Teck

Sä Dena Hes Mine

Post-Closure Surface Water Quality Predictions in Support of Post-Closure Licence Application

Prepared for

Teck Resources Ltd.

Prepared by

srk consulting 1974 40 2014

SRK Consulting (Canada) Inc.
1CT008.043
August 2014

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1 Introduction

1.1 Scope

The Sä Dena Hes lead/zinc mine operated from 1991 to 1992 and is currently owned by Teck Resources Limited (Teck) and Korea Zinc. The mine was in care and maintenance from 1992 to 2013. Permanent closure of the mine is currently underway. The demolition of the mill and removal of the south tailings and reclaim pond dams are planned for the summer of 2014. Following closure, the site will be monitored to ensure closure objectives have been met. Closure objectives have been defined in the Detailed Decommission and Reclamation Report (Teck 2013).

Ensuring water discharged from the site meets specific water quality limits is one of the post-closure objectives. The site contains mine components identified as loading sources that discharge water with elevated concentrations of zinc, cadmium and lead. These sources have been characterized in previous reports (SRK 2000, 2005a, 2005b, 2007, 2013, and 2014a). The loading sources are the tailings, 1380 Portal, and Burnick Portal. Water from these sources infiltrates the ground near the source and migrates downgradient as groundwater to areas of groundwater discharge (i.e., surface water features). Monthly and quarterly water quality monitoring results currently meet the effluent quality limits in the Water Licence at the receiving water bodies (Camp Creek, False Canyon Creek and Tributary E).

This report was prepared to support the post-closure water use licence application. The report presents a conceptual model describing the fate and transport of the dissolved constituents from the mine site loading sources and predicts post-closure receiving water quality for two scenarios:

- An expected case based on the last 15 years of monitoring data, and
- A conservative case in which the attenuation capacity of soils below the 1380 Portal is lost.

The water quality predictions are the basis for the development of the post-closure monitoring and mitigation programs. Water quality monitoring conducted as a condition of the current water license since 1991 has characterized mine constituent concentrations within the mining lease and in downgradient receiving water, providing over 23 years of data. These data show zinc, cadmium, and lead are the primary constituents that have periodically exceeded the current water license limits in discharge from loading sources. Consequently, this report focuses on predictions of zinc, cadmium, and lead concentrations in surface waters under variable flow conditions and loss of attenuation capacity. To complete these predictions, site hydrology was updated and is summarized in this report.

1.2 Regulatory Framework

Operation and closure of the site is authorized by a Quartz Mining Licence issued by the Yukon Energy, Mines and Resources. A Detailed Decommissioning Reclamation Plan (Teck 2013) describes closure objectives and activities. The Quartz Mining Licence expires December 31, 2015.

Water use and discharge is regulated under the Water Use Licence (WUL) QZ99-045, which also expires on December 31, 2015. Water quality and flow have been monitored according to the licence. The licence requires monthly data reports and an annual report. The most recent annual report was submitted to the Yukon Water Board in April 2014 (SRK 2014b).

