799** | **1300** | **1190** | **1258** | **1054** | **1380** | **1960** | **1960** | **1280** | **1534** | **1470** | **1333** | **1690** | **1390** | **1270** | **922** | **271** | **2078** |

*MDL – method detection limit. Text in blue exceeded the Canadian Council for Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG). Text in red exceeded the CCME Sediment Quality Guideline Probable Effects Level (PEL).*

## 6.2 WILDLIFE

The KHSD supports a variety of wildlife including ungulates, fur-bearers, small mammals, upland game birds and waterfowl. Moose (*Alces alces*) are the most common and important sustenance animal in the area, with woodland caribou and sheep no longer present in the area. Repeated survey work over the last 15 years has indicated a healthy, stable moose population that depend on the KHSD for important habitat. For example, the subalpine zones on the Keno Hill, Bunker Hill, and Sourdough Hill uplands are key rutting and post rutting aggregation areas (O'Donoghue, pers. comm. as cited in Lortie, 2009). Further, the wetlands associated with and above Pumphouse Pond, the South McQuesten River and the Elsa Valley Tailings Facility areas are important calving and post calving areas (O'Donoghue, pers. comm. as cited in Lortie, 2009). In 2011, Environment Yukon noted in their draft report that the moose population in the Mayo-Elsa-Keno area are experiencing a slight decline in population numbers compared to previous surveys. It is suspected that overharvesting may have been the main cause for lower numbers of moose. A late winter survey was conducted in 2014 for the Mayo Moose Management Unit, which includes the project area (O'Donoghue et al., 2016). This survey found that the highest densities of moose were found in areas with abundant willows along rivers and creeks and in lowland burns, especially in the lowland burns near Keno City. Recruitment rate (i.e., the ratio of calves to cows) was found to be at or slightly below average.

Black Bear (*Ursus americanus*) and Grizzly Bear (*Ursus arctos*; listed as 'Special Concern' by the Committee on the Status of Endangered Wildlife in Canada; COSEWIC) are common in the area. The remaining large mammals being carnivores are generally considered Fur Bearers: wolves (*Canis lupus*), coyotes (*Canis latrans*), foxes (*Vulpes vulpes*), marten (*Martes Americana)*, mink (*Neovison vison)*, lynx (*Lynx canadensis*), wolverine (*Gulo gulo*) and river otter (*Lontra canadensis*) are, to varying degrees, all indigenous to the area. Beaver and muskrat are also economically important and common in aquatic habitats in the region. Other small mammals common to the area include Ground Squirrel *(Marmotini),* Red Squirrel *(Sciurus vulgaris),* varying hare, Weasel *(Mustela),* Vole *(Cricetidae),* and Shrew *(Soricidae).* Less common are Porcupine *(Erethizon dorsatum)* and Chipmunk *(Tamias).* Alpine areas have local populations of Hoary Marmot (*Marmota caligata*) and Pika (*Ochotona*).

The KHSD is also host to a diverse community of birds including both waterfowl and songbirds, three species which are COSEWIC listed as threatened (common nighthawk), or of special concern (rusty blackbird and olive-sided flycatcher). A thorough and comprehensive narrative of birds in the area can be found within Heart of the Yukon (Bleiler et al., 2006). Additionally, a report on the recent site specific waterbird use of the Christal Creek area jointly produced by Ducks Unlimited and the FNNND was conducted in 2004 (Leach and Hogan, 2005).

The effects of the Project on flora and fauna were discussed in a Human Health and Ecological Risk Assessment by SENES Consultants Ltd. (2011, 2014). Key findings of the assessment indicate that there are no issues for large mammals directly exposed to conditions on site. Waterfowl that consume benthic invertebrates as their main food source and incidental sediments, and beaver may be exposed to elevated levels of arsenic, lead and selenium from Christal Creek and Christal Lake.

## 6.3 VEGETATION

Three bioclimatic zones exist within the general KHSD study area: Boreal High, Boreal Subalpine, and Alpine, described in Table 6-7. The Boreal High bioclimate zone is the most predominant, comprising roughly two thirds of the KHSD, followed by the Boreal Subalpine (approximately one quarter of the study area). The Boreal Subalpine bioclimatic zone is found on both Galena and Keno hills. The Alpine zone occurs over a relatively confined area on Keno Hill in the eastern extent of the claims.

### Table 6-7: Bioclimate Zones in the Keno Hill Silver District

| Bioclimatic Zone (elevation range) | Definition |
|---|---|
| Boreal High (500−1,225 m) | The Boreal High forested areas are predominantly a mix of white and black spruce, with a shrub, lichen, and moss understory. The higher elevation extents of this bioclimatic zone supports a mix of subalpine fir, scrub birch, and willow as it approaches the Boreal Subalpine zone. The Boreal High tends to have more of an open canopy than Boreal Low and a moderate to well-developed shrub layer. Non-forested areas include: wetlands, riparian areas, avalanche tracks, exposed soil/rock, and anthropogenic disturbances. |
| Boreal Subalpine (1,225−1,450 m) | Open to sparse forest canopy cover, main trees species are subalpine fir and white spruce that become less frequent at the higher elevations. A well-developed shrub layer is composed mainly of scrub birch, willow species, and vaccinium. At the higher extent of this zone small woody shrubs, Dryas, mosses, and lichen replace the forest cover with only a few krummholtz subalpine fir scattered amongst the landscape. |
| Alpine (1,450 m+) | Alpine communities include dwarf ericaceous shrubs, scrub birch, willow species, grass/sedges, forbs, lichen, and bare bedrock at elevations above the treeline. Trees if present are low growing krummholtz that exist in small microsites where they can receive enough moisture and nutrients to grow. This bioclimatic zone is present only on Keno Hill. |

An assessment of disturbance mine site areas completed by AEG (2016c) focused on historical waste rock pits, dumps, and trenching. Photo records kept of natural revegetation at historical disturbed waste rock storage and pit sites (No Cash mine) provided examples of the level of succession over a six-year period. As expected, once primary colonizing species were established on site, microsites were created that increased surface organics and promoted growing conditions for greater diversity of species. Several sites showed evidence of more than one factor that would limit successful revegetation such as: insufficient substrate moisture, unfavourable substrate texture and unfavourable slope. Vegetation trials at the KHSD historical environmental liabilities have been ongoing to determine feasible surface treatments for optimizing revegetation of disturbed sites including scarifying the disturbance with machinery to add microsite conditions, applying a seed mix and fertilizer amendment, and adding natural growth media in the form of organic material or coarse woody fragments.

The most vegetation disturbance at sites was generally around access roads, adits, waste rock pits, and tailings storage. Most disturbed sites that dated back 45 years were observed to support plant communities consistent with early stage serial succession. There was noticeable change in natural revegetation over a six-year period at No Cash 100 waste rock storage and pit (disturbed from 1948 to 1975). The trial sites show that once initial vegetation was established on site, it created microsites and increased surface organics which promoted growing conditions for additional species. Furthermore, the vegetation within the KHSD provided an abundant seed source that, if the right conditions exist, naturally established primary colonizing species. At locations being monitored for active revegetation work on newly disturbed waste rock it was found that vegetation coverage benefitted from a second application of fertilizer and seed, particularly the year immediately following the second application. The reapplication of seed and fertilizer seemed to have less of an impact the second year after application. Establishing significant vegetation cover will need time similar to natural revegetation.

Results of terrestrial effects assessments done by Environmental Dynamics Inc. (EDI, 2008; 2009; 2010) concluded there was aerial contamination of metals to lichens but was limited to the eastern portion of the Valley Tailings Facility (2007). Other results showed evidence of elevated heavy metal concentrations in some medicinal plants used by FNNND as compared to control sites, particularly near the tailings (2008). EDI noted that metal concentration in plants appears to be species-specific; willow samples had higher concentrations of metals, while Labrador tea contained lower concentrations. The data further suggests that in this region there is little to no correlation between metal concentration in soils and metal concentration in plants. Therefore, the most likely pathway of metal accumulation in plant samples is aerial deposition of dust from the Valley Tailings Facility on the surface of plant tissues and is likely not being incorporated into the tissues of plants (2009).

# 7 SOCIAL ENVIRONMENT

The KHSD lies within the traditional territory of the FNNND and near the communities of Keno City and Mayo. The area has been shaped by mineral development over the past hundred years. Silver and lead ore deposits were discovered on Keno Hill in the early 1900s and the area has since seen fluctuating levels of ongoing quartz and placer mining and exploration ever since. Today, the area supports not only mineral development, but also tourism, recreation, traditional pursuits, as well as the local people.

Keno City is a small community situated at the end of the Silver Trail Highway with a population of approximately 20 permanent residents (YG, 2022). The community was originally established to support mining operations in the area and the community's population has fluctuated over the last hundred years in response to local mineral development activity. Today, Keno City comprises seasonal and full-time residences, a few small and growing businesses, the Keno City Mining Museum, and the Keno City Alpine Interpretive Centre.

The community of Mayo is located approximately 50 km from the KHSD. Mayo has a population of approximately 188 people (YG, 2022) and serves as a distribution and service centre for the surrounding area, supporting mineral development, tourism, and other activities. Mayo is also the administrative centre for the FNNND. In addition to being a tourist destination, the community is a base for wilderness and mining tourism, canoeing, hiking, big-game hunting and fly-in fishing.

# 8 GEOCHEMISTRY

## 8.1 ORE

AKHM has not conducted geochemical testing to assess the potential for acid rock drainage and metal leaching (ARD/ML) related to the ore. Testing has instead focused on the tailings produced and waste rock extracted to access the ore.

## 8.2 WASTE ROCK

AKHM conducted waste rock geochemical characterization studies throughout the KHSD and specifically within each of the mineralized target zones (Bellekeno, Onek 990, Lucky Queen, Flame & Moth, and New Bermingham) to understand the weathering behavior and potential for acid rock drainage and metal leaching (ARD/ML) potential related to the rocks. These characterization studies have been ongoing since AKHM initiated exploration in 2006. The results of these studies were summarized in AEG (2019a) reports for each deposit were compiled as appendices to the New Bermingham Water Use Licence application (AEG, 2019b), and as updated in subsequent annual reports filed under WL QZ18-044.

### 8.2.1 LABORATORY TEST PROGRAM

The samples were sourced from exploration drill holes  from Bellekeno, Lucky Queen, Onek, Flame & Moth, Silver King, and New Bermingham and routine development and production underground sampling from Bellekeno, Flame & Moth and New Bermingham. The laboratory test program included static and kinetic testing by accredited laboratories. The static testing consists of:

- Acid base accounting (ABA) analyses, including:
    - Paste pH;
    - Modified Sobek and/or Siderite-corrected neutralization potential (NP) as per Skousen et al. (1997);
    - Total sulphur by Leco;
    - Sulphate sulphur by HCl extraction;
    - Sulphide sulphur by difference, used to calculate acid potential (AP); and
    - Total inorganic carbon (TIC) by HCl leaching.
- Bulk elemental analysis by aqua regia digestion and ICP-MS analysis of digestate; and
- Shake flask extraction (MEND SFE) to determine soluble constituents associated with these materials (Price, 2009).

Kinetic testing consists of humidity cells and field leach barrels. Humidity cells tests have been conducted for the following materials:

- Flame & Moth non-acid generating/metal leaching (N-AML) waste rock composite (98 weeks, completed);
- New Bermingham N-AML cover hole waste rock composite HC-01 (57 weeks, completed); and
- New Bermingham N-AML advance exploration hole waste rock composite HC-03 (107 weeks, completed).

Field kinetic testing consisted of five field barrels containing N-AML waste rock and potentially acid generating/metal leaching (P-AML) waste rock from the Flame & Moth.

Table 8-1 lists the number of samples tested per production zone. Table 8-2 provides a description of each lithology code, while Table 8-3 provides a breakdown of number of samples per lithology and per production zone. Further details on the material tested, testing program and interpretation results for each site can be found in Altura (2008) for Bellekeno, ACG (2011a) for Onek, ACG (2011b) for Lucky Queen, ACG (2011c) for Silver King, AEG (2016a) and Ensero (2023) for Flame & Moth, and AEG (2019) and Ensero (2023) for New Bermingham.

### Table 8-1: Number of ARD/ML Samples per ARD/ML Test and per Production Zone

| Production Zone | ARD/ML Test | | | | |
|---|---|---|---|---|---|
| | Acid Base Accounting | Elemental Analysis | Shake Flask Extraction | Humidity Cell | Field Bin |
| Bellekeno | 71 | 6478 | 12 | - | - |
| Onek and Lucky Queen | 74 | 7507 | 17 | - | - |
| Silver King | 24 | 24 | - | - | - |
| Flame & Moth | 230 | 188 | 81 | 1 | 5 |
| New Bermingham | 173 | 479 | 113 | 2 | - |
| **Total** | **572** | **14676** | **223** | **3** | **5** |

*ARD/ML – acid rock drainage and metal leaching*

### Table 8-2: Lithology Description and Code

| Description | Code |
|---|---|
| Chlorotic Schist | CHSCH |
| Calcareous Quartzite | CQTZT |
| Calcareous Schist | CQZT |
| interbedded Carbonaceous Quartzite and Schist | ICQS |
| Greenstone | GNST |
| Graphitic Schist | GSCH |
| Quartzite | QTZT |
| Schist, Undifferentiated | SCH |
| Sericite Schist | SSCH |
| Thin Bedded Quartzite | TQZT |

**Table 8-3: Lithologies Sampled for ARD/ML Characterization per Keno Hill Silver District Production Zones**

| Production Zone | Lithology (Number of Samples) | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | GNST | GSCH | QTZT | SSCH | TQZT | ICQS | CQTZT | CHSCH | CSCH | |
| Bellekeno | 12 | 13 | 12 | 11 | 0 | 0 | 12 | 1 | 0 | 61 |
| Onek | 4 | 14 | 17 | 8 | 0 | 0 | 0 | 1 | 0 | 44 |
| Lucky Queen | 0 | 2 | 13 | 0 | 9 | 0 | 0 | 0 | 0 | 24 |
| Silver King | 1 | 2 | 7 | 3 | 7 | 4 | 0 | 0 | 0 | 24 |
| Flame & Moth | 1 | 17 | 118 | 16 | 14 | 0 | 10 | 6 | 1 | 183 |
| New Bermingham | 6 | 91 | 243 | 6 | 73 | 0 | 11 | 2 | 0 | 422 |
| **Total** | **24** | **139** | **410** | **44** | **103** | **4** | **33** | **10** | **1** | **758** |

*ARD/ML – acid rock drainage and metal leaching*

## 8.2.2 RESULTS

### 8.2.2.1 STATIC TESTING

#### *8.2.2.1.1 Acid-Base Accounting*

ABA is used to quantify the acid potential (AP) and neutralization (NP) of rock samples and to determine the ratio of their potentially acid producing and potentially acid consuming minerals. This provides an indication of the potential of geologic materials to generate acid in the long-term. The potential for acid potential was assessed using the MEND criteria (Price, 2009). Based on these criteria, three categories of potential for acid generation can be defined based on the NP/AP ratio (or neutralization potential ratio; NPR):

- Samples are classified as potentially acid generating (PAG) if NPR<1;
- Samples are capable of acid generation but with some uncertainty if 1≤NPR≤2; and,
- Samples are classified as not potentially acid generating (non-PAG) if NPR>2.

Figure 8-1 presents NP values versus AP values for all the KHSD waste rock samples. NP values were plotted versus AP values for each major lithology from Figure 8-2 to Figure 8-6.

Most waste rock samples collected from (potential) production zones from the KHSD had low potential for acid generation (i.e., NPR>2). The majority of the samples from Lucky Queen, Onek, Flame & Moth, New Bermingham, and Bellekeno had low potential for acid generation (58%, 73%, 76%, 49%, and 87% of samples, respectively). Overall, the waste rock from the easternmost deposits (e.g., Bellekeno, Onek, and Flame & Moth) tended to have higher NP than waste rock from the deposits located in the western portion of the KHSD (i.e., Silver King and New Bermingham), consistent with ABA characterization of historical KHSD waste rock (SRK, 2009). Silver King had the most samples with high potential for ARD (i.e., NPR<1; 68%), largely due to their low NP content of the samples (Figure 8-1). Approximately 33% and 19% of the samples collected from New Bermingham were classified as PAG and Uncertain, respectively, due to combination of low NP and AP. Onek also had a few PAG samples (16%); however, unlike New Bermingham, these generally had high AP and NP.

Analyzed based by major lithology, the QTZT, TQTZT, and GSCH samples broadly reflected the general NPR sample distribution (11% to 31% PAG; 44% to 76% non-PAG), consistent with the numerical dominance of these lithologies. The GNST and SSCH samples were predominantly non-PAG (Figure 8-2 to Figure 8-6).

#### *8.2.2.1.2 Elemental Chemistry*

The bulk concentration of an element is not a direct measure of how mobile an element may be during weathering because a multitude of factors (e.g., hydrology, climate, pH, redox conditions, presence of complexing ligands) ultimately affect the mobility and bioavailability of an element. However, the bulk concentration provides a preliminary indication of constituents that are elevated in the rock samples and which may result in high leachate concentrations.

The results of the bulk elemental analysis were compared to 10 times (10x) the average crustal abundance to assess whether the waste rock from KHSD Mining Operations deposits is enriched or depleted compared to the crustal average (CRC, 2005). Bulk content of antimony, arsenic, selenium, silver, cadmium, and zinc often exceeded their respective average crustal abundance by one to three orders of magnitude. Also, elevated lead concentration was evident in a few rock samples from all deposits except Lucky Queen and Flame & Moth. The concentrations of these elements in waste rock from the KHSD Mining Operations deposits are shown in Figure 8-7.

Antimony and silver concentrations were higher than their respective 10x crustal abundance (2 and 0.85 ppm, respectively) in most waste rock samples from New Bermingham, Bellekeno, Onek, Lucky Queen, and Silver King. Lower antimony and silver concentrations were observed for Flame & Moth waste rock samples. Bulk selenium concentrations exhibited similar distributions and were elevated above the 10x crustal abundance (0.5 ppm) in the majority of New Bermingham and Flame & Moth samples. Selenium was not analyzed in Bellekeno or Onek waste rock and the poor detection limits (10 ppm) used for Lucky Queen and Silver King dataset prevent a meaningful interpretation of their selenium data.

The highest arsenic, cadmium, and zinc concentrations were observed in waste rock from Onek, New Bermingham, and Bellekeno. The lowest concentrations of these metal(loids), and silver, were recorded in Flame & Moth waste rock samples, which were consistently lower than the crustal abundance for all four elements.