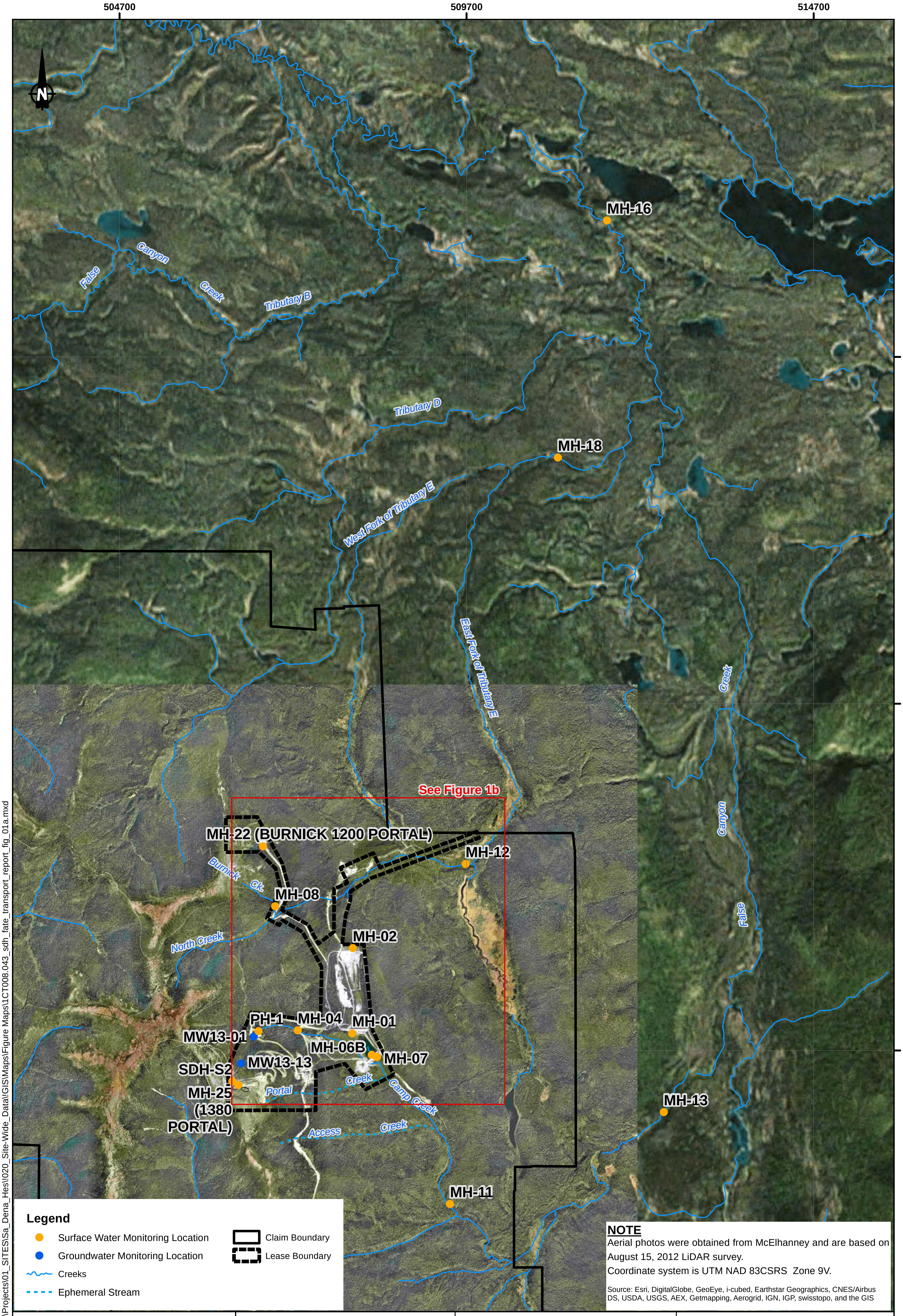
The water licence sets discharge quality and quantity limits. These are primarily for regulating the discharge from the Reclaim Pond to Camp Creek. Monitoring locations discussed in this report are shown on Figures 1a and 1b.

A new Water Use Licence will be required to govern continued water discharge after closure. This report provides the basis for the effects assessment on aquatic resources and downstream water quality, as required in a Project Proposal to Yukon Environmental and Socioeconomic Assessment Board (YESAB). This screening by YESAB is required prior to the application for a new Water Use Licence.

1.3 Report Organization

The report is organized as follows:

- Section 2 summarizes previous investigations on water quality monitoring, mine site mass loading sources, and attenuation mechanisms.
- Section 3 presents the mass loading used to predict water quality, including the conceptual model, model scenarios, model inputs, and methods.
- Section 4 presents the results of the water quality predictions.
- Section 5 presents a discussion of the water quality estimates presented in Section 4.
- Section 6 is the report conclusion and presents recommendations in the context of developing a post-closure adaptive management plan.



NOTE

Aerial photos were obtained from McElhanney and are based on August 15, 2012 LiDAR survey.

Coordinate system is UTM NAD 83CSRS Zone 9V.

Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS

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Teck

Sa Dena Hes Mine

Fate and Transport Report

Surface Water and Groundwater Monitoring Locations

Date:	Approved:	Figure:
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Legend

- ● Surface Water Monitoring Location
- ● Groundwater Monitoring Location
- 〰 Creeks
- - - - Ephemeral Stream
- ▭ Claim Boundary
- ⬚ Lease Boundary

NOTE

Aerial photo was obtained from McElhanney and are based on August 15, 2012 LiDAR survey.
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Teck

Sa Dena Hes Mine

Fate and Transport Report

Surface Water and Groundwater
Monitoring Locations

Date:	Approved:	Figure:
Aug 2014	TRS	1b

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2 Previous Investigations

2.1 Water Quality Monitoring

Water quality standards and monitoring requirements are presented in Part E – EFFLUENT QUALITY STANDARDS and Part F – MONITORING AND SURVEILLANCE of WUL QZ99-045. The WUL describes the water quality monitoring sites and program during operations and temporary closure, including required water quality parameters and sampling frequency (Appendices A to C of WUL QZ99-045). As part of WUL requirements, water quality at SDH has been monitored since the early 1990s. Figure 1a shows the locations of the water monitoring stations discussed in this report. Figure 1b shows the monitoring stations within the mine lease boundary.

As required by WUL QZ99-045, water quality data is reported to the Yukon Territory Water Board on a monthly basis. Recent monitoring results and a comparison to historic data (including when the mine was operating) are presented in SRK (2014b).

2.2 Mine Site Loading Sources

There were three zones that were mined at Sä Dena Hes: Main Zone, Burnick Zone, and Jewelbox. Drainage and seepage are routinely monitored at designated locations in these zones as part of WUL QZ99-045 (SRK 2014b). There have also been a number of surveys of mine components not routinely monitored (or without continuous flows) to investigate the presence of drainage (SRK 2000, SRK 2014a). Five mine components have been identified as loading sources that discharge contact water (i.e. mass loadings):

- Burnick Portal (MH-22),
- 1380 Portal (MH-25),
- Jewelbox Pit,
- North Tailings Dam Seepage (MH-02), and
- South Tailings Pond Outflow (MH-1)/Reclaim Pond Seepage (MH-6 and MH-7).

The monitoring location within the Main Zone Waste Rock Dump (SDH-S2) is used to evaluate metal attenuation within the waste rock pile below the 1380 Portal (MH-25).

Previous investigations (SRK 2000, 2005a, 2005b, 2007, 2013, 2014a, and 2014b) have shown the loads (mass per time or kg/d) of dissolved zinc, cadmium, and lead from the mine site are not observed at downstream monitoring locations (e.g., Camp Creek, Tributary E, and False Canyon Creek), implying the loads are either attenuated and/or have not arrived yet at downstream monitoring locations. Discharge from each station is described below, including an overview of the loading sources, geochemical processes (including attenuation mechanisms, as applicable), and flow paths.

2.2.1 Burnick Portal Drainage (MH-22)

The Burnick Portal is located 3 km from the Sä Dena Hes mill and was constructed to access the Burnick Zone (Figure 1b). There are two portals (1200 and 1300) at the Burnick Zone. The lower portal previously discharged continuously and is routinely monitored as part of WUL QZ99-045 as station MH-22. Discharge from MH-22 is presently ephemeral (June to November). The discharge water quality exceeds the WUL limits for zinc during low flow months.

MH-22 discharge flows through a buried culvert, cascades over the crest of the Burnick waste rock dump, and then infiltrates under the waste rock dump. The general flow direction would be expected to be directly downslope (to the east-northeast) to the West Fork of Tributary E (Figure 1a), which is more than 1.5 km downgradient of the portal. SRK surveyed the slopes below where the discharge infiltrated into the ground and did not find seepage corresponding to the mine water (SRK 2005a). A survey in 2013 by SRK confirmed these findings.

There is currently no evidence that the zinc load in the discharge is observed in Tributary E or False Canyon Creek (SRK 2005a). From this observation, SRK concluded zinc is attenuated through extensive contact with the soils between the Burnick Portal and the West Fork of Tributary E.

Column experiments using water collected from the Burnick Portal discharge (MH-22) and downstream soils were used to evaluate the attenuation mechanism (SRK 2005a). The testwork concluded that downgradient soils have the potential to significantly attenuate zinc concentrations at the levels observed in the discharge for much longer than 200 years. Column tests showed the attenuation capacity was not exhausted and no secondary minerals were formed. The studies confirmed that zinc is passively removed by contact with downgradient soils.