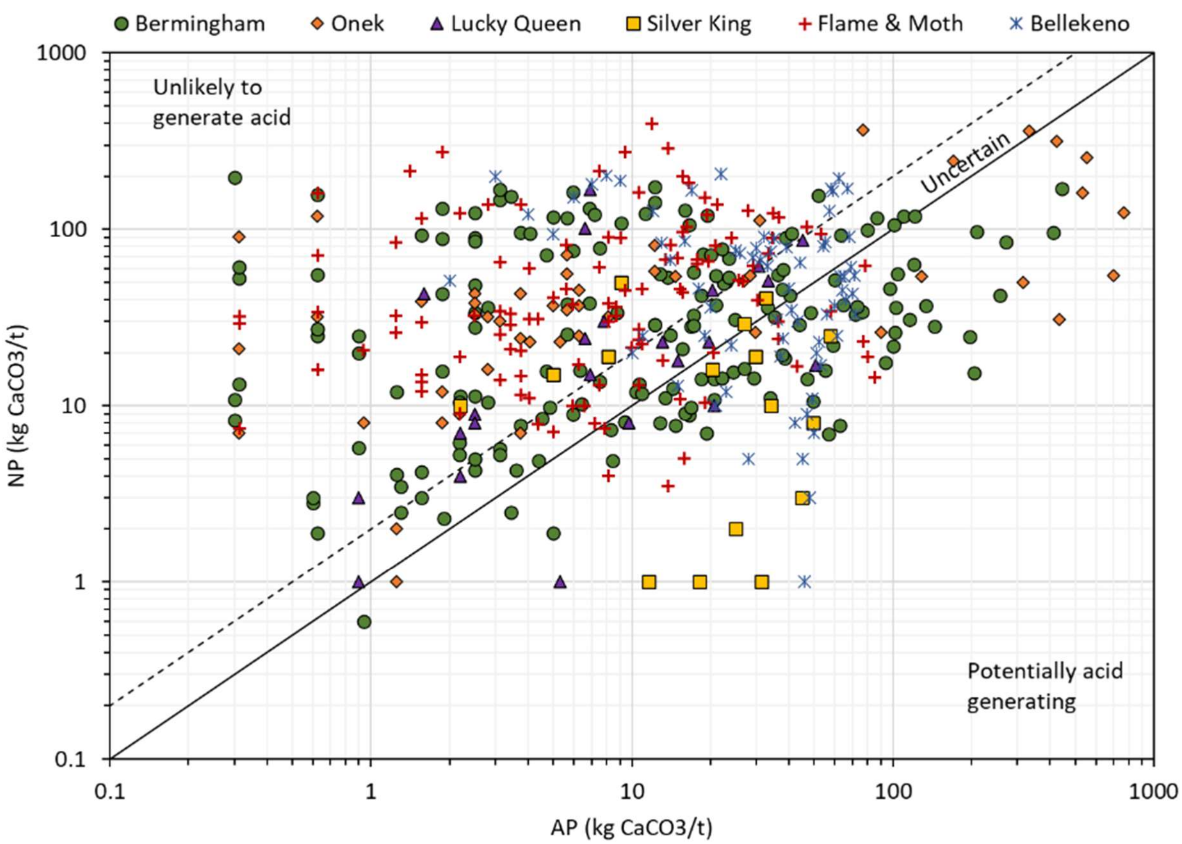



**Figure 8-1: Variability in NP and AP of Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

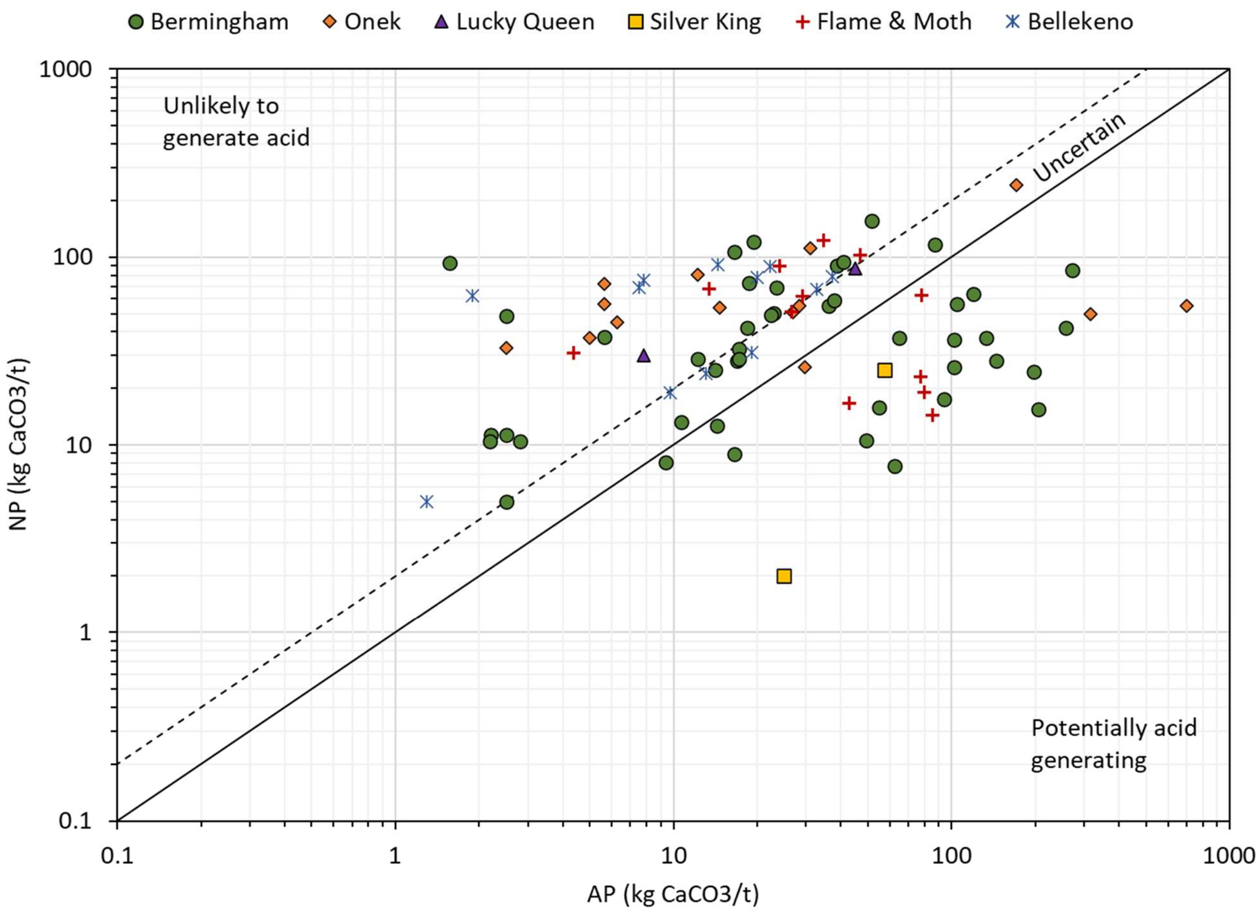



**Figure 8-2: Variability in NP and AP of GSCH Lithology Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

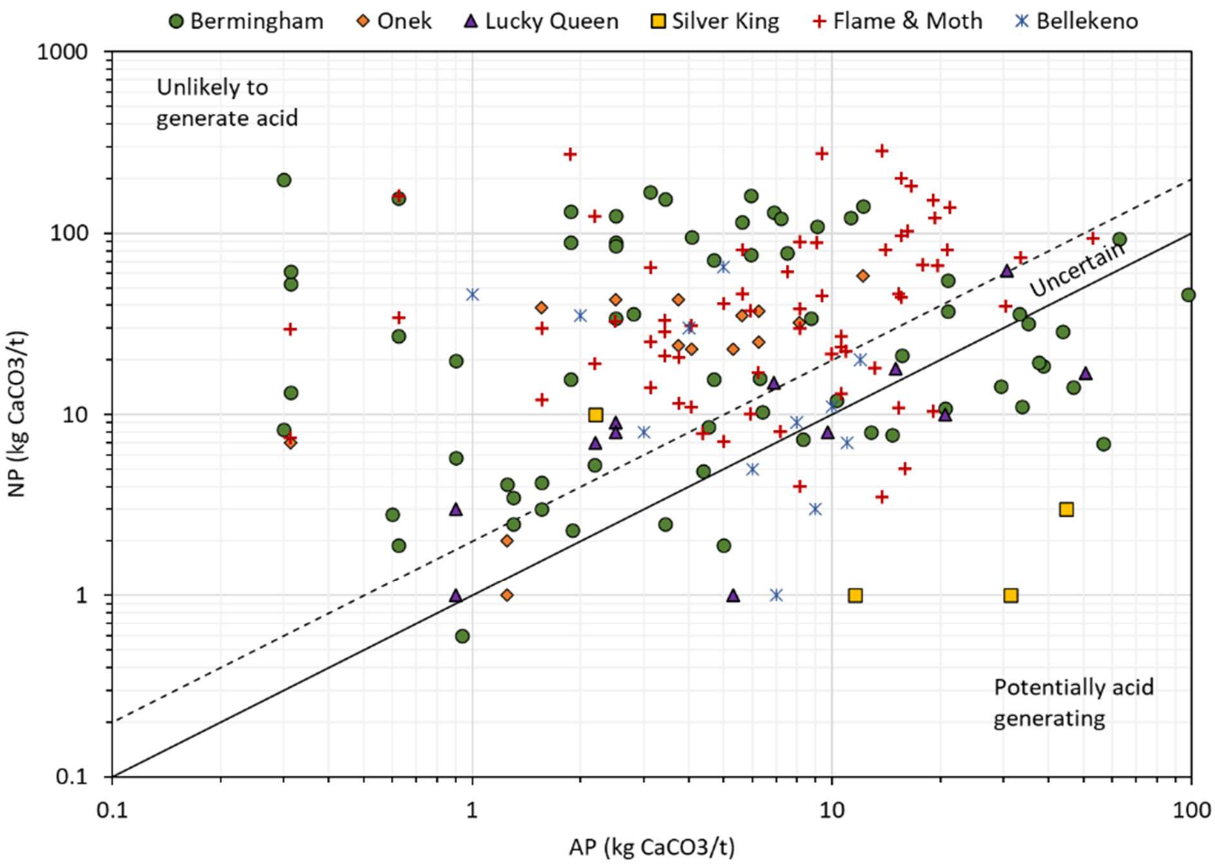



**Figure 8-3: Variability in NP and AP of QTZT Lithology Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

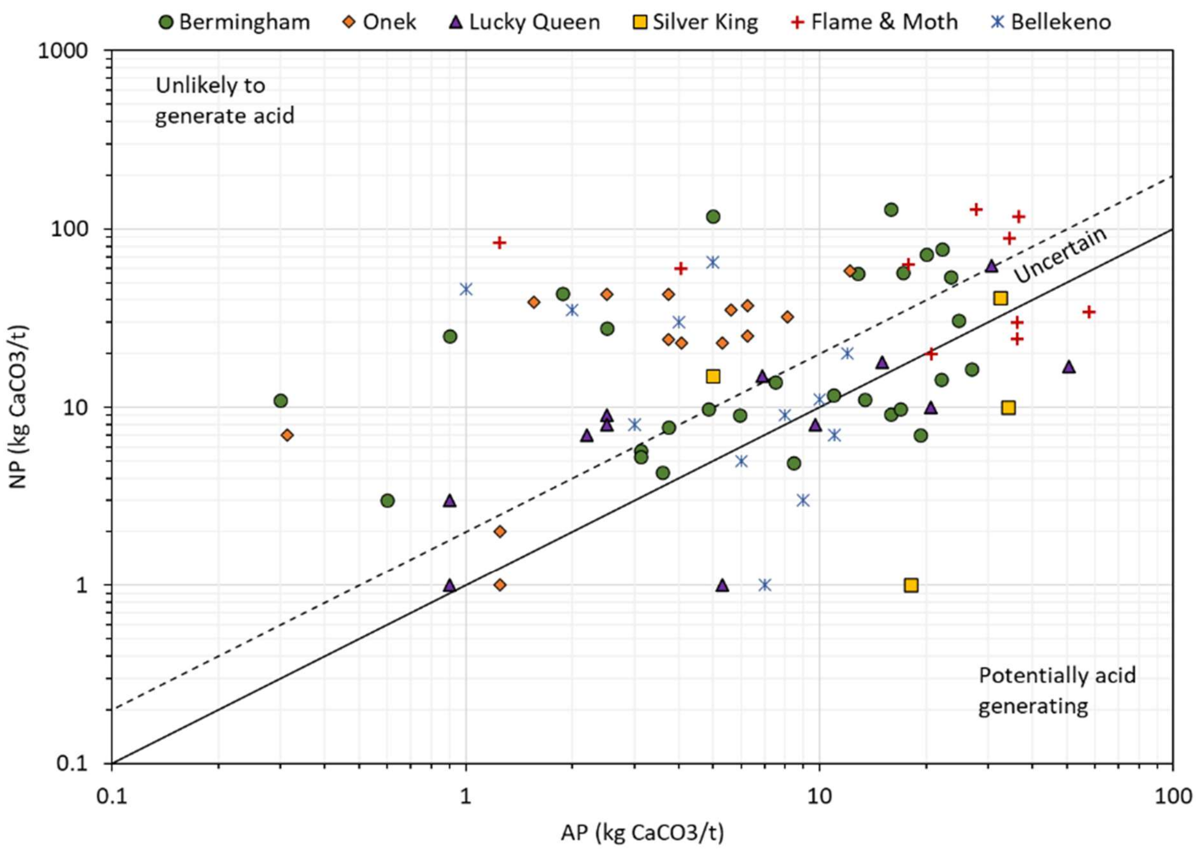



**Figure 8-4: Variability in NP and AP of TQTZT Lithology Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

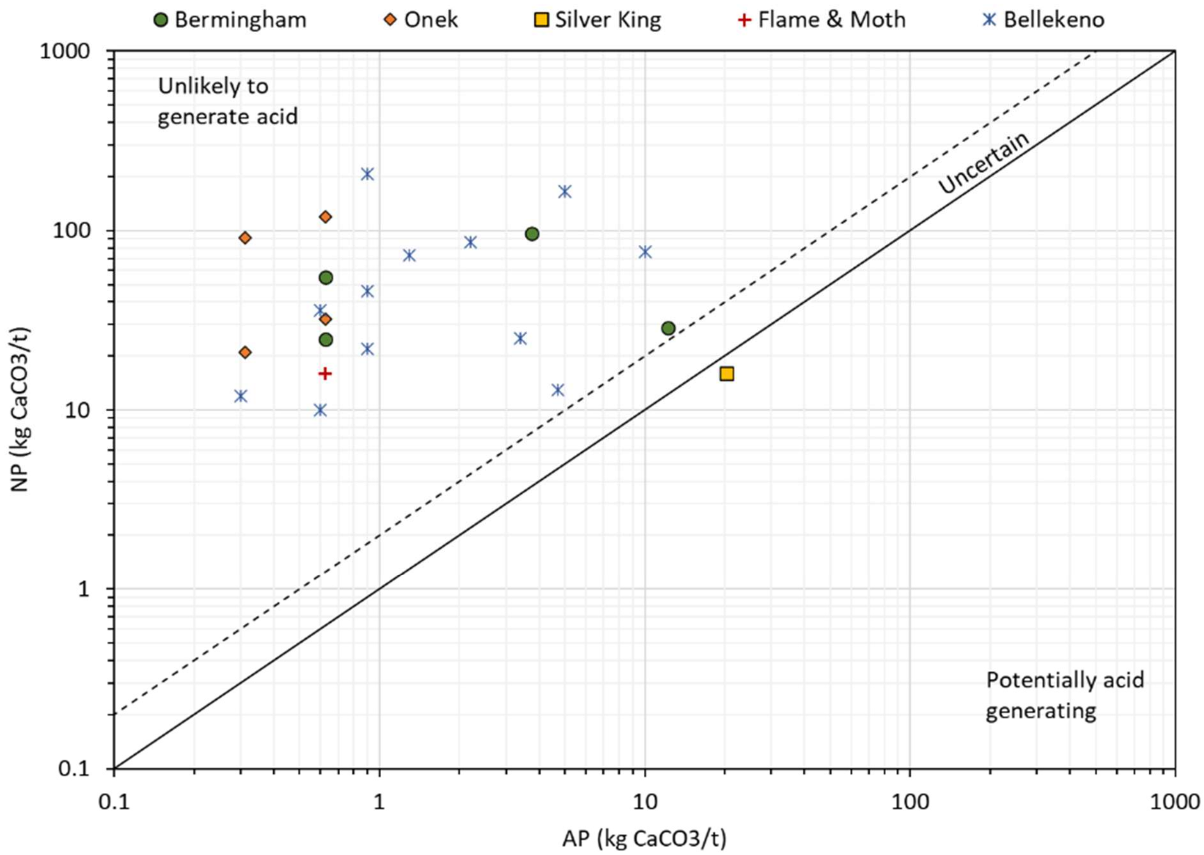



**Figure 8-5: Variability in NP and AP of GNST Lithology Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

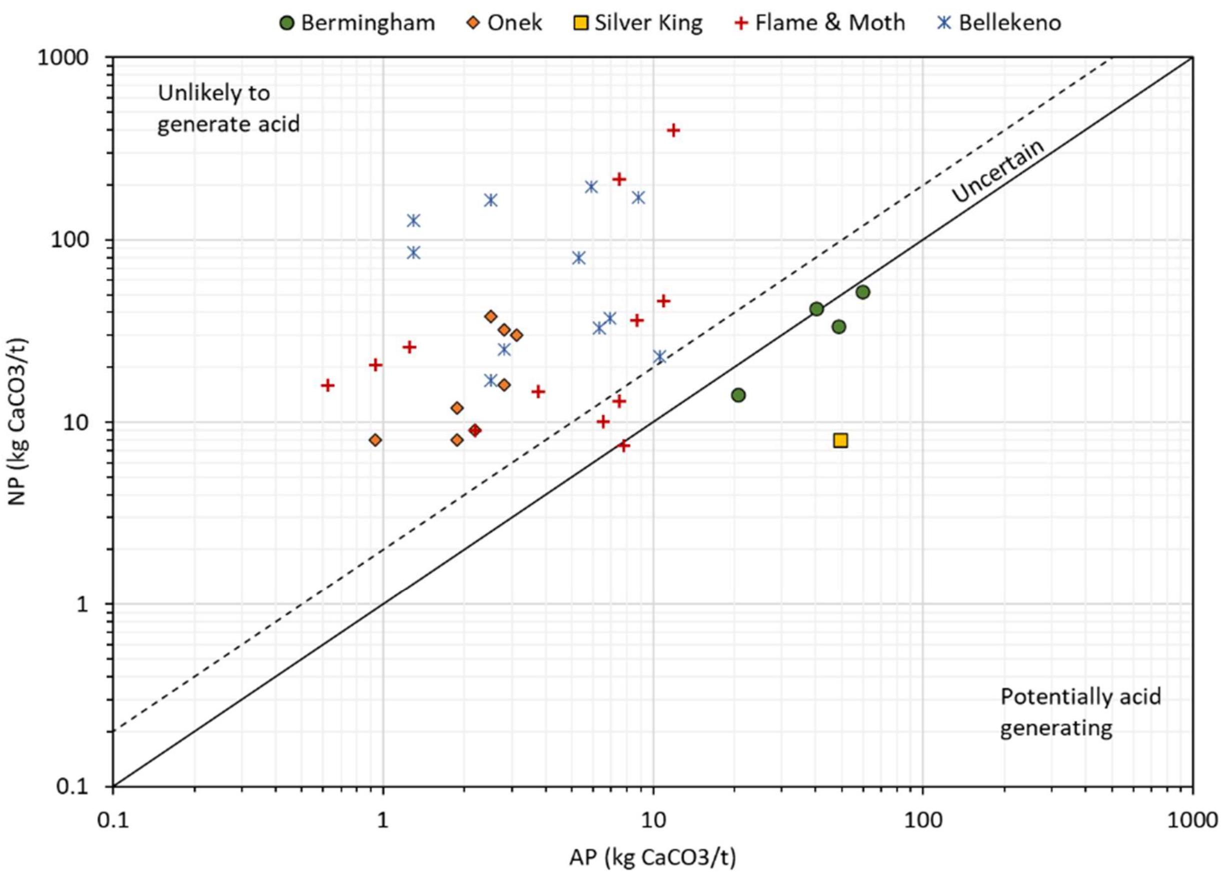



**Figure 8-6: Variability in NP and AP of SSCH Lithology Waste Rock Samples from Keno Hill Silver District Deposits**

*NP – neutralization potential; AP – acid potential; NPR – neutralization potential ratio. Solid and dashed lines indicate NPR = 1 and NPR = 2, respectively.*

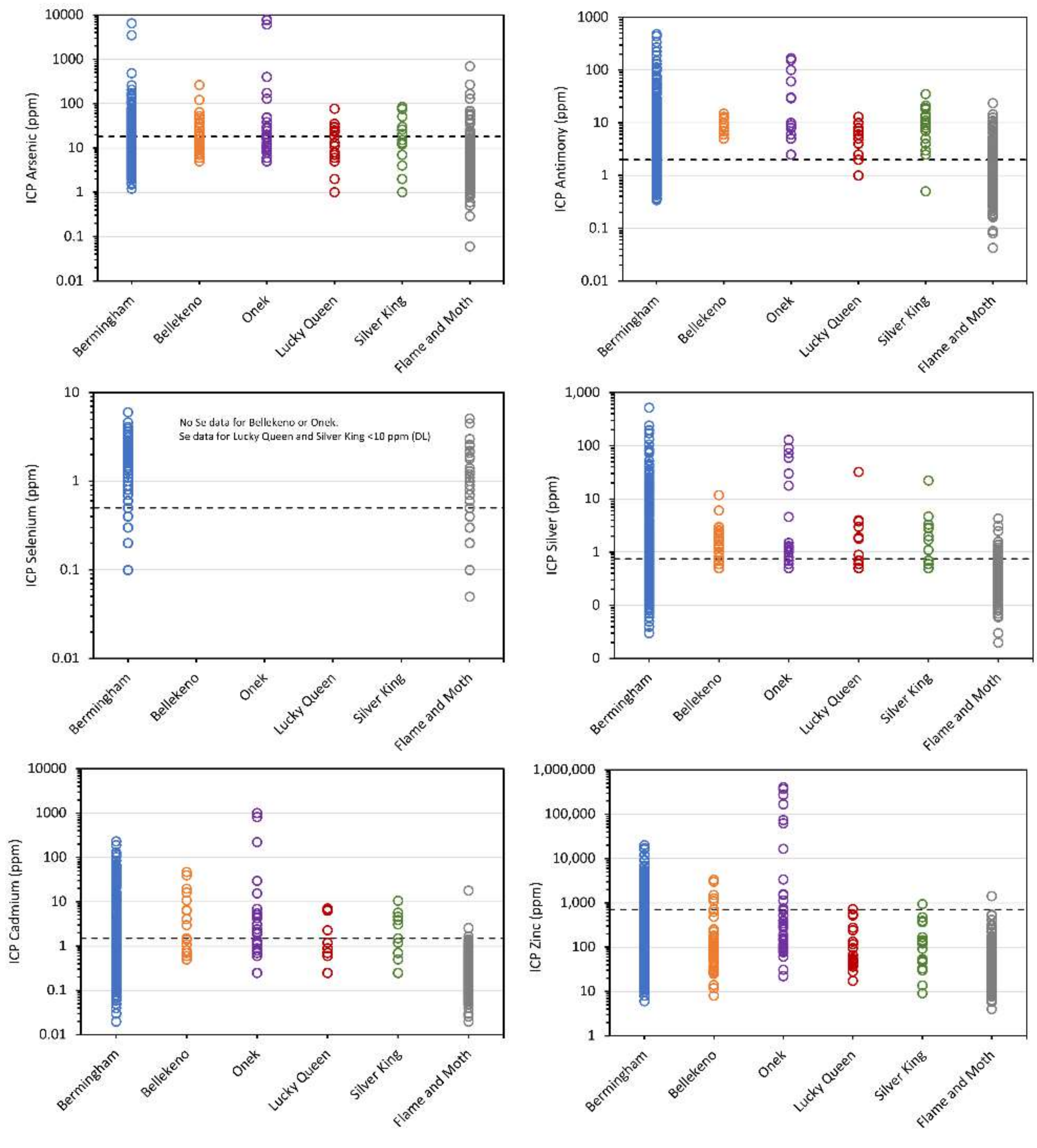



**Figure 8-7: Elemental Concentrations of Antimony, Arsenic, Selenium, Silver, Cadmium, and Zinc by Deposit**

*Dashed line represents 10x crustal abundance.*

#### *8.2.2.1.3 Shake Flask Extraction*

SFE provides an indication of readily soluble elements in a sample that may be mobilized/solubilized under the short-term leaching. A summary of results of SFE tests carried out on samples from the main lithologies at Flame & Moth and New Bermingham are reported in Table 8-4 and Table 8-5, respectively. No SFE data with adequate trace element detection limits for a meaningful comparison with generic water quality guidelines are available for the other deposits.

The focus of the discussion herein is on constituents that were enriched in the rock sample relative to 10x average crustal abundance during the elemental analysis and/or for constituents that had SFE results that were elevated relative to CCME (CCME, 2022) or British Columbia Ministry of the Environment (BCMOE, 2021) long-term water quality guidelines for the protection of freshwater aquatic life. The most recent of the two generic guidelines was used in the analysis as it represents the most up to date scientific data with respect to environmental risk assessment. This comparison aids in the identification of potentially elevated concentrations of soluble constituents and is strictly for reference purposes and does not indicate compliance or otherwise with respect to CCME or BCMOE guidelines.

The SFE pH of Flame & Moth and New Bermingham samples was circumneutral to alkaline, with five samples (three New Bermingham and two Flame & Moth) having pH higher than the upper CCME pH guideline (pH 9.0). Also, four New Bermingham samples had SFE pH lower than the CCME pH lower guideline (pH 6.5). 92% and 76% of samples from Flame & Moth exceeded fluoride and aluminum CCME guidelines (0.12 mg/L and 0.1 mg/L), respectively, whereas a lower proportion of exceedances for the same elements were obtained from New Bermingham samples (45% and 31% for fluoride and aluminum, respectively).

A high proportion of SFE antimony concentrations exceeded the BCMOE guideline (0.009 mg/L; 78% of samples) in the Flame & Moth dataset, whereas only 21% of New Bermingham samples exceeded despite higher bulk antimony concentrations in the New Bermingham waste rock samples (Figure 8-7). Conversely, a higher proportion of New Bermingham samples had SFE arsenic concentrations above the CCME water quality guideline (0.005 mg/L; 41% of samples) compared with the Flame & Moth SFE results (6% of samples), consistent with the higher elemental arsenic in New Bermingham samples compared to Flame & Moth (Figure 8-7). On the other hand, a similar proportion samples from both Flame & Moth and New Bermingham had SFE selenium concentrations that exceeded the BCMOE guideline for selenium (0.002 mg/L; 46% and 45% of samples, respectively) consistent with their comparable bulk selenium content.

In summary, the same constituents (fluoride and selenium) were observed at elevated levels in the SFE leachate in samples from both New Bermingham and Flame & Moth. The main differences were arsenic concentrations above the CCME guideline in 41% of the New Bermingham samples and 6% of the Flame & Moth samples, and antimony and aluminum concentrations above the guidelines in over 75% of Flame & Moth samples and less than 32% of the New Bermingham samples.

**Table 8-4: Comparison of SFE Data from Flame & Moth with Water Quality Guidelines**

| n = 50 | pH | Fluoride | Aluminum | Antimony | Arsenic | Selenium |
|---|---|---|---|---|---|---|
| | - | mg/L | mg/L | mg/L | mg/L | mg/L |
| **Guideline for Comparison** | **CCME** | **CCME** | **CCME** | **BCMOE** | **CCME** | **BCMOE** |
| **Aquatic Life Guideline** | **6.5 – 9.0** | **0.12** | **0.1 [a]** | **0.009** | **0.005** | **0.002** |
| Maximum | 9.2 | 4.49 | 6.2 | 0.13 | 0.012 | 0.030 |
| 3rd Quartile | 8.7 | 0.94 | 0.63 | 0.027 | 0.0018 | 0.0036 |
| Median | 8.6 | 0.51 | 0.29 | 0.013 | 0.0012 | 0.0018 |
| 1st Quartile | 8.4 | 0.28 | 0.10 | 0.0094 | <0.0005 | 0.00085 |
| Minimum | 7.9 | 0.068 | 0.017 | 0.00099 | <0.0005 | 0.00025 |
| Samples >CCME/BCMOE | 4% | 92% | 76% | 78% | 6% | 46% |

*SFE – shake flask extraction. Results exceeding CCME/BCMOE are presented in red.*

**Table 8-5: Comparison of SFE Data from New Bermingham with Water Quality Guidelines**

| n = 29 | pH | Fluoride | Aluminum | Antimony | Arsenic | Cadmium | Selenium |
|---|---|---|---|---|---|---|---|
| | - | mg/L | mg/L | mg/L | mg/L | mg/L | mg/L |
| **Guideline for Comparison** | CCME | CCME | CCME | BCMOE | CCME | CCME | BCMOE |
| **Guideline Value** | 6.5 – 9.0 | 0.12 | 0.1 [a] | 0.009 | 0.005 | 0.0002 [b] | 0.002 |
| **Method Detection Limit** | - | 0.01 | 0.0005 | 0.00005 | 0.00002 | 0.000005 | 0.00004 |
| Maximum | 9.3 | 0.80 | 0.58 | 0.032 | 0.066 | 0.0004 | 0.03 |
| 3rd Quartile | 8.8 | 0.26 | 0.11 | 0.005 | 0.011 | 0.00004 | 0.004 |
| Median | 8.1 | 0.10 | 0.04 | 0.002 | 0.003 | 0.00002 | 0.002 |
| 1st Quartile | 7.1 | 0.07 | 0.02 | 0.001 | 0.002 | 0.00001 | 0.0004 |
| Minimum | 6.2 | 0.04 | 0.004 | 0.0004 | 0.0006 | 0.000003 | 0.00005 |
| Samples >CCME/BCMOE | 7 | 13 | 9 | 6 | 12 | 1 | 13 |
| Percent >CCME/BCMOE | 24% | 45% | 31% | 21% | 41% | 3% | 45% |

*SFE – shake flask extraction. Results exceeding CCME/BCMOE are presented in red.*

#### 8.2.2.2 KINETIC TESTING

The results of completed laboratory humidity cell and ongoing field leach barrel tests are presented and discussed herein. The discussion is focused on constituents identified as constituents of potential interest due to their elevated concentration. The EQS set out in water licence QZ17-076, water quality objectives (WQO) at KV-21 for Bermingham, and CCME or BCMOE water quality guidelines are used for comparison with leachate chemistry. The hardness, DOC, and pH of nearest receiving environment was used to calculate the guidelines for hardness-, DOC- and pH-dependent elements. Station KV-51 in Christal Creek and Station KV-21 in No Cash Creek were used as the nearest receiving environment stations for the Flame & Moth and Bermingham datasets, respectively.

###### *8.2.2.2.1 Humidity Cell*

###### *8.2.2.2.1.1 Flame & Moth*

Figure 8-8 to Figure 8-10 present the humidity cell leachate data collected for constituents of interest for 98 weeks of testing of N-AML Flame & Moth waste rock.

**pH, Acidity, Alkalinity and Sulphate**

The leachate of the N-AML humidity cell was slightly alkaline during the entire test period, ranging from pH 7.5 to 8.4. The alkalinity was much higher than the acidity generated during the entire test period. It declined from a peak of 127 mg/L $CaCO_3$ at week 1 and stabilized around 50 – 60 mg/L $CaCO_3$ since week 60. While acidity was not measured during the first 9 weeks of humidity cell operations, acidity was 17 mg/L $CaCO_3$ at the initial sampling at week 10 then remained below 6 mg/L $CaCO_3$ during the reminder of the test (Figure 8-8).

Dissolved sulphate concentrations were below the BCMOE guideline (429 mg/L) at all times. Dissolved sulphate concentrations were highest during the initial rinse cycle (183 mg/L at week 0) as soluble metal sulphate salts stored in the sample were rinsed out of the cell. Sulphate concentrations then declined slightly before reaching a plateau of between 100 and 130 mg/L for weeks 2 to 11 as a result of metal sulphide weathering. Thereafter, sulphate concentration declined and stabilized between 20 and 30 mg/L since week 66.

**Constituents of Interest**

Dissolved concentrations of cadmium, zinc, silver, lead, nickel, and copper in the N-AML humidity cell leachate were typically below their respective detection limits for most of the test duration, and well below their respective water quality guidelines (Figure 8-8 and Figure 8-9).

The concentrations of antimony were highest during the initial rinse (0.011 mg/L), marginally above the BCMOE WQG (0.009 mg/L), then gradually declined over time, stabilizing below 0.001 mg/L since week 41 (Figure 8-10). Arsenic concentrations were stable between week 0 and week 20 (between 0.00071 and 0.00091 mg/L), then rose slowly reaching 0.0024 mg/L by week 54. Thereafter, arsenic concentration declined then stabilized between 0.0016 and 0.002 mg/L (Figure 8-10). Arsenic concentration was at least two times lower than the CCME guideline (0.005 mg/L) during the test.

Selenium concentrations in the leachate had a pattern different from all other constituents. Selenium initially declined sharply from the initial flush value of 0.0028 mg/L to approximately 0.001 mg/L over the first two weeks before rising sharply to a peak concentration of 0.0031 mg/L at week 8 (Figure 8-10). The selenium peak coincided with the sulphate peak suggesting that the dissolution of selenium-bearing sulphides is the likely source of selenium. Selenium concentrations then tailed off sharply, stabilizing between 0.0003 and 0.0005 mg/L from week 31 onwards (falling below the BCMOE guideline of 0.002 mg/L after week 12).

Sulphide and NP depletion times were estimated at 16 and 54 years, respectively, indicating that substantial amounts of NP will remain after the sulphide minerals have been exhausted (i.e., the waste rock is non-PAG). The Flame & Moth N-AML humidity cell was terminated after the concentrations of constituents of interest had stabilized.

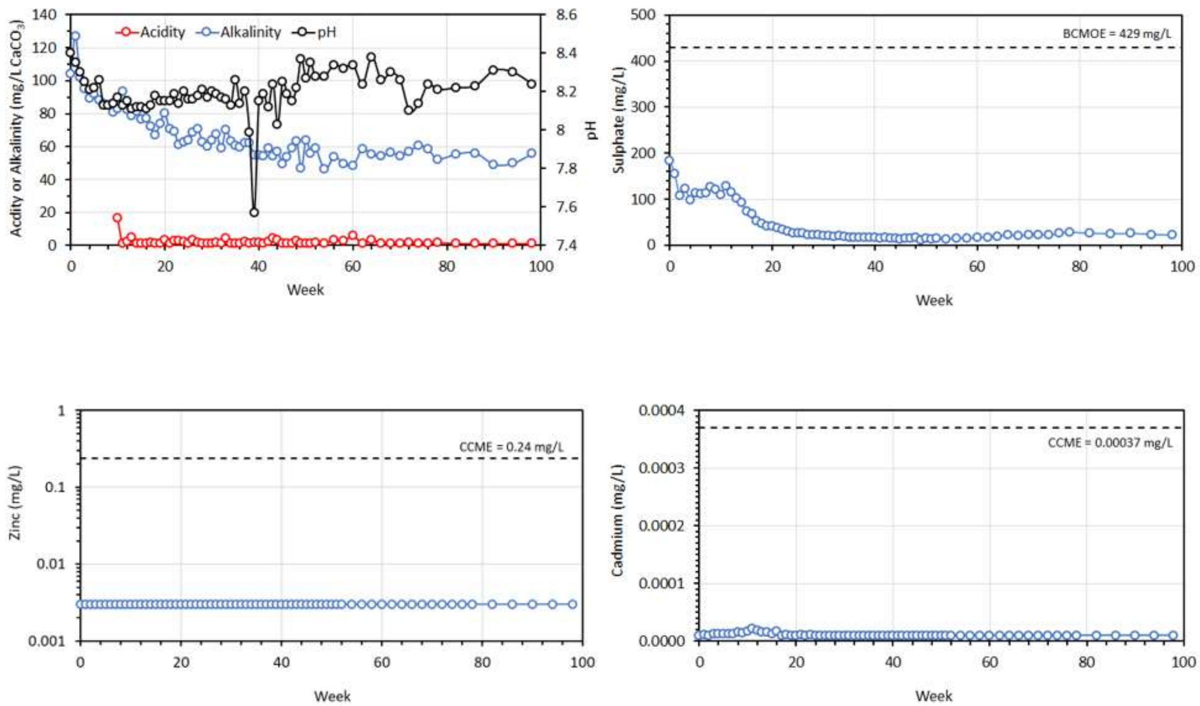



**Figure 8-8: Acidity, Alkalinity, pH, Sulphate, Zinc and Cadmium Trends of Flame & Moth Humidity Cell**

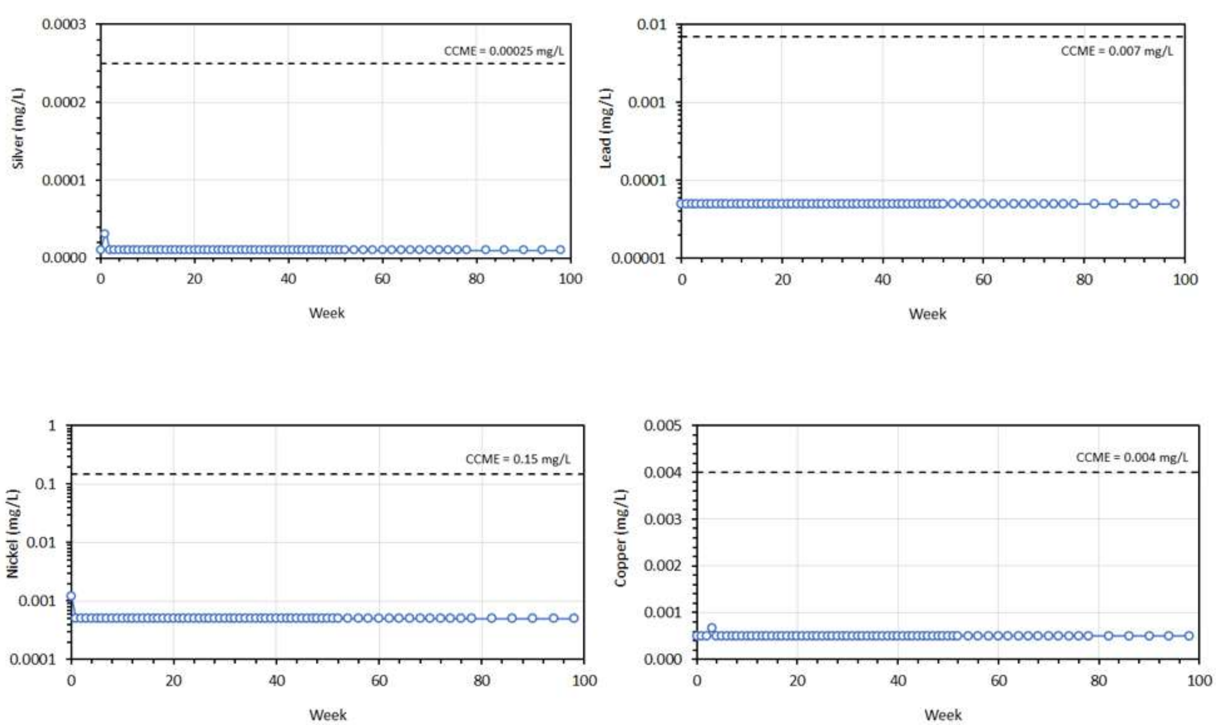



**Figure 8-9: Silver, Lead, Nickel, and Copper Trends of Flame & Moth Humidity Cell**

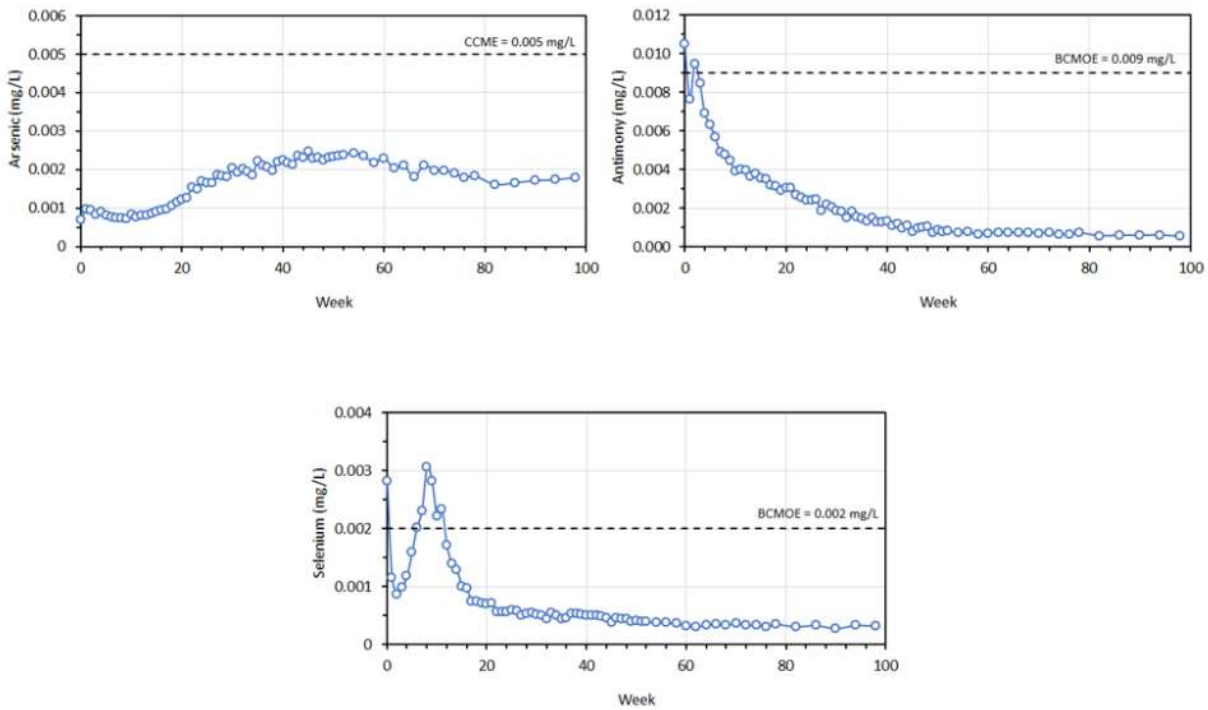



**Figure 8-10: Arsenic, Antimony and Selenium Trends of Flame & Moth Humidity Cell**

###### *8.2.2.2.1.2 New Bermingham*

Two waste rock humidity cells were operated for New Bermingham in order understand the potential for ARD/ML and rates of release from the New Bermingham N-AML waste rock. The first humidity cell (HC-01) was constructed using a composite of N-AML New Bermingham waste rock from cover holes with total sulphur and NP closer to the lower percentile (36%), NP close to the median (51%) of ABA data, and an NPR of 4.1 (total sulphur = 0.09 wt.%; NP = 10.3 kg $CaCO_3$/t; AP = 2.5 kg $CaCO_3$/t). The cell also had trace metal contents close to the 70$^{th}$ percentile and was operated for 57 weeks. The second humidity cell (HC-03) was constructed using a composite of N-AML New Bermingham waste rock from advanced exploration drill holes with total sulphur close to the 78$^{th}$ percentile, NP close to the 87$^{th}$ percentile, AP close to the 79$^{th}$ percentile of ABA data, and an NPR of 2.6 (Total sulphur = 0.36 wt.%; NP = 29.0 kg $CaCO_3$/t; AP = 11.3 kg $CaCO_3$/t). The second cell also had trace metal content close to the 90$^{th}$ percentile of the elemental data and operated for 107 weeks. Figure 8-11 to Figure 8-13 show the cell leachate data collected for constituents of interest.