2.2.2 1380 Portal Drainage (MH-25), Jewelbox Pit, and Main Zone Waste Rock Dump (SDH-S2)

The Main Zone Pit is a box cut located in the headwaters of Camp Creek. The 1380 Portal is located at the south end of the cut. In June 1999, drainage from the portal was observed. The drainage is routinely monitored as part of WUL QZ99-045 as station MH-25. Drainage from MH-25 is ephemeral (June to October) and consistently exceeds the WUL limits for zinc and cadmium and less frequently for lead.

In 1999, MH-25 was sampled for the first time in support of the closure plan and was found to contain 41 mg/L dissolved zinc. Sampling of rock in the portal area showed that zinc is leached from oxidizing exposures and talus containing sphalerite. The source water is probably shallow groundwater with some minor contributions from the small upslope Jewelbox Pit (SRK 2002). Jewelbox Pit water quality has been monitored periodically and was marginally above the permit levels for zinc (0.5 mg/L) in 2013 (SRK 2002, 2014a). During open water season, discharge from MH-25 infiltrates into the waste rock dump downgradient of the portal (monitored as SDH-S2) and then flows through the soils in the dry headwaters of Camp Creek.

In 2000, MH-25 was monitored continuously for two months to determine the variation in flow and chemistry. SRK (2000) reported that the drainage from the Main Zone pit portal contained elevated zinc, cadmium, and lead concentrations. Flow was estimated at 1 L/s. While flow decreased following freshet, constituent concentrations were relatively constant. The constituent load associated with this flow was not detectable in Camp Creek or False Canyon Creek (stations MH-04, MH-11, MH-13, and MH-16) at any time during the summer, suggesting attenuation along the flow path.

Flow within the Main Zone waste rock dump (SDH-S2) is audible but difficult to locate and/or access, resulting in infrequent monitoring. The water flowing within the waste rock dump (SDH-S2) has similar sulphate concentrations to the 1380 Portal discharge (MH-25). Zinc concentrations differ between the 1380 Portal discharge and water flowing in the Main Zone waste rock dump. Sampling of SDH-S2 in 2002 and 2013 indicated that zinc levels are approximately 10 mg/L (SRK 2014a). The decrease in zinc levels between MH-25 and SDH-S2 suggests a removal mechanism that decreases concentrations by a factor of about four. In June 2013, cadmium concentrations were 4.9 times lower in flow in the waste rock dump as in the 1380 Portal discharge. Lead was not attenuated as strongly within the waste rock pile: lead concentrations were only 1.7 times lower than in the 1380 Portal discharge. Geochemical modelling indicates that that precipitation of zinc, cadmium, and lead carbonates is the probable attenuation mechanism resulting from the interaction of MH-25 drainage with marble waste rock (Day and Bowles 2005).

A column experiment was conducted to evaluate the attenuation capacity of the soils located downgradient of the waste rock dump. The column experiments passed water from the 1380 Portal (MH-25) through saturated subsurface media (e.g., soils) to evaluate zinc attenuation. The results of the column test showed very strong attenuation of zinc from 44.0 mg/L to <0.001 mg/L through secondary mineral precipitation. Cadmium was attenuated to <0.0001 mg/L (Day and Bowles 2005). Based on the results of the column experiments, SRK calculated that the flow path length (600 m) through the soils in the gully and Camp Creek headwater at PH-01 contained sufficient attenuation capacity to explain the lower zinc load in Camp Creek since the portal was opened. The results also suggested that the attenuation capacity of the soils to remove constituents to low levels was finite (SRK 2005a).

Following a meeting with agency representatives at the Yukon Government offices on September 12, 2006, the effect of loss of attenuation capacity in the soils in the headwaters of Camp Creek was evaluated (SRK 2007). A mass loading model was used to estimate zinc concentrations in Camp Creek (at MH-11) assuming that the attenuation capacity of the soils was consumed. A zinc concentration of 10 mg/L was selected to represent the zinc levels at SDH-S2. Unlike the soils, which have a finite attenuation capacity, the alkalinity from the dissolution of the marble waste rock will persist. Zinc levels downstream were calculated to be 0.04 to 0.06 mg/L at MH-11 and almost met CCME water quality guidelines (SRK 2007).

Two groundwater wells (MW13-13 and MW13-01) downgradient of the 1380 Portal were installed in 2013 (Figure 1b). MW13-13 is located in the upper gulley approximately 400 m downgradient from the portal and MW13-01 is located approximately 800 m downslope of the portal. Hydraulic testwork at MW13-01 indicated that the hydraulic conductivity (K) of the screened interval between 20 m and 26 m below ground surface ranged from 0.0000071 to 0.000011 m/s (SRK 2014c). MW13-13 was not tested because the water level did not return to the static water level after developing and sampling the well.