**pH, Acidity, Alkalinity, and Sulphate**

Humidity cell HC-01 leachate was circumneutral (pH 6.7 to 7.6; Figure 8-11), with relatively low levels of alkalinity (4.5 to 16 mg/L $CaCO_3$) and negligible acidity (below or at the detection limit of 0.5 mg/L $CaCO_3$). Sulphate concentrations were also low (2.5 to 15.3 mg/L) and much lower than the sulphate WQO (524 mg/L; Figure 8-11).

Humidity cell HC-03 leachate was also neutral to slightly alkaline (pH 7.3 to 8.1) with relatively low levels of alkalinity (9.0 to 42.1 mg/L $CaCO_3$) and negligible acidity (<0.5 to 1.1 mg/L $CaCO_3$). Sulphate concentrations from HC-03 were higher than HC-01, ranging between 10.9 and 42.8 mg/L, reflecting its higher sulphur content. The sulphate concentration difference between the two cells gradually widened after cycle 16 but the sulphate concentration of the HC-03 was also much lower than the WQO (Figure 8-11).

**Constituents of Interest**

Aside from selenium in HC-01 and antimony and copper in HC-03, the concentrations of all constituents of interest in the leachates of New Bermingham N-AML humidity cells were well below their respective WQO, EQS, CCME, or BCMOE values (Figure 8-11 to Figure 8-13). Except for selenium, HC-03 had higher (pH, sulphate, zinc, nickel, arsenic, antimony and molybdenum) or comparable (cadmium, silver, lead, and copper) leachate concentrations with HC-01.

Selenium concentrations in HC-01 peaked at 0.009 mg/L after week 1, then gradually declined with concentrations by week 11 (0.0018 mg/L) below the BCMOE guideline (0.002 mg/L). Selenium concentrations in HC-03 had a similar trend as HC-01, though concentrations remained consistently below the BCMOE. Cadmium concentrations of HC-01 and HC-03 were comparable and more than two orders of magnitude lower than the EQS (0.01 mg/L). Arsenic concentrations in HC-01 and HC-03 were relatively low and also more than an order of magnitude lower than the WQO (0.025 mg/L) (Figure 8-13).

The concentrations of cadmium, zinc, lead, nickel, and copper in the New Bermingham N-AML humidity cell HC-01 and HC-03 were relatively low and more than an order of magnitude below their respective WQO (Figure 8-11 and Figure 8-12). Silver was below the detection limit in all humidity cell samples.

Sulphide and NP depletion time calculations were 21 and 39 years for HC-01, respectively, and 18 and 21 years, for HC-03, respectively. This indicates that a significant amount of NP will remain in HC-01 after the depletion of sulphide minerals, but only a limited amount of NP will remain after HC-03 is depleted of its sulphides, confirming the non-PAG character of the waste rock used for these humidity cells. Both humidity cells were terminated after the concentrations of constituents of interest had stabilized.

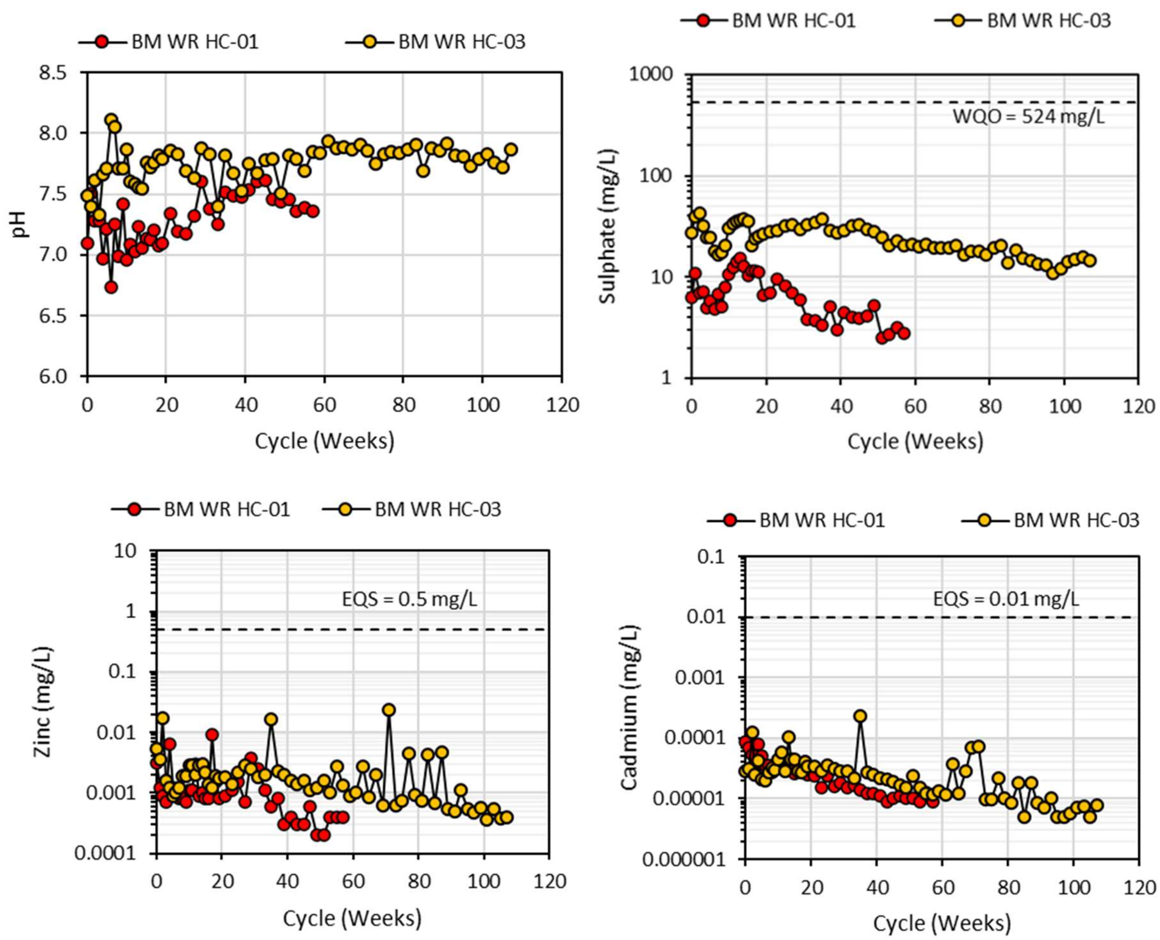



**Figure 8-11: pH, Sulphate, Zinc, and Cadmium Trends within the New Bermingham N-AML Waste Rock Humidity Cells**

*N-AML – non-acid generating/metal leaching; BM WR – New Bermingham waste rock.*

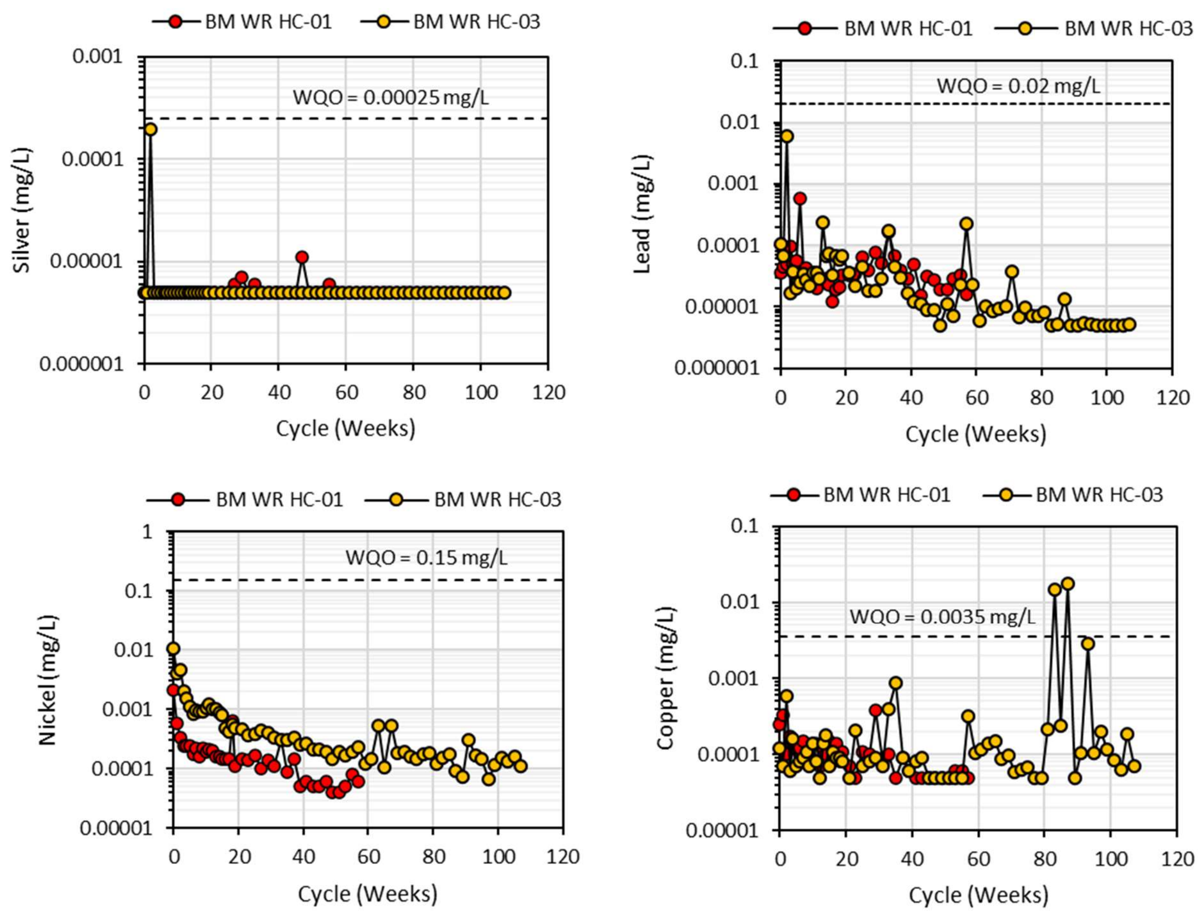



**Figure 8-12: Silver, Lead, Nickel, and Copper Trends within the New Bermingham N-AML Waste Rock Humidity Cells**

*N-AML – non-acid generating/metal leaching; BM WR – New Bermingham waste rock.*

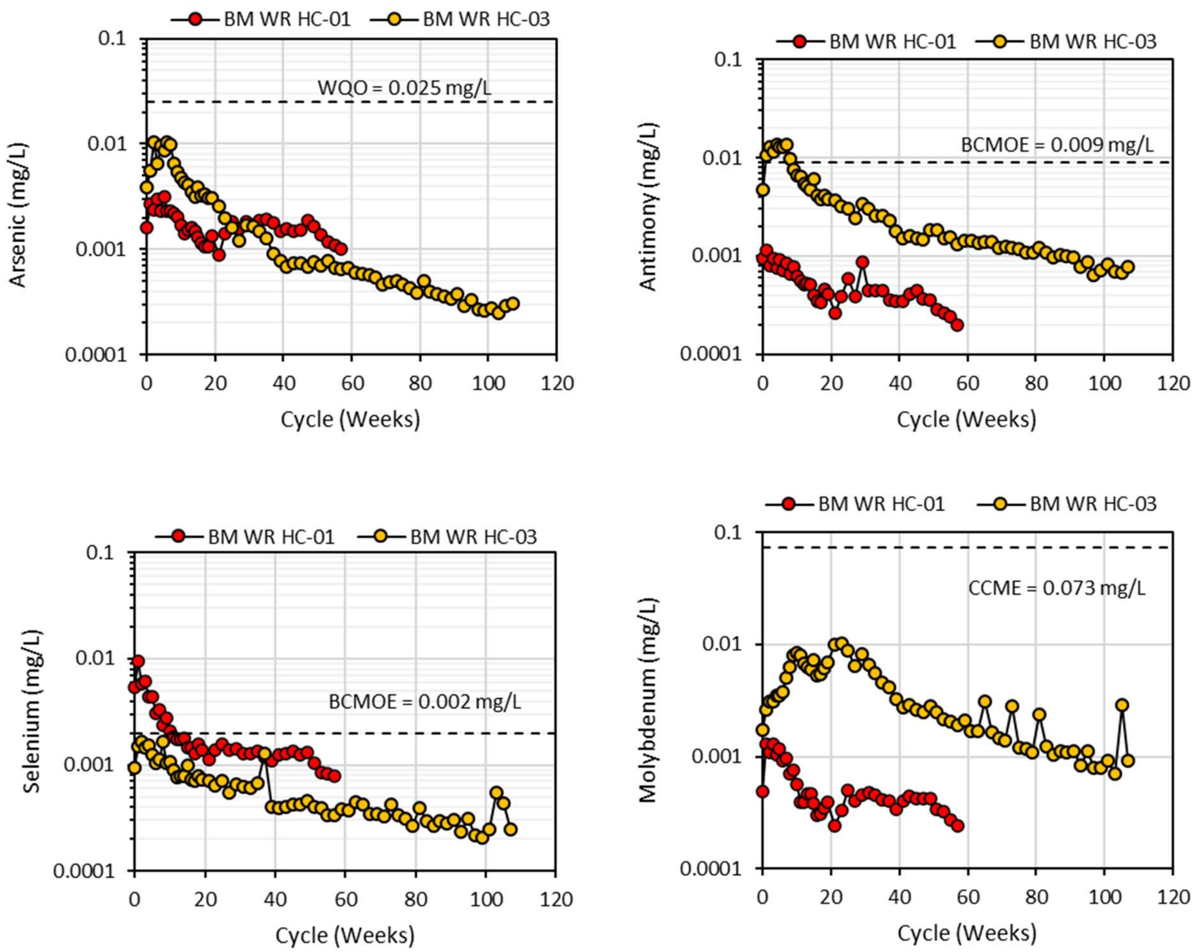



**Figure 8-13: Arsenic, Antimony, Selenium, and Molybdenum Trends within the New Bermingham N-AML Waste Rock Humidity Cells**

*N-AML – non-acid generating/metal leaching; BM WR –New Bermingham waste rock.*

##### *8.2.2.2.2 Field Leach Barrels*

Five field barrels containing Flame & Moth waste rock were constructed onsite in the June 2013 and continue to be monitored to date. Only field leach barrels 1 to 4 (FMB1 to FMB4) are used to evaluate the geochemical characteristics of the waste rock. FMB1 to FMB4 were also used to examine the ARD/ML potential of P-AML and N-AML rocks from the dominant lithologies identified during the development of the Flame & Moth deposit. Field barrel 1 (FMB1) was filled with P-AML rock with elevated sulphur content (median 2.79%), median NPR <1, and high maximum metal concentrations. Field barrel 2 (FMB2) was filled entirely with N-AML rock and had the highest median NP, relatively low sulphur content, and highest metal content of all the field bins. Field barrels 3 and 4 (FMB3 and FMB4, respectively) were filled with N-AML rock based on Flame & Moth screening criteria. This is primarily reflected in the sulphur content (median 0.39% and 0.43% for FMB3 and FMB4, respectively) and NPR (median 1.9 and 3.1 for FMB3 and FMB4, respectively). Damage to the FMB1 barrel was observed in early 2020 and the barrel was replaced in June 2020. This is coincident with a shift to higher pH leachate and lower metal concentrations.

The results are discussed and displayed herein and further details regarding the composition of the field barrels can be found in AEG (2016b). The field leach barrels are generally sampled three to five times a year except in 2019 when they were only sampled twice due to dry conditions and lack of leachate in the collection bins.

**pH, Acidity, Alkalinity and Sulphate**

Leachates from FMB1 to FMB4 had circumneutral to slightly alkaline pH during the monitoring period until 2016. Since 2016, leachate pH below 6.5 was observed in FMB1 and occasionally observed in seven sampling events for FMB2, five times for FMB3, and eight events for FMB4. FMB1 generally displayed pH below 6.0 values between September 2017 and September 2019, consistent with its P-AML status, then increased to circumneutral levels thereafter (when the barrel was replaced). The highest pH values were often recorded in the leachate from FMB3 although its pH intermittently decreased below 6.5 from September 2018 to 2022 samplings events. All N-AML barrels showed intermittent low pH (<6.5) during the September 2018 and 2022 sampling events (Figure 8-14).

FMB1 exhibited higher acidity (<1.0 – 1560 mg/L $CaCO_3$) than observed for FMB2, FMB3 and FMB4 (<1.0 – 42 mg/L $CaCO_3$). The difference between the leachate acidity from P-AML (FMB1) and the N-AML barrels (FMB2 to FMB4) decreased since July 2020 (Figure 8-14). The September 2019 acidity result for FMB1 was unusually high (1560 mg/L $CaCO_3$) as soluble products may have accumulated in the barrel since the barrel was not sampled between May and July.

Alkalinity of FMB1 decreased from the start of the experiment and then stabilizing from September 2013 to 2019. It is worth noting that FMB1 alkalinity was below the detection limit during July 2017 to September 2019, indicating a reduction in buffering capacity and explaining the acidic leachate pH observed. FMB1 alkalinity later increased, ranging from 21 to 42 mg/L from July 2020 to September 2022. After the initial reduction in alkalinity in the 2013 sampling event, the leachate alkalinity fluctuated but appeared to be relatively stable for FMB2 to FMB4 from 2014 to 2022.

FMB1 showed the highest dissolved sulphate concentrations, ranging from 415 to 4930 mg/L with a median of 1710 mg/L (Figure 8-14). FBM2 to FMB4 had comparable dissolved sulphate concentrations with median values ranging from 301 to 577 mg/L. Dissolved sulphate concentrations were typically highest in the summer months (July-September) and lowest in the spring and fall sampling events, except for the 2017 and 2018 datasets, which showed a general increase in sulphate concentrations through the year. Sulphate concentrations in all the FMB1 leachate samples exceeded the BCMOE guideline of 429 mg/L. Sulphate concentrations in the FMB2, FMB3, and FMB4 leachates were intermittently above the BCMOE guideline. All field barrel samples exceeded the BCMOE sulphate guidelines in September 2019, 2021, and 2022, likely due to the build up of soluble products in the field barrels between May and July and subsequent flushing in September.

**Constituents of Interest**

The trends of trace element broadly reflected the P-AML/N-AML classification of the barrels. FMB1 was composed of PAG material and the leachate from it regularly contained the highest concentrations of zinc, cadmium, nickel, lead, copper, and silver (Figure 8-15 and Figure 8-16). FMB1 showed cadmium and zinc concentrations constantly exceeding the EQS and nickel and copper concentrations in exceedance from August 2016 to September 2019. FMB2, FMB3, and FMB4 were primarily composed of waste rock with low potential for ARD. These field barrels generally exhibited zinc, cadmium, nickel, lead, copper, and silver leachate concentrations below the EQS, with several exceptions. The exceptions include eight copper exceedances in FMB4, one copper and one zinc exceedance in FMB2, and one copper, two cadmium and three zinc exceedances in FMB3 (Figure 8-15 and Figure 8-16). The similar patterns of zinc, cadmium, nickel, copper, and lead and their high concentrations in the P-AML leach barrel FMB1 coincide with high sulphate and acidity levels, indicating a common source via sulphide oxidation. Conversely, the low concentrations of arsenic, antimony, and selenium in FMB1 leachates compared with the N-AML field barrels may suggest lower release rate of oxyanions under acidic conditions of the P-AML rock drainage compared with circumneutral N-AML drainage. Additionally, concentrations of cadmium, copper, lead, nickel, silver, and zinc were markedly lower in FMB1 leachate since September 2019, coincident with the increased pH recorded during this period.

***Zinc***

The zinc concentrations were consistently below the CCME guideline in the N-AML FMB4 leachate, showing the lowest zinc concentrations than other three field barrels (Figure 8-15). Zinc concentrations of FMB2 leachate were also below the CCME guideline but higher than FMB4. Zinc concentrations from FMB3 were higher than FMB2 and mostly lower than the EQS for zinc (0.5 mg/L), except for the sampling events in September 2019 and 2022, coinciding with the high sulphate and lower pH measurements. Most FMB1 samples collected during 2013 to 2019 had zinc concentrations above the EQS for zinc, approximately one to two orders of magnitude higher than the zinc levels in the other field barrels. FMB1 showed an increasing trend in zinc concentrations (0.4 – 722 mg/L) between 2013 and 2019, subsequently decreased and stabilized to approximately 1 mg/L or lower since September 2020 to September 2022. The increasing trend in zinc concentrations of FMB1 between 2013 to 2019 coincided with the increasing trends in sulphate and acidity observed during this period, reflecting the character of P-AML rock in FMB1. The decreasing trend in zinc concentrations of FMB1 from 2020 to 2022 is coincident with the increased pH levels recorded during this period.

The zinc concentration in leachate collected from the N-AML field leach barrels FMB2, FMB3, and FMB4 have remained below the EQS. The high zinc releases observed in September 2019 and September 2022 coincided with the high sulphate releases, indicating a common source, likely the flushing of soluble weathering products stored in the field barrels between May and September.

***Cadmium***

Cadmium concentrations had very similar trends to those of zinc (Figure 8-15). Cadmium concentrations in FMB1, FMB2, and FMB3 leachates exceeded the CCME guideline (0.00037 mg/L) for all samples collected to date, except one sample of FMB2 in 2015. FMB1 displayed the highest cadmium concentrations ranging from 0.01 to 6.9 mg/L, above or comparable to the EQS of 0.01 mg/L, reflective of the metal-leaching nature of P-AML material. Cadmium concentrations in FMB4 leachates were regularly lower or just slightly above CCME, except for five occasions in August of 2021 and 2022 and September of 2019, 2021, and 2022 when concentrations were approximately one order of magnitude higher than the CCME guideline. Like zinc, cadmium concentrations in FMB1 leachate exhibited an increasing trend from 2013 to 2019, then decreased and stabilized since September 2020. The increasing cadmium concentrations in FMB1 leachate from 2013 to 2019 coincided with the decreasing pH and increasing sulphate and acidity during this period, reflecting the character of P-AML rock in FMB1. The decreasing and then stabilizing cadmium concentrations between 2020 to 2022 coincided with an increase in leachate pH.

The other three N-AML field barrels (FMB2 to FMB4) contained cadmium levels below the EQS, except for FMB3, which showed concentrations above the EQS threshold in September of 2019 and 2022. The high cadmium releases observed in these two months coincided with the high sulphate releases, indicating a common source, likely the flushing of soluble weathering products stored in the field barrels between May and September.

***Nickel***

Nickel concentrations were highest in P-AML FMB1 leachate collected from 2013 to 2020, consistently exceeding the CCME threshold of 0.15 mg/L and intermittently exceeding the EQS of 0.5 mg/L (Figure 8-15). Like zinc and cadmium, nickel concentrations in FMB1 displayed an increasing trend from 2013 to 2019, coinciding with the minor increasing trends in sulphate and acidity observed during this period. Nickel concentrations in FMB2, FMB3 and FMB4 (N-AML) leachates gradually declined from September 2019 to September 2020, subsequently decreasing and stabilizing from September 2020 to 2022. The reason for the increasing and then decreasing patterns in nickel concentrations of FMB1 is likely the same as it is for zinc and cadmium, related to the higher pH observed for this period.

Nickel concentrations in leachate from FMB2, FMB3, and FMB4 were consistently lower than the CCME guideline and EQS, except for FMB3, showing elevated nickel concentrations above the CCME and EQS threshold in September 2022. Like zinc and cadmium, the high nickel releases observed in September 2022 coincided with elevated sulphate, indicating a common source, likely the flushing of soluble weathering products stored in the field barrels between May and September. Like zinc, sulphate, and cadmium, nickel concentrations were relatively higher in September 2019 and 2022 than other months for FMB2 to FMB4, likely due to accumulation of soluble nickel-bearing weathering products over the summer.

***Lead***

FMB1 generally contained the highest lead concentrations (0.0013 – 0.74 mg/L) from 2013 to 2019, consistently above the CCME threshold (0.007 mg/L) between August 2016 and September 2019. Lead concentrations in FMB1 also exceeded the EQS (0.2 mg/L) in July 2018 and September 2019 (Figure 8-15), reflective of the P-AML nature of its waste rock content. Similar to the aforementioned constituents of interest, lead concentrations showed a minor increasing trend from 2013 to 2019, followed by a decrease and stabilization between 2020 to 2022.

Lead concentrations from the three N-AML field barrels (FMB2, FMB3, and FMB4) were typically below the CCME guideline of 0.007 mg/L (Figure 8-15) except in a few instances for FMB2 and one instance for FMB4. The highest lead concentrations were recorded in September of 2019 and 2022, likely due to flushing of soluble lead-bearing weathering products accumulated over the summer.

***Copper***

FMB1 and FMB4 generally had higher copper concentrations than FMB2 and FMB3 between 2013 to 2019 (0.003 – 7.7 mg/L) and exceeded the EQS (0.1 mg/L) for the first three sampling events in 2013 and most sampling events between 2017 and 2019 (Figure 8-16). Copper concentrations in FMB1 leachates decreased and then stabilized from 2020 to 2022. Copper concentrations in N-AML FMB3 remained below both the EQS and CCME guideline for most sampling events since late 2014 except in August 2018, and September 2019 and 2022. Conversely, FMB2 exceeded the copper EQS once in 2017. The copper concentrations from both FMB2 and FMB4 frequently exceeded the CCME threshold since the beginning of each test (Figure 8-16). Like all previous metals, an unusually high copper concentration was measured in FMB1 in September 2019 due to flushing of accumulated weathering products. The copper concentrations observed in the leachate from the N-AML field barrels in September 2019 were broadly consistent with historical levels.

***Silver***

FMB1 displayed the highest silver concentration of all field leach barrels (<0.00005 – 0.001 mg/L). Silver concentrations in P-AML FMB1 were comparable to the N-AML field barrels (<0.00001 – 0.0001 mg/L; Figure 8-16) until September 2017, after which the silver concentrations in the leachate from N-AML field barrels fell below the detection limit, whereas the P-AML silver concentration remained an order of magnitude higher. Only the initial sampling event and the September 2019 sample event (0.00046 and 0.001 mg/L, respectively) of FMB1 exceeded the silver CCME guideline (0.00025 mg/L; Figure 8-16). The silver levels in leachate from all the N-AML field barrels were below the CCME threshold and more than two orders of magnitude lower than the EQS (0.02 mg/L).

***Arsenic***

The leachate from FMB1 and FMB3 had comparable levels of arsenic (typically 0.0005 – 0.012 mg/L), which were below the CCME threshold (0.005 mg/L) for all but three FMB1 samples (Figure 8-16). Arsenic concentrations in FMB2 and FMB4 were also comparable (0.006 – 0.019 mg/L), higher than FMB1 and FMB3, and exceeded or were comparable to the CCME guideline for most samples (Figure 8-16). Arsenic concentrations in FMB2 leachate gradually decreased since May 2016 and stabilized to levels below the CCME guideline since September 2017. The arsenic concentrations in all the field barrel leachates were well below the EQS (0.1 mg/L). Unlike all constituents of interests discussed thus far, no increase of arsenic concentration was observed in any of the N-AML field barrels in September 2019 or 2022, except for FMB1 in September 2019 and FMB3 in September 2022.

***Antimony***

All field barrels exhibited a decreasing trend in the antimony concentrations during the monitoring period (Figure 8-16). The lowest antimony concentrations were observed in leachates from FMB1 and FMB3 (0.0013 – 0.026 mg/L), in which the majority of the samples were comparable to or below the BCMOE working guideline (0.009 mg/L) (Figure 8-16). The antimony concentrations in the FMB4 and FMB2 were the highest and above or comparable to the BCMOE guideline, with the latter field barrel showing the highest antimony concentrations (0.01 – 0.07 mg/L).

***Selenium***

Selenium concentrations exceeded the BCMOE guideline (0.002 mg/L) in most leachate samples from all field barrels (Figure 8-17). The lowest (FMB3: 0.00037 – 0.017 mg/L) and highest (FMB2: 0.002 – 0.065 mg/L; FMB4: 0.0037 – 0.034 mg/L) selenium concentrations were observed in the leachate from the N-AML field barrels, suggesting that the leaching behaviour of this element cannot be predicted based on AML classification. It is however worth noting that a similar pattern in selenium was observed for all field barrels since June 2016 to June 2021, and selenium concentrations in FMB1 and FMB3 were almost comparable during the same period. Selenium concentrations in FMB2, FMB3, and FMB4 shared a similar changing pattern comparable between June 2021 and September 2022, whereas selenium concentration in FMB1 continued to decrease during this period.