2.2.3 North Tailings Dam Seepage (MH-02)

During operations, most tailings were discharged in the North Tailings Pond. Tailings deposition was primarily subaerial on the North Dam. Currently there is no ponded water in the North Tailings Pond and there is seepage from the toe of the North Dam.

Seepage at the toe of the North Tailings Dam (MH-02) is routinely monitored as required by WUL QZ99-045. Zinc concentrations increased from less than 0.01 mg/L to about 0.3 mg/L from the beginning of monitoring in 1990 to 1999 (SRK 2002). After 1999, zinc concentrations decreased over time at a similar rate as the increase from 1990 to 1999. In 2002, total zinc concentrations were between 0.099 and 0.15 mg/L. In 2013, flow at MH-02 was monitored monthly and the median zinc concentration was 0.091 mg/L.

Seepage emerging at MH-02 is likely tailings porewater diluted by groundwater from the valley sides and runoff from the North Dam face (SRK 2000). Flow at MH-02 is highest during freshet and lowest during the winter. The seepage flows as surface water downgradient a short distance from the North Tailings Dam and then infiltrates the ground. This water then flows as groundwater and discharge to surface water in North Creek before flowing toward the East fork of Tributary E. There have not been any column studies evaluating metal attenuation from the North Dam seepage.

2.2.4 South Tailings Pond Outflow (MH-1) / Reclaim Pond Seepage (MH-6 and MH-7)

During operations, a small amount of tailings were deposited in the South Tailings Pond. Most of the tailings are subaerial. During operations and temporary closure, water from the South Tailings Pond was discharged to the Reclaim Pond and was routinely monitored as required by the water licence as station MH-1. Discharge from the South Tailings Pond to the Reclaim Pond was originally through a decant tower, but siphons have been used in more recent years. Accordingly, the sampling station for MH-1 has varied between water from the decant tower, the South Pond surface water, and water discharged from the siphons.

Water from the Reclaim Pond has been monitored at two stations as required by the water license. Seepage from the toe of the Reclaim Dam is monitored at MH-07 and water in or from the pond is monitored as MH-06A and MH-06B, respectively. WUL monitoring station MH-11 is the first monitoring point in Camp Creek downstream of the South and Reclaim Ponds and intrinsically includes the loads from these facilities.

The South Dam and Reclaim Dam were decommissioned in summer 2014 and no longer retain significant volumes of water that require active management. There is a small pond above what remains of the South Dam for settling suspended sediment. The Camp Creek Diversion has been removed and Camp Creek flows through a constructed channel along its original alignment. Some areas of the former South Pond and Reclaim Pond are covered and the associated water is being discharged into Camp Creek. The metal load from tailings seepage is expected to remain the same as during temporary closure.

3 Model Description

The water quality model addresses mine site loadings to and predictions of water quality in Camp Creek/Upper False Canyon Creek, Tributary E, and Lower False Canyon Creek (Figure 1a). The objective of the model is to predict post-closure water quality in surface water within the 25-year period of the post-closure WUL. The components and model scenarios for each of the creeks are based on the existing monitoring data and the conceptual model (Section 3.1).

3.1 Conceptual Model

The site conceptual model synthesizes the current understanding of loading sources, the pathways between sources and the receiving environment, and the processes that can attenuate or produce the constituents affecting water chemistry. The conceptual model is the framework for the predictive water quality loading model.

3.1.1 Loading Sources

As presented in Section 2.2, there are five loading sources at Sä Dena Hes:

- 1380 Portal drainage,
- Jewelbox pit,
- South Tailings Pond,
- North Tailings Dam seepage, and
- Burnick Portal drainage.