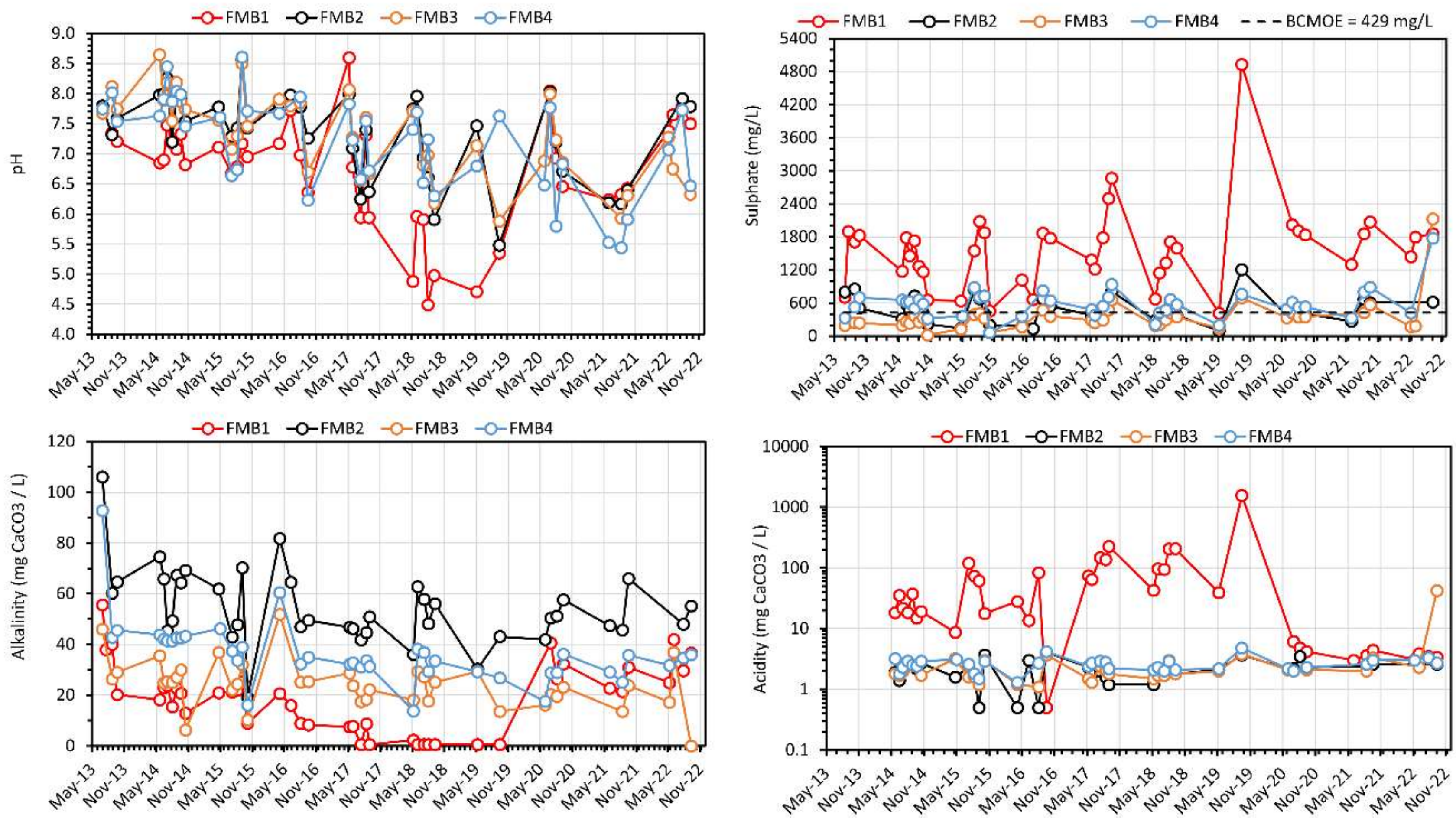



**Figure 8-14: Trends of pH, Sulphate, Alkalinity and Acidity in Flame & Moth Field Barrels**

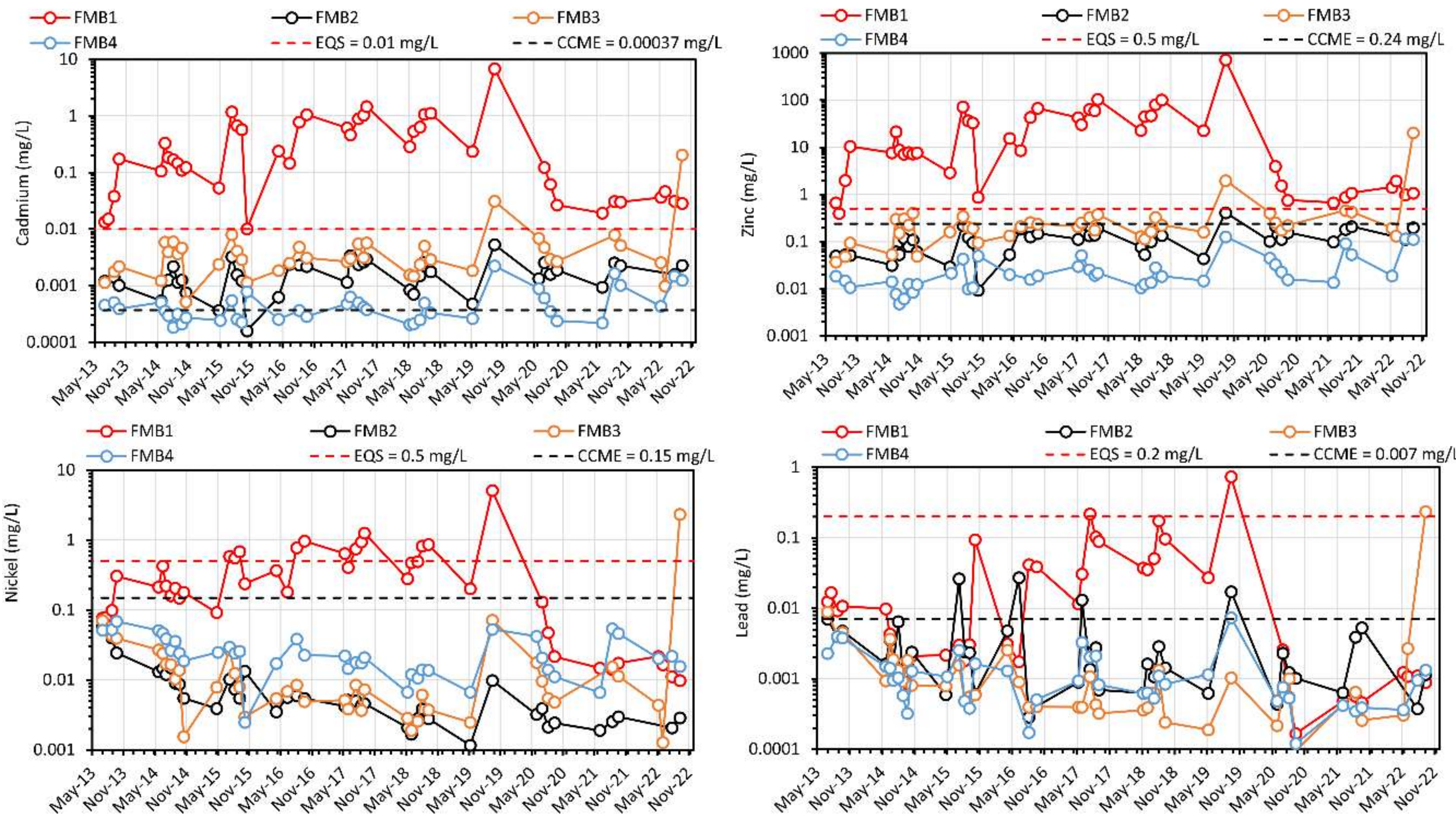



**Figure 8-15: Trends of Cadmium, Zinc, Nickel, and Lead Concentration in Flame & Moth Field Barrels**

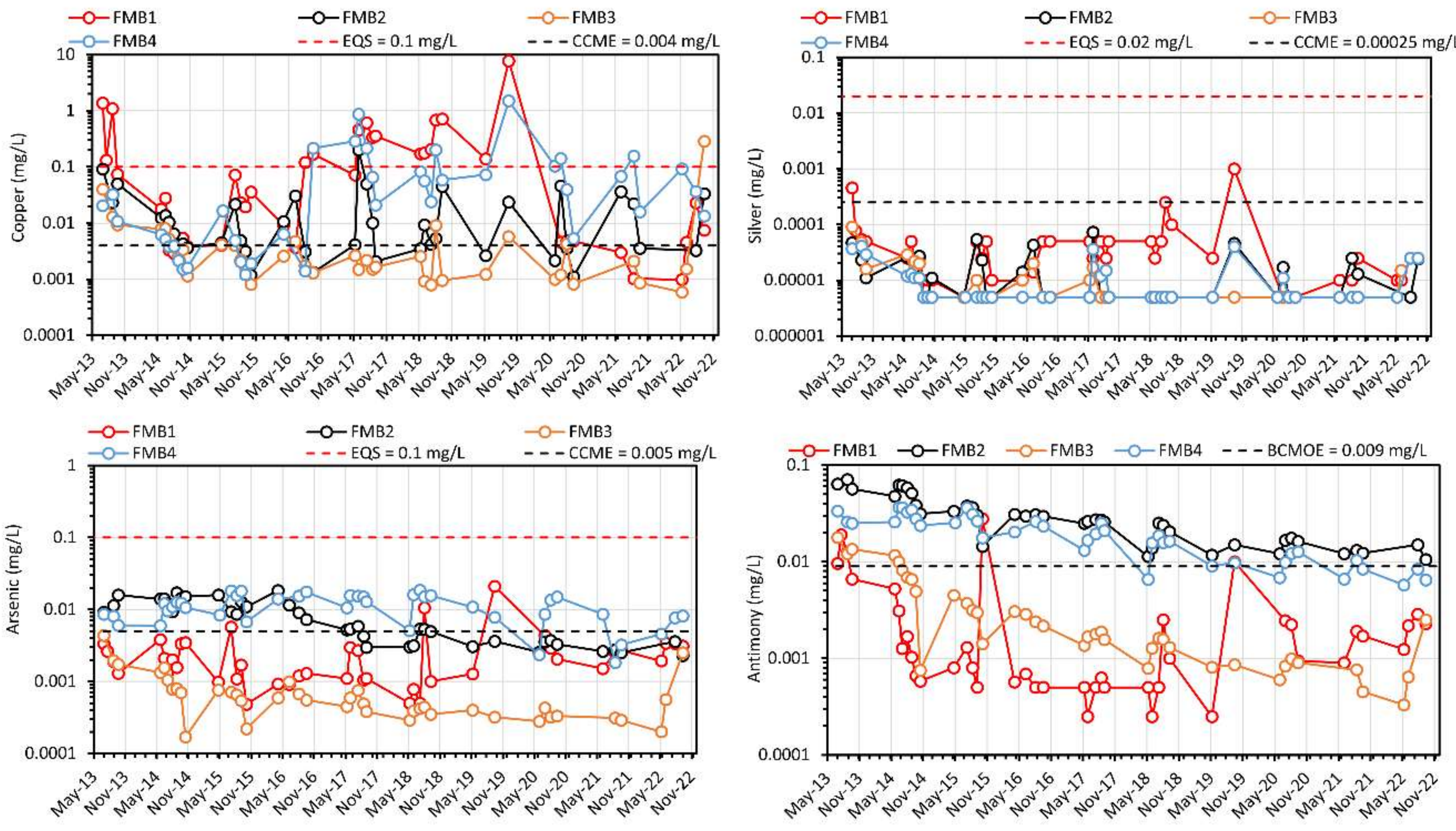



**Figure 8-16: Trends Copper, Silver, Arsenic, and Antimony Concentrations in Flame & Moth Field Barrels**

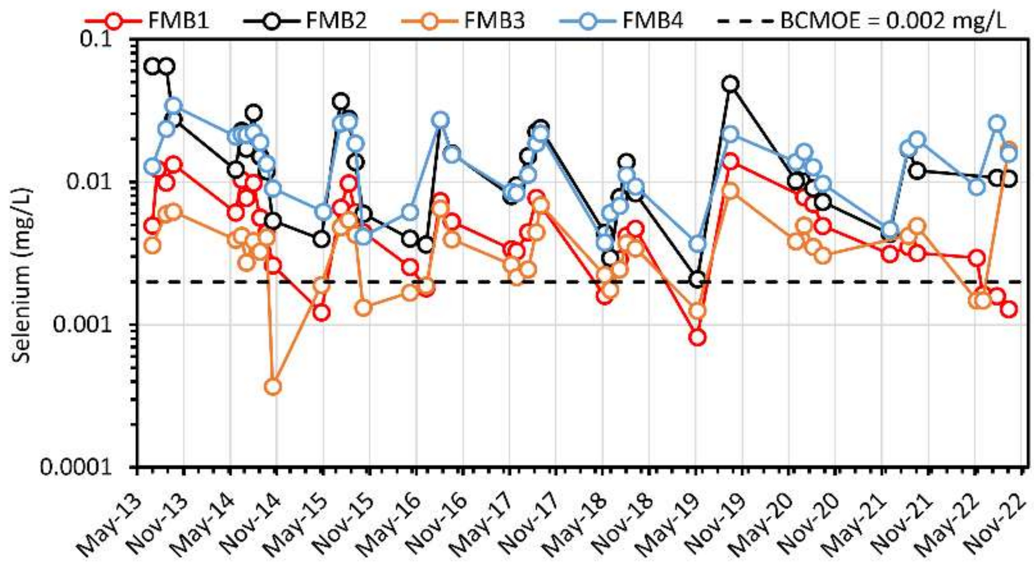



**Figure 8-17: Trends of Selenium Concentrations in Flame & Moth Field Barrels**

## 8.3 TAILINGS

AKHM also carried out geochemical characterization of the tailings from each of the mineralized target zones in order to understand their potential ARD/ML. These characterization studies have been ongoing for several years and continue to date. The results of the characterizations were reported for the Onek, Lucky Queen, and Flame & Moth tailings in ACG (2012; 2015), New Bermingham in AEG (2019c), Bellekeno and New Bermingham in Ensero (2022a), and New Bermingham and Flame & Moth are summarized herein. This section also provides a comparison of the main geochemical characteristics of the tailings from Flame & Moth, Bellekeno, Lucky Queen, Onek, and New Bermingham.

### 8.3.1 LABORATORY TEST PROGRAM

The laboratory test program included static and kinetic tests. The static testing consisted of:

- Acid-base accounting;
- Elemental analysis;
- Shake flask extraction (MEND SFE);
- Net acid generating (NAG); and
- Mineralogy by X-ray diffraction (XRD) with Rietveld refinement.

The kinetic testing consisted of standard laboratory humidity cell as follow:

- Flame & Moth tailings (113 weeks, completed);
- Bellekeno tailings (208 weeks, completed); and
- New Bermingham tailings (103 weeks, completed).

### 8.3.2 RESULTS

#### 8.3.2.1 STATIC TESTING

##### *8.3.2.1.1 Acid-Base Accounting*

Table 8-6 presents the ABA testing results of the New Bermingham Locked Cycle Test (LCT), Flame & Moth F4+F5 composite tailings, Onek F7+F8 tailings, and Lucky Queen F9+F10 tailings, as well as the averages of the results from Bellekeno tailings, New Bermingham tailings, and New Bermingham and Flame & Moth mixed tailings, and New Bermingham and Bellekeno mixed tailings between 2011 and 2022.

The tailings from the deposits had circumneutral to slightly alkaline paste pH (7.4 to 8.2). New Bermingham LCT tailings, Flame & Moth F4+F5 composite tailings, and Bellekeno tailings showed relatively high carbonate NP, ranging from 152 to 389 kg $CaCO_3$/t, significantly higher than the siderite-corrected bulk NP of 50.5 to 129 kg $CaCO_3$/t. The much higher carbonate NP than siderite-corrected NP indicates that iron and/or manganese carbonates such as siderite ($FeCO_3$) comprise a substantial portion of the carbonate mineralogy of the tailings. On the other hand, New Bermingham tailings, mixture of New Bermingham and Bellekeno tailings, and mixture of New Bermingham and Flame & Moth Tailings had relatively low carbonate NP, ranging from 54 to 77 kg $CaCO_3$/t, lower than the siderite-corrected bulk NP of 72 to 85 kg $CaCO_3$/t. For these tailings, the bulk of the NP is derived from carbonate NP, supplemented by a smaller amount of NP from non-carbonate minerals such as aluminosilicates, which provide a slower reacting source of acid neutralization than carbonate minerals.

ABA shows that the New Bermingham LCT tailings have a slightly alkaline paste pH (7.6 – 8.2), a very high carbonate neutralization potential (carbonate-NP; 184-204 kg $CaCO_3$/t) and relatively low bulk neutralization potential (bulk NP; 50.5 – 56.3 kg $CaCO_3$/t). The carbonate-NP was nearly four times higher than the bulk NP due to the anticipated presence of iron and/or manganese carbonates (i.e., siderite and ankerite) that do not contribute to the net acid neutralization. The sulphate content of the tailings samples was at the detection limit of 0.01 wt. % indicating that the bulk of total sulphur consisted of sulphide-sulphur (1.29 -1.38 wt.%).

The sulphate contents of the tailings from New Bermingham, Flame & Moth, Bellekeno, Lucky Queen, and Onek were also extremely low (maximum = 0.1 wt. %), indicating that sulphide-sulphur was the primary form of sulphur. The mixtures of New Bermingham and Bellekeno tailings had the highest sulphide-sulphur content (6.8 wt.%), followed by the mixture of New Bermingham and Flame & Moth (4.7 wt.%), Bermingham tailings (2.5 wt.%), Bellekeno tailings (2.2 wt.%), and New Bermingham LCTs (1.29 to 1.38 wt.%). The tailings from the Flame & Moth, Lucky Queen, and Onek had sulphide-sulphur concentrations less than 0.5 wt.%.

The NPR, calculated as the ratio of the (siderite-corrected) NP to AP, indicates that the New Bermingham and Bellekeno tailings were classified as “Uncertain” with an NPR of 1.4 and 1.9, respectively. New Bermingham and Bellekeno tailings mixture and New Bermingham and Flame & Moth tailings mixture had NPR values less than 1, classified as PAG. Onek, Lucky Queen, and Flame & Moth tailings had NPR values larger than 4, defined as non-PAG.

ABA data indicate Uncertain potential for ARD for New Bermingham and Bellekeno tailings and further testing are needed to provide a final ARD classification of the material. The bulk NP may be underestimated due to the oxidation of Mn (II) during the siderite-corrected NP method. Mn(II) is metastable in oxidizing environments and can provide NP under mildly reducing conditions. Furthermore, while pyrite contributes acid upon oxidation, galena and sphalerite oxidation by oxygen is not an acid generating process. Therefore, significant galena and/or sphalerite contributions to the sulphide-sulphur content of the tailings may also result in an overestimate of their acid generating potential. This is supported by detailed mineralogical examination of historical tailings deposited in the KHSD in which material initially classified as PAG by conventional ABA analysis was found to be non-PAG when its manganese carbonate and non-pyrite sulphide content was included in the NPR calculation (SRK, 2009).

### Table 8-6: Averages of Acid Base Accounting Results for Tailings from New Bermingham LCT, Flame & Moth, Bellekeno, Lucky Queen, Onek, New Bermingham, Mixture of New Bermingham and Bellekeno, and Mixture of New Bermingham and Flame & Moth

| Sample | Paste pH | Total Sulphur | Sulphate Sulphur | Sulphide Sulphur | $CO_2$ | $CO_3$-NP | Siderite-Corrected NP | AP | NPR |
|---|---|---|---|---|---|---|---|---|---|
| | - | Wt. % | Wt. % | Wt. % | Wt. % | kg $CaCO_3$/t | | | - |
| Berm LCT1 | 7.6 | 1.30 | 0.01 | 1.29 | 8.09 | 184 | 50.5 | 40.3 | 1.3 |
| Berm LCT2 | 8.2 | 1.39 | 0.01 | 1.38 | 8.96 | 204 | 56.3 | 43.1 | 1.3 |
| Onek F7 + F8 average | 7.8 | 0.16 | 0.04 | 0.12 | - | - | 31.4 | 3.8 | 8.4 |
| Lucky Queen F9 + F10 average | 7.9 | 0.19 | 0.04 | 0.15 | - | - | 19.1 | 4.5 | 4.2 |

| Sample | Paste pH | Total Sulphur | Sulphate Sulphur | Sulphide Sulphur | $CO_2$ | $CO_3$-NP | Siderite-Corrected NP | AP | NPR |
|---|---|---|---|---|---|---|---|---|---|
| Flame & Moth F4+F5 Composite | 8.0 | 0.45 | 0.02 | 0.43 | 17.1 | 389 | 100 | 14.1 | 7.1 |
| Bellekeno Tailings | 8.1 | 2.3 | 0.04 | 2.2 | 11.6 | 152 | 129 | 70.6 | 1.9 |
| New Bermingham Tailings | 7.7 | 2.5 | 0.05 | 2.5 | - | 54 | 85 | 75.6 | 1.4 |
| New Bermingham and Bellekeno Mixed Tailings | 7.4 | 6.9 | 0.1 | 6.8 | - | 47 | 78 | 210.9 | 0.7 |
| New Bermingham and Flame & Moth Mixed Tailings | 7.6 | 4.8 | 0.1 | 4.7 | - | 77 | 72 | 146.6 | 0.6 |

*AP – acid potential; NP – neutralization potential; NPR – neutralization potential ratio*

##### *8.3.2.1.2 Sequential NAG*

The NAG test is commonly used to determine the potential for net acid generation of geologic material or as a cross check on the ABA results. During the NAG test, hydrogen peroxide rapidly oxidizes the sulphide minerals in the sample. The NAG test was only done on the New Bermingham LCT tailings and was performed sequentially such that four successive NAG cycles were conducted on the same sample to ensure the oxidation of all sulphide-sulphur. The pH of the NAG leachate after each cycle provides an indication of the capacity of the acid neutralizing of the sample to buffer the acid produced from sulphide oxidation. The NAG test indicates that a sample is non-PAG if the NAG pH is greater than 4.5 and PAG if the NAG pH is less than 4.5.

Table 8-7 shows that a negligible amount of acidity (i.e., 0.19 kg $CaCO_3$/t) was generated during the test and only during the first cycle suggesting that the sulphides in the tailings are not reactive. The potential for acid generation is considered low because the NAG pH was greater than 4.5 during the four cycles. The sequential NAG provides clarification regarding the "Uncertain" acid generation potential indicated by the ABA work – that is, net acid generation is not expected from New Bermingham tailings.

**Table 8-7: Results of Sequential NAG for New Bermingham LCT Tailings**

| Sample ID | Cycle Number | NAG pH | NAG Volume to pH 4.5 | NAG Volume to pH 7.0 | NAG NaOH Conc. | NAG Acidity pH 4.5 | NAG Acidity pH 7.0 |
|---|---|---|---|---|---|---|---|
| | | pH Units | mL | mL | N | kg $CaCO_3$/t | kg $CaCO_3$/t |
| Berm LCT2 | Cycle 1 | 6.56 | - | 0.1 | 0.1 | - | 0.192 |
| | Cycle 2 | 7.81 | - | - | 0.1 | - | - |
| | Cycle 3 | 8.28 | - | - | 0.1 | - | - |
| | Cycle 4 | 7.81 | - | - | 0.1 | - | - |

##### *8.3.2.1.3 Mineralogy*

The results of the XRD reported in Table 8-8 show that the New Bermingham LCT, Flame & Moth, and Bellekeno tailings are mainly composed of quartz ($SiO_2$; 45.2 to 63.2 wt. %) and calcium rich siderite ($FeCO_3$; 21.2 to 45.3 wt. % as calcian siderite). The New Bermingham LCT tailings contain pyrite ($FeS_2$; 1.6 to 2.2 wt. %) as the main sulphide and sphalerite (ZnS; 0.3 to 0.6 wt. %) and galena (PbS; 0.3 to 0.8 wt. %) as secondary. The Bellekeno tailings had 2.3 wt.% of pyrite, 2.4 wt.% of sphalerite, and 0.6 wt.% of galena. The Flame & Moth tailings had a lower content in pyrite (0.7 wt.%) and were devoid of sphalerite and galena. The mixture of New Bermingham and Flame & Moth tailings had 5.5 wt.% of pyrite and 1.3 wt.% of sphalerite, with no detection of galena.

New Bermingham tailings contained another carbonate mineral with no effective buffering capacity under oxidizing conditions, ankerite (Ca (Fe, Mg, Mn) $(CO_3)_2$; 1.0 to 1.4 wt. %). Ankerite was also found in the Bellekeno tailings (0.4 wt.%) but was not in the Flame & Moth composite. Flame & Moth and Bellekeno tailings contained 1.2 and 3.2 wt.% calcite, respectively, but no calcite ($CaCO_3$) was detected in the New Bermingham tailings.

These XRD data indicate that the KHSD Mining Operations tailings consist predominantly of geochemically inert silica and iron and manganese carbonate minerals. The major difference between the four tailings is the lack of calcite in the New Bermingham LCT tailings and absence of sphalerite and galena in the Flame & Moth tailings. Iron and manganese carbonates provide no net neutral buffering capacity under aerobic conditions as the acidity consumed by carbonate is equivalent of the acidity produced by the subsequent oxidation and hydrolysis of iron or manganese. However, the XRD data indicates a calcium rich siderite where substitution of calcium for iron occurs which may result in some neutralization capacity of a portion of the siderite.

The potential AP of New Bermingham LCT tailings estimated from the pyrite content of the tailings is approximately 37 kg $CaCO_3$/t, slightly lower than the AP estimated from the ABA of average 42 kg $CaCO_3$/t. This suggests that the sulphide-sulphur of galena and sphalerite, minerals that do not generate acid when oxygen is the only oxidant, may be the source of excess of AP in the ABA test. The XRD data also corroborate the New Bermingham LCT tailings ABA showing that the low bulk NP is due to the deficiency in calcite. The higher AP values for the Bellekeno tailings and New Bermingham and Flame & Moth mixed tailings reflects their higher pyrite and sphalerite contents and the presence of trace chalcopyrite and wurtzite. The low sulphide mineral content (0.7 wt.% as pyrite) of the Flame & Moth sample confirms its low AP.

### Table 8-8: Averages of XRD Results for Tailings from New Bermingham LCT, Flame & Moth, Bellekeno, and Mixture of New Bermingham and Flame & Moth

| Mineral | Unit | Bermingham LCT1 | Bermingham LCT2 | Flame & Moth F4 + F5 Composite | Bellekeno Tailings | Bermingham and Flame & Moth Mixed Tailings |
|---|---|---|---|---|---|---|
| Ankerite – Dolomite | wt. % | 1.4 | 1.0 | - | 0.4 | 0.4 |
| Calcite, Magnesian | | - | - | 1.2 | 3.2 | 1.5 |
| Cassiterite | | - | - | 0.5 | - | - |
| Clinochlore | | - | - | 1.3 | 0.4 | 1.2 |
| Dravite | | - | - | 3.2 | - | 2.3 |
| Galena | | 0.8 | 0.3 | - | 0.6 | - |
| Gypsum | | - | - | - | - | 0.9 |
| Illite-Muscovite 2M1 | | 9.6 | 8.2 | 2.5 | 6.6 | 6.7 |
| Kaolinite | | 1.0 | 0.9 | - | - | - |
| Pyrite | | 1.6 | 2.2 | 0.7 | 2.3 | 5.5 |
| Quartz | | 63.2 | 59.3 | 45.2 | 52.6 | 65.6 |

| Mineral | Unit | Bermingham LCT1 | Bermingham LCT2 | Flame & Moth F4 + F5 Composite | Bellekeno Tailings | Bermingham and Flame & Moth Mixed Tailings |
|---|---|---|---|---|---|---|
| Rutile | | 0.6 | | - | 0.3 | 0.4 |
| Siderite, calcian | | 21.2 | 27.8 | 45.3 | 29.8 | 14.6 |
| Sphalerite | | 0.6 | 0.3 | - | 2.4 | 1.3 |
| Plagioclase | | - | - | - | 0.8 | - |
| Gahnite | | - | - | - | 0.2 | - |
| Chalcopyrite | | - | - | - | 0.1 | - |
| Wurtzite | | - | - | - | 0.2 | - |
| K-Feldspar | | - | - | - | 0.3 | - |
| Total | | 100 | 100 | 100 | 100 | 100 |

##### *8.3.2.1.4 Elemental Chemistry*

Table 8-9 presents the elemental analysis results of the New Bermingham LCT, Flame & Moth F4+F5 composite tailings, Onek F7+F8 tailings, and Lucky Queen F9+F10 tailings, as well as the averages of the results from Bellekeno tailings, New Bermingham tailings, New Bermingham and Flame & Moth mixed tailings, and New Bermingham and Bellekeno mixed tailings between 2011 and 2022.

The screening of the tailings metal content against the 10x their crustal abundance (CRC, 2005) indicates that antimony, arsenic, bismuth, cadmium, copper, iron, lead, manganese, molybdenum, selenium, silver, and zinc were typically high. The elevated metals and metalloids concentration were expected considering the source of the parent material (i.e., ore). The Bellekeno tailings generally had the higher or highest concentrations of lead and zinc, corroborating the presence of sphalerite, galena, chalcopyrite, and wurtzite suggested by XRD results. The Bellekeno tailings also had the higher concentrations of arsenic, antimony, and cadmium.