Discharge from the 1380 Portal (MH-25), Burnick Portal (MH-22), and seepage from the North Dam (MH-02) are routinely monitored water quality locations in the current water licence. Jewelbox Pit and the South Tailings and Reclaim Ponds are intrinsically monitored at downstream stations as follows:

- Jewelbox pit is upgradient of the 1380 Portal. Water from Jewelbox pit likely flows to the 1380 Portal and makes up a small proportion of flow monitored at MH-25. Therefore drainage from MH-25 intrinsically includes any loads from the Jewelbox pit.
- The South Tailings Pond Outflow (MH-01), Reclaim Dam seepage (MH-07), and direct discharge of Reclaim Pond water (MH-06A) have flowed to Camp Creek in the past. The effect of loadings from these sources has been monitored in Camp Creek at MH-11 and other locations farther downstream. Both the South Pond and Reclaim Pond will be drained and the dams breached in 2014. The small portion of tailings deposited in the South Tailings pond will be covered. Metal loading from these tailings is not expected to change significantly from current conditions.

3.1.2 Migration Pathways

Water from each of the loading sources (North Tailings Dam seepage, 1380 Portal discharge, and Burnick Portal discharge) is transported along similar flow paths from the source to receiving water. The loading source water infiltrates through variably saturated material near the loading sources. Suspended solid phase metals in the water will not infiltrate into groundwater and are physically attenuated (filtered) by the solid media. Dissolved metals are carried with the water to groundwater.

The source water mixes with other groundwater and interacts with the solid media through which it flows downgradient. Dispersion along flow paths affects the rate at which groundwater flows. Groundwater dispersion results from water traveling faster through the center of pores than at the edges, some water traveling through longer flow paths in the subsurface media than other parcels of water, and some pores being larger than others so the groundwater velocity is greater. These factors cause a slug of water infiltrating groundwater to disperse as it travels and arrive at a downstream location at different times. As the potentiometric gradient becomes less steep, groundwater discharges to surface water along stream channels and/or in marshy areas. Surface water flows in the existing drainage network.

North Dam seepage flows as groundwater to North Creek and the headwaters of the East Fork of Tributary E. Downstream water quality stations include MH-12 in North Creek, MH-18 in Tributary E, and MH-16 in False Canyon Creek below its confluence with Tributary E (Figure 1a).

The migration pathway for discharge from the 1380 Portal is through the Main Zone waste rock pile, infiltration to groundwater, and then flow as groundwater downgradient in the gully toward PH-01, where the flow discharges to surface (Figure 1a). The length of this flow path from the 1380 Portal to the spring (PH-01) near the headwaters of Camp Creek is approximately 900 m. PH-01 is a relatively large spring where the southern fork of Camp Creek originates. It then mixes about a 100 m downstream with water from a second groundwater spring on the southwestern flank of Mt. Hundere. Monitoring location MH-04 is about 200 m downstream from the confluence of these springs.

Discharge from the Burnick Portal flows onto the surface of the Burnick waste rock pile and infiltrates into ground under the waste rock pile. It then flows downgradient as groundwater to the headwaters of the West Fork of Tributary E (Figure 1a). The headwaters of the West Fork of Tributary E are marshy and channeled surface flow is intermittent. Surface water flows to the east-northeast. Water from the Burnick Portal flows as groundwater along this flow path and eventually discharges to surface water. The distance from the portal to where there is contiguous surface water flow in the West Fork of Tributary E is more than 1,600 m.

3.1.3 Attenuation Mechanisms

Attenuation of constituents along groundwater flow paths has been demonstrated for 1380 Portal and Burnick Portal. Details of the attenuation mechanisms are presented in Section 2.2. Attenuation of metals in seepage from the North Dam as it flows as groundwater has not been evaluated. Loadings from these sources are addressed in the model as follows:

- No attenuation of metals from the North Tailings Dam Seepage (MH-02) is assumed in the water quality predictions.

- Burnick Portal discharge (MH-22) is attenuated as it flows through downstream soils. Studies indicate that the mechanism of zinc removal will last much more than 200 years, which is sufficiently longer than the 25 year duration of the post-closure water licence.
- 1380 Portal drainage (MH-25) drainage flows through the marble waste rock immediately downstream of the portal. The dissolution of the marble attenuates zinc, cadmium, and lead by precipitation of metal carbonates. This attenuation mechanism of drainage from MH-25 is considered to last in perpetuity. Station SDH-S2 is the monitoring station for 1380 Portal discharge within the waste rock and characterizes the attenuation of metals from the 1380 Portal discharge after attenuation by the waste rock.
- Drainage from the Main Zone waste rock pile (SDH-S2) is further attenuated downstream as groundwater flow through the soils within the flow path to Camp Creek. Studies indicate that there may eventually be a loss of attenuation capacity in the soils.