Lucky Queen tailings had the lowest arsenic content (17.5 ppm). The New Bermingham LCT, Onek, New Bermingham, and Flame and Moth tailings had arsenic content ranging from 369 to 816 ppm. Tailings from Bellekeno, mixture of New Bermingham and Bellekeno and New Bermingham, and mixture of New Bermingham and Flame and Moth had the highest arsenic content of over 1,800 ppm. The high concentration of arsenic is likely due to its known presence as trace element in sulphidic ore.

Antimony was found higher in tailings from Bellekeno, mixture of New Bermingham and Bellekeno and New Bermingham, and mixture of New Bermingham and Flame and Moth, ranging from 83.1 to 114.5 ppm. Onek and Lucky Queen had the lowest antimony content below 10 ppm. Cadmium was higher in tailings from Bellekeno, New Bermingham, mixture of New Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth, ranging from 92 to 505 ppm. Onek and New Bermingham LCTs tailings had cadmium content ranging from 23 to 73 ppm. The lowest cadmium was found in Lucky Queen and Flame & Moth tailings, showing cadmium content lower than 8 ppm.

Zinc content was higher in tailings from Onek, Bellekeno, mixture of New Bermingham and Bellekeno, and mixture of Bermingham and Flame & Moth, ranging from 8,784 to 15,750 ppm. New Bermingham LCTs, New Bermingham, and Flame & Moth tailings had the second highest zinc contents, ranging from 1,265 to 5,382 ppm. The lowest zinc was found in Lucky Queen tailings, showing zinc content lower than 600 ppm. Lead content was higher in tailings from Bermingham LCTs, Bellekeno, New Bermingham, mixture of New Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth, ranging from 2,200 to 7,460 ppm. Tailings from Onek, Lucky Queen, and Flame & Moth exhibited lower content in lead, ranging from 413 to 789 ppm.

Selenium contents were comparable in all tailings samples, ranging 0.1 to 0.9 ppm. Silver content was found comparable in tailings from New Bermingham LCTs, Bellekeno, New Bermingham, mixture of Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth, ranging from 33.1 to 99.6 ppm. Tailings from Flame & Moth, Onek, and Lucky Queen had relatively low silver content, ranging from 6.4 to 12.4 ppm.

### Table 8-9: Averages of Elemental Metal Results for Tailings from New Bermingham LCT, Flame & Moth, Bellekeno, Lucky Queen, Onek, New Bermingham, Mixture of New Bermingham and Bellekeno, and Mixture of New Bermingham and Flame & Moth

| Element | Unit | Berm LCT1 | Berm LCT2 | Onek F7 + F8 average | Lucky Queen F9 + F10 average | Flame & Moth F4+F5 Composite | Bellekeno Tailings | Bermingham Tailings | Bellekeno and Bermingham Mixed Tailings | Bermingham and Flame & Moth Mixed Tailings | 10x Crustal Abundance |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Silver (Ag) | ppm | 99.6 | 56.4 | 6.4 | 16.4 | 12.35 | 48.5 | 33.1 | 43.15 | 53.9 | 0.075 |
| Aluminum (Al) | % | 0.15 | 0.16 | 0.36 | 0.74 | 0.2 | 1,077 | 0.43 | 0.25 | 0.3 | 8.23 |
| Arsenic (As) | ppm | 369 | 401 | 375 | 17.5 | 699 | 2,126 | 816 | 1,809 | 3,263 | 1.8 |
| Barium (Ba) | ppm | 30 | 30 | 24 | 125 | 11.5 | 19.0 | 34.1 | 31 | 34.8 | 425 |
| Bismuth (Bi) | ppm | 0.06 | 0.04 | <2 | <2 | 6.59 | 1.80 | 1.9 | 5.0 | 10.4 | 0.0085 |
| Calcium (Ca) | % | 0.63 | 0.73 | 0.47 | 0.38 | 0.59 | 10,134 | 1.19 | 1.12 | 1.1 | 4.15 |
| Cadmium (Cd) | ppm | 46.1 | 23.4 | 72.8 | 3.95 | 7.19 | 158 | 92.1 | 505.5 | 151.7 | 0.15 |
| Cobalt (Co) | ppm | 4.3 | 4.3 | 2 | 3 | 2.7 | 9.7 | 6.0 | 7.4 | 5.8 | 25 |
| Chromium (Cr) | ppm | 133 | 115 | 174 | 265.5 | 185.5 | 11.4 | 163.3 | 71.5 | 71.8 | 102 |
| Copper (Cu) | ppm | 60.8 | 57.5 | 377 | 254 | 565 | 245 | 87.4 | 345.2 | 161.5 | 60 |
| Iron (Fe) | % | 6.35 | 7.07 | 18.6 | 6.4 | 16.3 | 67,270 | 7.6 | 9.33 | 8.2 | 5.63 |
| Mercury (Hg) | ppm | 0.19 | 0.13 | - | - | 0.055 | 0.18 | 38.46 | 0.90 | 0.35 | 0.085 |
| Potassium (K) | % | 0.07 | 0.08 | 0.08 | 0.275 | 0.03 | 233 | 0.11 | 0.07 | 0.06 | 2.09 |
| Magnesium (Mg) | % | 0.32 | 0.36 | 0.47 | 0.34 | 0.31 | 2,097 | 0.41 | 0.29 | 0.31 | 2.33 |
| Manganese (Mn) | % | 37,900 | 4.43 | 5.19 | 2.47 | 4.28 | 21,434 | 19,364 | 8,153 | 19,802 | 0.095 |
| Molybdenum (Mo) | ppm | 2.06 | 2.02 | <1 | 2 | 3.74 | 1.16 | 1.31 | 1.31 | 1.4 | 1.2 |
| Sodium (Na) | % | <0.01 | <0.01 | 0.02 | 0.025 | 0.006 | 90.0 | 0.013 | 0.01 | 0.01 | 2.36 |
| Nickel (Ni) | ppm | 49.8 | 49.1 | 44 | 51 | 86.6 | 19.3 | 23 | 22.3 | 18.75 | 84 |
| Lead (Pb) | ppm | 7,460 | 2,330 | 413 | 555 | 789 | 6,236 | 2,189 | 4,350 | 2,540 | 14 |
| Antimony (Sb) | ppm | 99.8 | 44.6 | <5 | 9 | 41 | 114.5 | 41.9 | 83.1 | 103.8 | 0.2 |
| Selenium (Se) | ppm | 0.9 | 0.8 | - | - | 0.1 | 0.5 | 0.7 | 0.9 | 0.58 | 0.05 |
| Tin (Sn) | ppm | 2.7 | 2 | - | - | 32.9 | 17.0 | 15.1 | 78.15 | 68.8 | 2.3 |
| Strontium (Sr) | ppm | 14.3 | 15 | 11 | 15 | 4.81 | 27.4 | 32.05 | 21.45 | 18.5 | 370 |
| Titanium (Ti) | % | <0.005 | <0.005 | <0.01 | 0.02 | 0.001 | 15.5 | <0.005 | <0.005 | <0.005 | 0.56 |
| Thallium (Tl) | ppm | 0.78 | 1.9 | 17.5 | 11 | 0.652 | 0.13 | 0.38 | 0.28 | 0.27 | 9.6 |
| Uranium (U) | ppm | 0.39 | 0.38 | - | - | 0.406 | 1.02 | 0.57 | 0.645 | 0.61 | 2.7 |
| Vanadium (V) | ppm | 6 | 5 | 5.5 | 12.5 | 9.4 | 5.3 | 12.3 | 7 | 7.17 | 120 |
| Zinc (Zn) | ppm | 3,510 | 2,080 | 8,784 | 557 | 1,265 | 12,043 | 5,382 | 15,750 | 7,029 | 70 |

*Note: **r**esults **that** exceed 10X crustal abundance values are highlighted in red.*

### *8.3.2.1.5 Shake Flask Extraction*

SFE test results provide an indication of the soluble metal load that may be released in the short term due to the leaching of excavated material by meteoric water. The SFE test results were therefore used to screen for potential exceedances of water quality objectives, discharge standards or generic water quality guidelines. The SFE data were compared to the District Mill Site pond EQS at KV-83. This comparative assessment is not and should not be used as a measure of compliance with site water quality standards and objectives. It rather provides a guide for assessing for constituents of potential concern in drainage from the tailings.

Table 8-10 presents the data averaged from SFE results of tailings from New Bermingham LCT, Flame & Moth, Lucky Queen, Bellekeno, mixture of New Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth, as well as the EQS at KV-83. With two exceptions, all tailings had a circumneutral pH (pH 7.0 – 8.1) within the EQS range and were consistent with the ABA paste pH values. Tailings from mixture of New Bermingham and Bellekeno and mixture of New Bermingham and Flame & Moth had mildly acidic pH of 6.8 and 6.3, respectively. The pH of the New Bermingham and Flame & Moth mixed tailings was lower than the EQS at KV-83. This likely reflects the overall higher acid potential (AP) tested by ABA and higher content in sulphide minerals identified by XRD. The mildly acidic pH values of the mixed tailings are consistent with the ABA paste pH values.

New Bermingham LCT tailings had very low leachable sulphate content (19.1- 46.1 mg/L) and extremely low acidity (often less than the method detection limit of 0.5 mg/L $CaCO_3$). The leachable sulphate content in tailings from Flame & Moth, Lucky Queen, and New Bermingham was higher than New Bermingham LCTs, ranging from 162 to 312 mg/L. Tailings from Bellekeno, mixture of New Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth showed higher leachable sulphate, ranging from 603 to 1,174 mg/L.

With the exceptions of cadmium and zinc, the screening of the SFE data against the Mill pond EQS indicates that none of the regulated elements exceeded the Mill pond EQS. Leachable cadmium concentration was higher than the EQS of 0.01 mg/L in tailings from Lucky Queen, mixture of New Bermingham and Bellekeno, and mixture of New Bermingham and Flame & Moth, ranging from 0.026 to 0.25 mg/L. Leachable zinc concentrations were higher than the EQS value of 0.5 mg/L in the New Bermingham and Bellekeno mixed tailings and the New Bermingham and Flame & Moth mixed tailings (9 mg/L and 1.3 mg/L, respectively). As discussed, bulk cadmium and zinc exceeded their respective 10X crustal abundance in the mixed tailings.

**Table 8-10: Averages of SFE Results for Tailings from New Bermingham LCT, Flame & Moth, Bellekeno, Lucky Queen, New Bermingham, Mixture of New Bermingham and Bellekeno, and Mixture of New Bermingham and Flame & Moth**

| Leachable Metals | Unit | Berm LCT1 | Berm LCT2 | Flame & Moth F4+F5 Composite | Lucky Queen F9+F10 | Bellekeno Tailings | Bermingham Tailings | Bellekeno and Bermingham Mixed Tailings | Bermingham and Flame & Moth Mixed Tailings | KHSD Mill Site EQS (KV-83) |
|---|---|---|---|---|---|---|---|---|---|---|
| pH | - | 7.3 | 8.2 | 7.9 | 8.1 | 8.1 | 7 | 6.8 | 6.3 | 6.5-9.5 |
| EC | uS/cm | 154.5 | 97.1 | 547 | 393 | - | - | - | - | - |
| $SO_4$ | mg/L | 46.1 | 19.1 | 245 | 162 | 603 | 312 | 1173.5 | 874.9 | - |
| Acidity to pH 4.5 | mg/L | <0.5 | <0.5 | - | - | - | - | - | - | - |
| Acidity to pH 8.3 | mg/L | 2.1 | <0.5 | - | - | 12.4 | 31.2 | 28.1 | 15.2 | - |
| Total Alkalinity | mg/L | 11 | 14 | 39.9 | 26.7 | 41.0 | N/D | 32.9 | 22.2 | - |
| Bicarbonate | mg/L | 14 | 18 | - | - | - | - | - | - | - |
| Carbonate | mg/L | <0.5 | <0.5 | - | - | - | - | - | - | - |
| Hydroxide | mg/L | <0.5 | <0.5 | - | - | - | - | - | - | - |
| Fluoride | mg/L | 0.27 | 0.2 | 0.19 | 0.057 | 0.8 | 0.09 | 0.6 | 0.1 | - |
| Hardness $CaCO_3$ | mg/L | 55.6 | 35 | - | 181 | 627.0 | 322 | 845.5 | 695.5 | - |
| Aluminum (Al)-Leachable | mg/L | 0.0061 | 0.021 | 0.011 | <0.0005 | 0.024 | 0.011 | 0.012 | 0.004 | - |
| Antimony (Sb)-Leachable | mg/L | 0.0042 | 0.0111 | 0.0217 | 0.014 | 0.039 | 0.0156 | 0.014 | 0.019 | |
| Arsenic (As)-Leachable | mg/L | 0.00022 | 0.00033 | 0.006 | <0.001 | 0.007 | 0.0006 | 0.0032 | 0.0119 | 0.1 |
| Barium (Ba)-Leachable | mg/L | 0.0354 | 0.0134 | 0.0253 | 0.041 | 0.03 | 0.0189 | 0.05 | 0.03 | - |
| Beryllium (Be)-Leachable | mg/L | <0.00001 | <0.00001 | <0.0005 | <0.0005 | <0.0001 | <0.0001 | <0.0001 | <0.00001 | - |
| Bismuth (Bi)-Leachable | mg/L | <0.000005 | <0.000005 | <0.0005 | <0.0005 | <0.0001 | <0.0001 | <0.0001 | <0.00001 | - |
| Boron (B)-Leachable | mg/L | <0.05 | <0.05 | 0.071 | 0.0195 | 0.09 | 0.07 | 0.09 | 0.1 | - |
| Cadmium (Cd)-Leachable | mg/L | 0.0027 | 0.00031 | 0.0024 | 0.026 | 0.005 | 0.0025 | 0.25 | 0.028 | 0.01 |
| Calcium (Ca)-Leachable | mg/L | 18.7 | 12.4 | 105 | 67.3 | 146.8 | 109 | 320.5 | 267.0 | - |
| Chromium (Cr)-Leachable | mg/L | <0.0001 | <0.0001 | <0.0005 | <0.0005 | 0.0 | <0.0005 | 0.0005 | 0.0002 | - |
| Cobalt (Co)-Leachable | mg/L | 0.00093 | 0.0001 | 0.0004 | 0.0036 | 0.0003 | 0.0007 | 0.0083 | 0.0032 | - |
| Copper (Cu)-Leachable | mg/L | 0.00012 | 0.00033 | 0.027 | 0.04 | 0.0079 | 0.0007 | 0.0053 | 0.0007 | 0.1 |
| Iron (Fe)-Leachable | mg/L | 0.0022 | <0.001 | <0.030 | <0.03 | <0.01 | <0.01 | <0.01 | 0.0022 | - |
| Lead (Pb)-Leachable | mg/L | 0.0607 | 0.0188 | 0.0144 | 0.065 | 0.0791 | 0.0094 | 0.138 | 0.0427 | 0.2 |
| Lithium (Li)-Leachable | mg/L | 0.00339 | 0.00294 | 0.0071 | <.0.005 | 0.0328 | 0.0222 | 0.0306 | 0.0129 | - |
| Magnesium (Mg)-Leachable | mg/L | 2.15 | 0.988 | 6.9 | 3.1 | 6.1 | 12.2 | 11.0 | 6.7 | - |
| Manganese (Mn)-Leachable | mg/L | 2.28 | 0.445 | 1.95 | 0.95 | 0.8 | 1.84 | 7.6 | 3.6 | - |
| Mercury (Hg)-Leachable | mg/L | <0.00005 | <0.00005 | 0.0001 | <0.00005 | <0.00005 | <0.05 | 0.00004 | <0.00002 | - |

| Leachable Metals | Unit | Berm LCT1 | Berm LCT2 | Flame & Moth F4+F5 Composite | Lucky Queen F9+F10 | Bellekeno Tailings | Bermingham Tailings | Bellekeno and Bermingham Mixed Tailings | Bermingham and Flame & Moth Mixed Tailings | KHSD Mill Site EQS (KV-83) |
|---|---|---|---|---|---|---|---|---|---|---|
| Molybdenum (Mo)-Leachable | mg/L | 0.000225 | 0.00093 | 0.0024 | 0.002 | 0.01 | 0.0043 | 0.0026 | 0.0026 | - |
| Nickel (Ni)-Leachable | mg/L | 0.0021 | 0.00037 | 0.0012 | 0.0016 | 0.001 | 0.003 | 0.0126 | 0.0066 | 0.5 |
| Phosphorus (P)-Leachable | mg/L | 0.05 | 0.041 | <0.3 | <0.3 | 0.2 | 0.2 | 0.2 | 0.1 | - |
| Potassium (K)-Leachable | mg/L | 1.89 | 1.7 | 2.04 | 2.9 | 11.5 | 5.78 | 21.8 | 7.2 | - |
| Selenium (Se)-Leachable | mg/L | 0.00006 | 0.00004 | 0.0009 | 0.0067 | 0.001 | <0.0005 | 0.0 | 0.0 | - |
| Silicon (Si)-Leachable | mg/L | 0.42 | 0.45 | 1.55 | 1.51 | 3.3 | 0.76 | 1.3 | 0.7 | - |
| Silver (Ag)-Leachable | mg/L | <0.000005 | 0.00003 | 0.0009 | 0.003 | 0.0024 | 0.00002 | 0.0018 | 0.0001 | 0.02 |
| Sodium (Na)-Leachable | mg/L | 0.854 | 0.596 | 2.36 | 5.4 | 23.1 | 5.44 | 9.0 | 9.7 | - |
| Strontium (Sr)-Leachable | mg/L | 0.0261 | 0.0172 | 0.38 | 0.17 | 0.5 | 0.249 | 0.6 | 0.5 | - |
| Thallium (Tl)-Leachable | mg/L | 0.000335 | 0.000177 | 0.0001 | 0.0001 | 0.0002 | 0.00036 | 0.0007 | 0.0006 | - |
| Tin (Sn)-Leachable | mg/L | <0.0002 | <0.0002 | <0.0005 | <0.0005 | 0.0005 | <0.0005 | 0.0001 | <0.00005 | - |
| Titanium (Ti)-Leachable | mg/L | <0.0005 | <0.0005 | 0.01 | <0.01 | 0.0093 | <0.0005 | <0.005 | <0.0002 | - |
| Uranium (U)-Leachable | mg/L | <0.000002 | <0.000002 | 0.00005 | 0.00001 | 0.0013 | 0.00018 | 0.0002 | 0.0001 | - |
| Vanadium (V)-Leachable | mg/L | <0.0002 | <0.0002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | |
| Zinc (Zn)-Leachable | mg/L | 0.142 | 0.017 | 0.156 | 0.057 | 0.1 | 0.079 | 9.0 | 1.3 | 0.5 |

*Notes: results that exceed KHSD Mill Site EQS (KV-83) are highlighted in red.*

### 8.3.2.2 KINETIC TESTING

One tailings humidity cell (HC) was operated for each of the following deposit: Flame & Moth, Bellekeno, and New Bermingham LCT. Flame & Moth, Bellekeno, and New Bermingham LCT tailings cells were terminated after 113, 208, and 103 weeks of testing, respectively. To compare the geochemical properties of the tailings from the KHSD Mining Operations sites, the same period from the beginning to the 103rd week (cycle) of New Bermingham LCT, Flame & Moth, and Bellekeno kinetic data are discussed herein.

Time series of selected constituents of interest (i.e., pH, alkalinity, acidity, sulphate, and metals and metalloids of potential environmental concern) are presented in Figure 8-18 , Figure 8-19, and Figure 8-20, and discussed to assess the long-term ARD/ML potential. The Mill Pond EQS are also plotted for comparative purposes only rather than an assessment of compliance with site water quality standards.