3.1.4 Receiving Waters

The receiving water for all loading sources is ultimately False Canyon Creek at monitoring location MH-16. Intermediate receiving waters by loading source are:

- North Tailings Dam seepage
  - North Creek
  - East Fork of Tributary E (MH-12)
  - False Canyon Creek (MH-16)
- 1380 Portal discharge
  - Camp Creek (MH-04)
  - False Canyon Creek (MH-11, MH-13 and MH-16)
- Burnick Portal discharge
  - West Fork of Tributary E
  - False Canyon Creek (MH-16)

3.2 Model Scenarios

Two scenarios were modeled:

- An expected case
- A conservative case

The expected case is the base case and assumes that processes that have controlled water quality over the last 20 years will not change in the future and future water quality will follow historical seasonal trends. The attenuation mechanisms will continue to reduce metal loadings from the three source areas. In this case, predictions are made using observed monthly average water quality predictions from data collected since 1999. It assumes background water quality will not change over time.

The conservative case predicts water quality using reasonable loading conditions based on previous investigations of processes responsible for metal attenuation and their longevity. These studies (see Section 3.1.3) demonstrated that metal attenuation from Burnick Portal discharge is expected to last 200 years and the attenuation capacity of soils along the flow path between the 1380 Portal and Camp Creek is likely finite. Attenuation of metals from North Dam seepage has not been evaluated and is not included in the prediction. The conservative case models water quality if there is no attenuation by the soils in the 1380 Portal gully.

Two flow conditions were evaluated for the conservative case:

- Average monthly flow
- The 7-day average flow low that occurs once every 20 years during the summer (7Q20s)

Site hydrology data were updated in 2013 (Section 3.3.2 and Appendix A).

The conservative case predicts concentrations when the attenuation capacity in the soils has been lost. Realistically, concentrations in the receiving streams would not instantaneously increase to these predicted concentrations, but would increase gradually as attenuation capacity is lost and from dispersion as the plume migrates. The estimates therefore represent the maximum possible adverse impact to receiving environment water quality.

3.3 Model Inputs

3.3.1 Water Quality Data

The model is based on and predicts total metal concentrations. Total concentrations were used rather than dissolved because total concentrations have been consistently monitored since the early 1990s. Total metal concentrations are the sum of the dissolved and suspended particulate fractions, of which only the dissolved fraction will infiltrate into the ground. Suspended particulates will be filtered in the subsurface and will not infiltrate to the groundwater. Using total concentrations to estimate the load from the source areas that subsequently flow in the subsurface provides a conservative estimate of water quality.

Background Surface Water Quality Monitoring Locations

Water quality trends in Camp Creek (MH-04) and Upper False Canyon Creek (MH-11) show two distinct periods: an initial period after operations until 1999, when concentrations generally decreased, and the period from 1999 to the present, when concentrations remained relatively constant (SRK 2014b). Because the water quality has been relatively constant since 1999 to the present, total zinc, lead, and cadmium data from 1999 to the present were used to estimate average monthly concentrations for MH-04, MH-08, MH-11, MH-13, and MH-16.

Concentrations below the analytical detection limit were estimated to be one half of the detection limit. Monthly average total concentrations were calculated for zinc, lead, and cadmium. The data were reviewed and values that were greater than the mean monthly concentration plus two standard deviations were excluded from the dataset. A revised monthly mean was then calculated.

1380 Portal Discharge

Discharge from the 1380 Portal (MH-25) only occurs from May to October. There is no discharge from November through April when it is frozen. The constituent load from the 1380 Portal was averaged over the period it flows (May through October) and used in the model to predict the maximum potential impact on downstream water quality. The average annual load from 1380 Portal was used instead of monthly loads because of dispersion and the travel time to reach surface water. Groundwater flow and dispersion act to average the load, so loads are not applied as discrete monthly inputs. As discussed in Section 3.1, the load from South Pond is intrinsically included in MH-04. Accordingly, the data from MH-06 and MH-07 were not incorporated into the model as this would have resulted in duplicating the load from the tailings.