The pH, acidity, alkalinity, and sulphate released from the leachate of the New Bermingham LCT during the tests are plotted in Figure 8-18 . All the tailings HCs had neutral pH within the EQS range (6.5 - 9.5), ranging between 7.1 and 8.0 with a median of 7.4. All the tailings HCs showed fairly low acidity of less than 7.4 mg/L $CaCO_3$, with a median equivalent to the detection limit 0.5 mg/L $CaCO_3$. On the other hand, the alkalinity of each cell was sufficient to buffer the acidity released, showing a maximum of 39.6 mg/L $CaCO_3$ and a median of 20.8 mg/L $CaCO_3$. The sulphate concentrations were relatively low (median 51 mg/L) in all the tailings cells, indicating a low sulphide oxidation rate. The acidity, alkalinity, and sulphate concentrations showed a first flush effect, resulting from the release of readily soluble products, followed by a decrease then stabilization of the concentrations until cycle 43 and 37 for acidity and alkalinity, respectively. Recurrent spikes of acidity were observed until cycle 69, after which the acidity was typically below the detection limit. Alkalinity gradually increased after cycle 37 from 12 mg/L to 40 mg/L at cycle 99, coincident with an increase in pH from 7.3 to 8.0. The sulphate concentrations showed a slight increase between cycles two and nine (85 mg/L), then decreased and continued to decline during the test reaching 29 mg/L during the last two cycles.

The pH and alkalinity levels in the leachate from the New Bermingham LCT humidity cell were lower than those observed in the Flame & Moth and Bellekeno tailings HCs (Figure 8-18), reflecting its lower NP and lack of calcite. During the first 30 cycles, sulphate concentration decreased from 374 to 29 mg/L in the New Bermingham LCT leachate and decreased from 1,150 to 158 mg/L in the Bellekeno HC. The sulphate concentrations were markedly lower in the New Bermingham LCT HC than those observed in the Bellekeno HC. Then, sulphate concentrations from both New Bermingham LCT and Bellekeno HCs decreased and became similar from cycle 55 onward. Sulphate concentrations of the Flame & Moth HC leachate also exhibited a decreasing trend during the first 17 cycles from 1130 mg/L to approximately 40 mg/L, after which the sulphate concentration fluctuated but remained relatively stable ranging from approximately 20 to 30 mg/L. This trend is expected for Bellekeno, which has a higher sulphide-sulphur content (4.8 wt.%) than the New Bermingham LCT tailings (1.4 wt.%) but is somewhat unexpected for the early cycles of the test for Flame & Moth because of its lower sulphide-sulphur content (0.7 wt.%). Sulphides in the Flame and Moth tailings were likely exposed to leaching at the onset of the test resulting in higher release rate early on and gradual decline thereafter. However, the three tailings generally showed a similar sulphate release pattern despite the difference in absolute concentration, although the sulphate released from the Flame & Moth HC stabilized whereas sulphate concentrations in the New Bermingham LCT and Bellekeno HCs continued to slowly decrease (Figure 8-18).

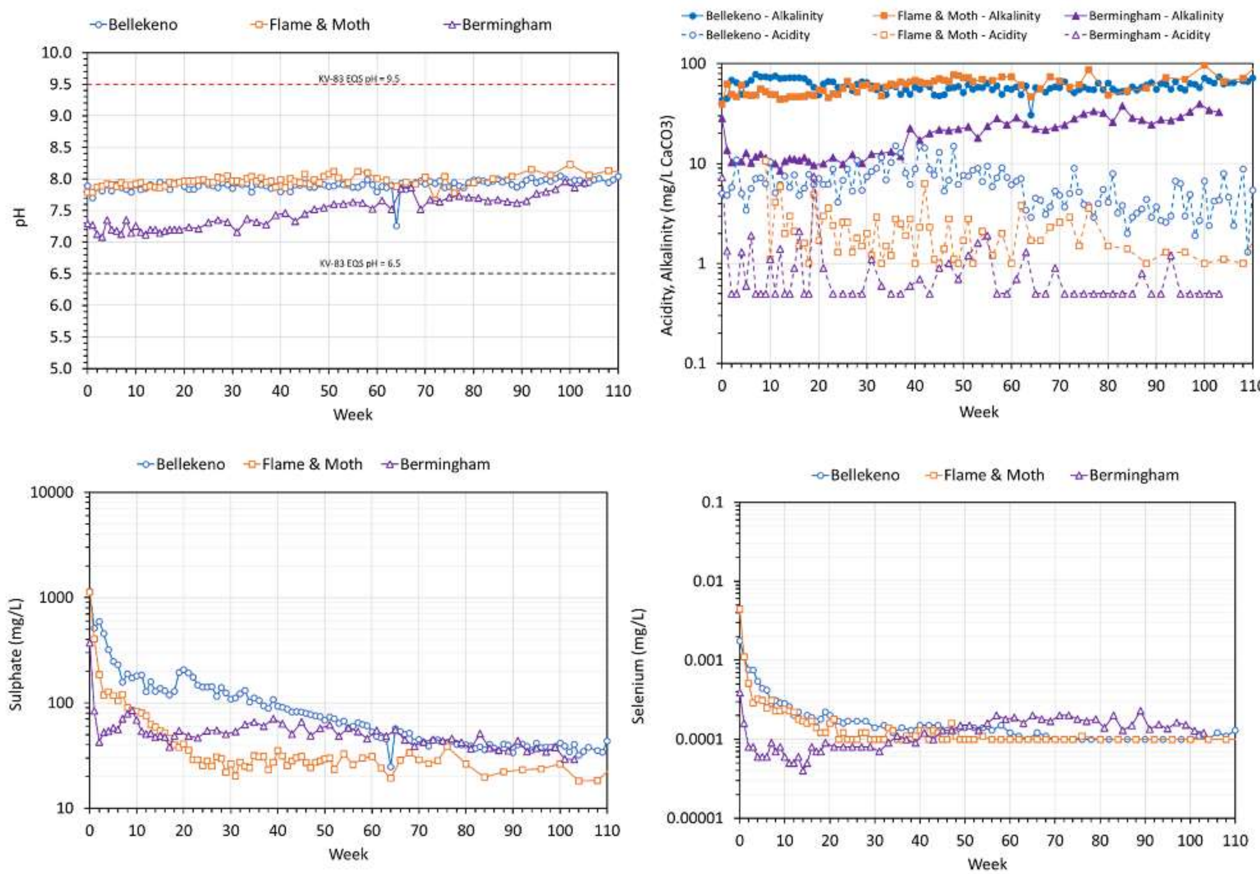



**Figure 8-18: pH (top left), Acidity and Alkalinity (top right), Sulphate (bottom left), and Selenium (bottom right) of the New Bermingham LCT, Flame & Moth, and Bellekeno Tailings Humidity Cells**

Figure 8-19 presents the time series of arsenic, antimony, cadmium, and copper, and Figure 8-20 displays the time series of lead, nickel, silver, and zinc. Only cadmium and zinc of the Bellekeno HC were regularly above their respective EQSs. The Bellekeno HC generally had the highest concentration release for sulphate, cadmium, lead, and zinc throughout the 103 cycles, and nickel during the last 70 cycles. The leachate of the New Bermingham LCT had the highest nickel during the first 30 cycles. The Flame & Moth HC had the highest concentration release for arsenic, antimony, copper, and silver during the first 80 cycles.

Time-series metals and metalloids of the New Bermingham LCT humidity cell showed similar patterns, showing the highest concentration at cycle 0 due to flush effect, followed by a decreasing trend in concentration and a stabilization as early as cycle 11 onward (antimony and silver) or later (cycle 55 onward for arsenic, copper; cycle 81-89 onward for cadmium, lead and nickel; cycle ~95 for zinc.). All metal and metalloid concentrations fluctuated sporadically but the fluctuations in concentrations were more evident for arsenic, nickel, silver, lead, and copper.

Aside from the initial flush, the arsenic concentration in the New Bermingham LCT humidity cell leachate was lower than that of the Bellekeno and Flame & Moth HC leachates, likely due to its lower bulk arsenic concentration. Arsenic concentrations in the New Bermingham LCT HC were at least an order of magnitude lower than those in the Bellekeno and Flame & Moth HCs since cycle 35. During the first 35 cycles, cadmium and zinc concentrations were comparable in the New Bermingham LCT and the Flame & Moth HCs leachates, showing similar decreasing trends in both HC leachates. After cycle 35, cadmium and zinc concentrations in the leachate of the New Bermingham LCT HC were markedly lower by up to two orders of magnitudes than those of the Bellekeno HC. Except for the first cycle, exceedances of the cadmium and zinc EQS (0.01 and 0.5 mg/L, respectively) were only observed in the Bellekeno HC leachate. These trends likely reflect the higher contents of zinc and cadmium in the Bellekeno tailings bulk elemental composition (Table 8-9).

Lead concentrations in the New Bermingham LCT HC leachate gradually decreased from approximately 0.1 mg/L to 0.0001 mg/L throughout a total of 103 cycles. Lead concentrations of the New Bermingham LCT HC leachate exhibited a significant fluctuation during cycle 21 to cycle 55, showing occasionally high releases of lead with concentrations varying from 0.0001 to 0.01 mg/L. Lead concentrations of the Flame & Moth HC leachate continued to decrease until stabilized from cycle 81 to cycle 103. The Bellekeno HC leachate showed a relatively stable lead concentrations throughout the 103 cycles, varying from 0.05 to 0.1 mg/L.

Nickel concentrations in the leachate of the New Bermingham LCT humidity cell were relatively stable during the first 35 cycles, ranging from 0.002 to 0.009 mg/L, higher than those in the Flame & Moth and Bellekeno HC leachates during the same period. Nickel concentration decreased from 0.002 mg/L at cycle 35 to 0.0001 mg/L at cycle 75, subsequently remaining relatively from cycle 75 to 103. The Bellekeno HC leachate showed a relatively stable nickel concentrations throughout the test, varying from 0.001 to 0.006 mg/L.

Copper concentrations in the leachate of the New Bermingham LCT humidity cell were relatively stable from cycle 1 to 20, varying from 0.0004 to 0.001 mg/L. Copper concentrations in the New Bermingham LCT HC increased slightly to 0.003 mg/L and remained the same order of magnitude from cycle 46 to 103. Copper concentrations in the Flame and Moth HC leachate decreased gradually from 0.004 to 0.001 mg/L during 103 cycles. The Bellekeno HC leachate showed a fluctuating trend in nickel concentrations, varying from 0.0001 to 0.001 mg/L.

Silver concentrations in the leachate of the New Bermingham LCT humidity cell were generally below the detection level (i.e., <0.000005 mg/L) similar to the silver release from the Bellekeno cell although spikes of concentration (0.0001 mg/L) were recurrent during the test. Silver concentrations in the Flame & Moth HC leachate fluctuated and decreased from 0.001 mg/L to below the detection limit of 0.00001 mg/L during the test. Antimony concentrations in the New Bermingham LCT HC leachate were lower than that of the Bellekeno and Flame and Moth HC leachates despite a bulk antimony concentration (44.6 ppm) that was comparable with the Flame and Moth tailings (41 ppm; Table 8-9).

Selenium concentrations in the leachate of the New Bermingham LCT humidity cell exhibited a pattern different from all the parameters of interest (Figure 8-18). From the first flush to cycle 20, selenium concentration decreased by up to an order of magnitude in all HC leachate. Selenium concentrations stabilized in the Bellekeno and Flame & Moth HC leachates from cycle 20 to 103, showing concentrations of approximately 0.0001 mg/L for both HC leachates. A more evident fluctuation was observed in selenium concentrations of the New Bermingham LCT HC leachate after the first 20 cycles, varying from 0.00008 to 0.0002 mg/L.

The tailings kinetic test results indicate that the trace element release rates for New Bermingham LCT were lower than the effluent quality standards (EQS) at KV-83, the KHSD Mill Site. It is worth noting that trace element concentrations released from the Bellekeno and Flame and Moth tailings HC were also lower than the EQS at KV-83 with the exception of zinc and cadmium in Bellekeno (Figure 8-19 and Figure 8-20). This is likely related to the elevated bulk zinc and cadmium concentrations in the Bellekeno tailings compared to the other tailings.

Additional information derived from the analysis of New Bermingham LCT HC data included:

- The concentration of ammonia was very low (median = 0.005 mg/L), at or below the detection limit in 76% of the cycles and well below the EQS of 5 mg/L;
- The concentrations of the following constituents were below the detection limit in all or the majority of leachates since cycle four: nitrate, nitrite, ammonia, beryllium, bismuth, boron, cesium chromium, lanthanum, iron, mercury, silver, sodium, tellurium, thorium, tin, titanium, tungsten, vanadium and zirconium; and
- The concentration of molybdenum was below the detection limit in the second half of the test.

The neutral pH, significant alkalinity, low acidity and sulphate releases, and lower concentration of metal and metalloids compared to the EQS are evidence of low potential for acid generation and metal release from the New Bermingham LCT, Bellekeno, and Flame & Moth tailings, consistent with the sequential NAG and SFE results.

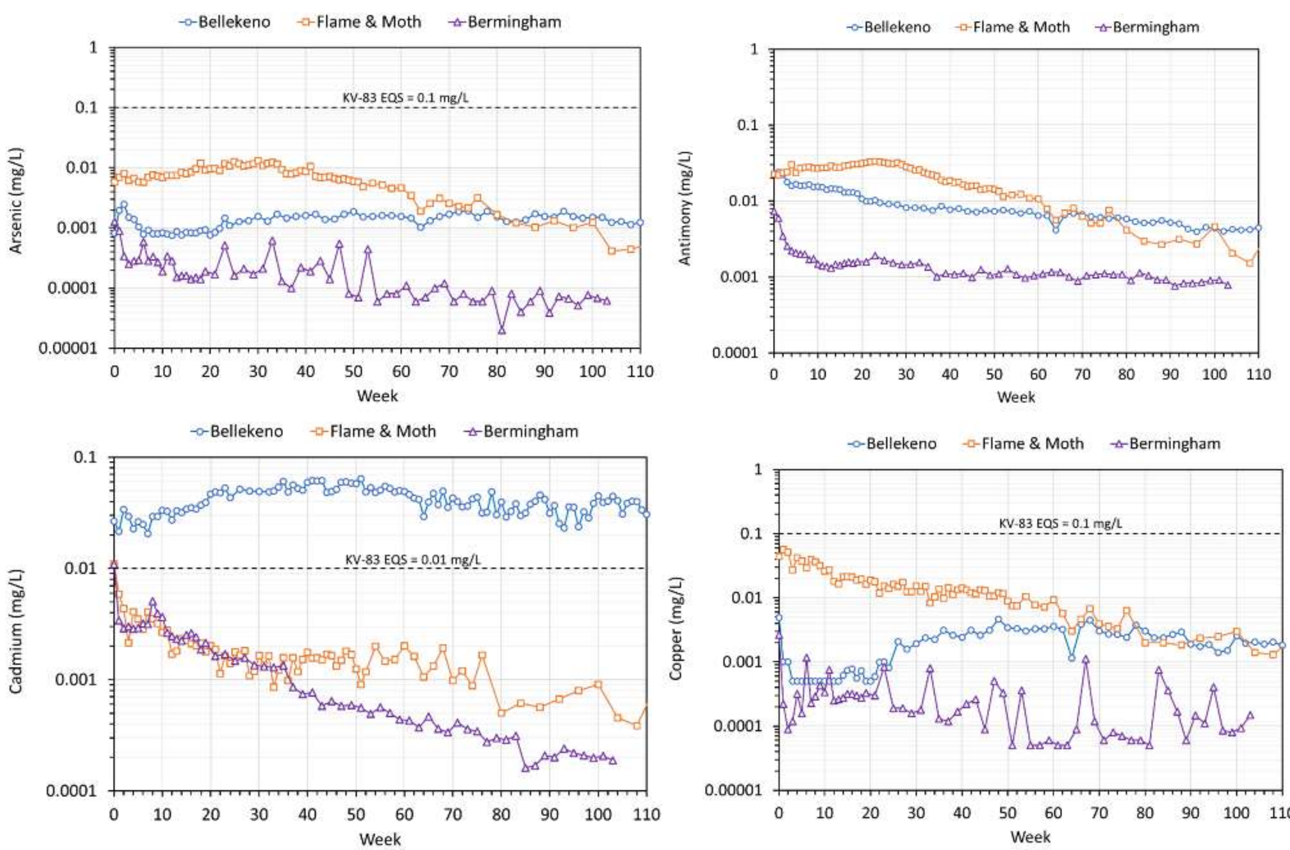



**Figure 8-19: Arsenic (top left), Cadmium (bottom left), Antimony (top right), and Copper (bottom right) Trends of the New Bermingham LCT, Flame & Moth, and Bellekeno Tailings Humidity Cells**

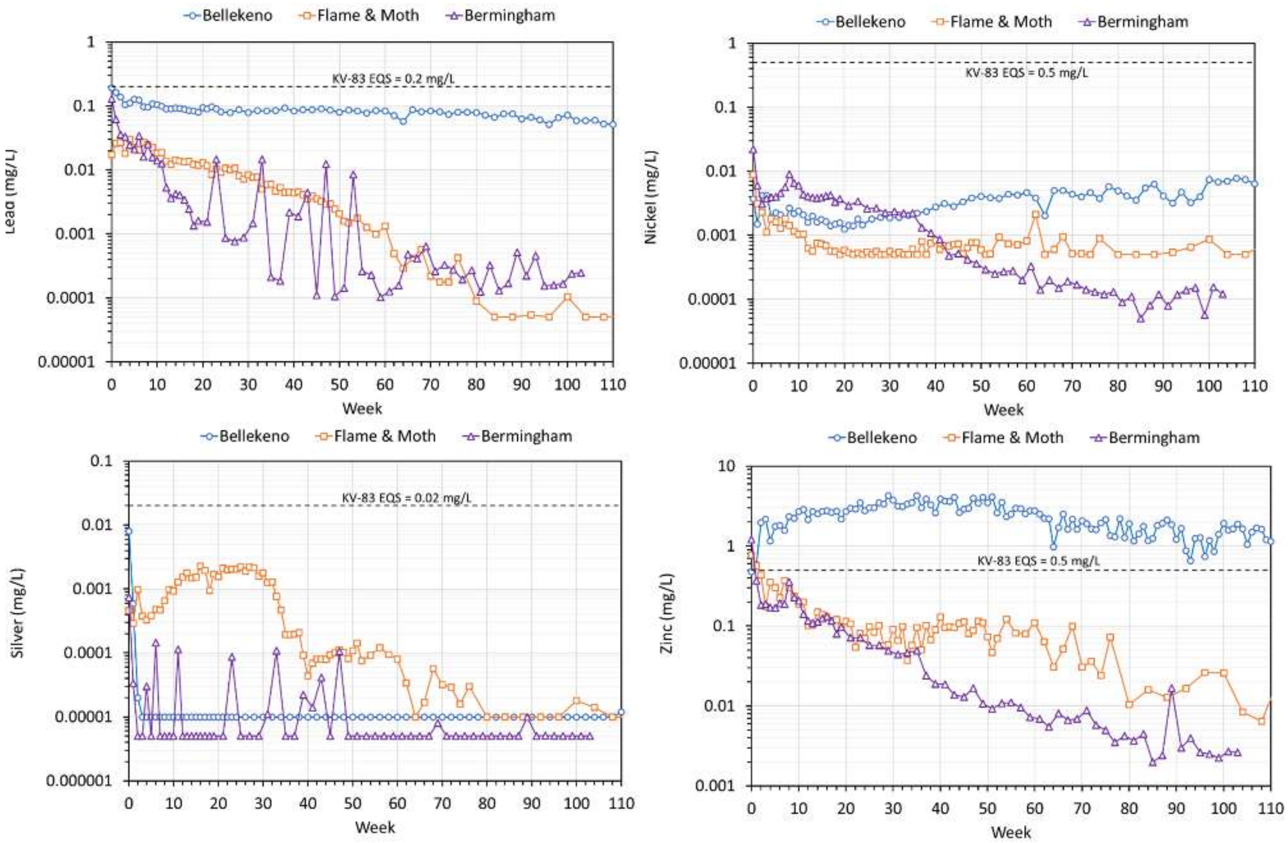



**Figure 8-20: Lead (top left), Silver (bottom left), Nickel (top right), and Zinc (bottom right) Trends of the New Bermingham LCT, Flame & Moth, and Bellekeno Tailings Humidity Cells**

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