Burnick Portal Discharge

The Burnick Portal (MH-22) historically discharged water year-round but currently flows only from June to November. As previously discussed in Sections 2.2.1 and 3.1.1, zinc removal from the Burnick Portal drainage by the downgradient soils is expected to last more than 200 years. As the attenuation capacity is significantly longer than the 25 year licence term under review, only the expected case prediction is appropriate.

North Dam Seepage

Seepage from the North Tailings Dam flows throughout the entire year. The seepage infiltrates into the ground a short distance from the dam, mixes with groundwater, and then discharges to surface water along North Creek and Tributary E. This path conservatively assumes that the entire constituent load discharges to North Creek above MH-12. The monthly average load is used instead of the annual average to estimate concentrations because of the relatively short distance to MH-12. Since there has been no evaluation of attenuation of constituent loads from MH-02, no metal attenuation was assumed along the flow path to the headwaters of the East Fork of Tributary E.

3.3.2 Hydrologic Data

The site hydrologic analysis was updated by SRK in 2013 to use in the water and load balance model for predicting post-closure surface water quality downgradient of the Sä Dena Hes Mine. Average monthly and low flow conditions were estimated for the following water sampling stations relevant to the water and load balance model:

- MH-04: Lower Camp Creek immediately above the West Interceptor Ditch.
- MH-08: Burnick Creek, a small drainage upgradient of the North Tailings Dam that contributes to the upper end of the East Fork of Tributary E.
- MH-11: Upper False Canyon Creek, 1 km downstream of the Portal Creek confluence.

- MH-12: North Creek to East fork of Tributary E, approximately 2 km of the North Tailings Dam.
- MH-13: False Canyon Creek, approximately 10 km downstream of the Reclaim Pond and upstream of a tributary that flows north from a small lake.
- MH-16: False Canyon Creek, approximately 22 km downstream of the Reclaim Pond and downstream of the confluence with Tributary D.
- MH-18: Tributary E, just upstream of its confluence with False Canyon Creek.

The flows estimated in this section of the report are based on estimation techniques described previously (SRK 1990, Teck 2000, and SRK 2005b). Some modifications were made to the techniques to accommodate the longer streamflow records that are now available at regional Water Survey of Canada (WSC) stations and the new site flow data collected since 2005. Appendix A describes the analyses used to estimate these flows.

Mean monthly flows for average conditions and the two low flow statistics (7Q20a and 7Q20s). The resulting flow estimates for post-closure conditions are shown in Table 1.

Table 1. Estimated Flows for Key Locations in the Receiving Environment

Station	**MH-04**	**MH-08**	**MH-11**	**MH-12**	**MH-13**	**MH-14**	**MH-16**	**MH-18**
Catchment area (km^2)	2.07	2.773	9.5	10	34.5	74.4	144	30.06
Catchment median elevation (m)	1301	1327	1135	1064	1081	990	986	996
MAR (mm)	342	353	267	236	243	203	201	205
Average Monthly Discharge (L/s)								
Jan	5	7	16	14	52	89	171	37
Feb	4	6	14	12	43	73	140	30
Mar	4	5	12	11	40	70	134	29
Apr	4	5	18	19	66	133	257	54
May	45	59	207	210	733	1467	2827	596
Jun	83	117	264	231	836	1388	2654	571
Jul	49	68	166	150	539	936	1794	384
Aug	24	33	77	68	246	417	798	171
Sep	19	26	68	63	224	402	772	165
Oct	17	23	63	60	212	390	749	159
Nov	10	14	35	32	116	207	398	85
Dec	6	9	22	20	71	127	243	52
Average Annual Discharge (L/s)	22	31	81	75	266	477	916	195
7Q20s (L/s)	4.2	5.6	19	20	70	151	292	61
7Q20a (L/s)	0.7	0.9	3.0	3	10.9	23	45	9

Source: \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Load Data January 2014\SDH_loadcalcs_20140624_mdp_trs.xlsx

3.4 Model Prediction Methods

3.4.1 Expected Case Prediction Method

The water quality was predicted in Camp Creek and False Canyon Creek at monitoring locations MH-04 and MH-11 (Camp Creek) and MH-13 and MH-16 (False Canyon Creek). MH-04, MH-11 MH-13, and MH-16 have been consistently monitored during the temporary closure period. The mine site source loadings to Camp Creek are 1380 Portal drainage (MH-25) and loading from the South Tailings Pond and Reclaim Pond (formerly MH-06 and MH-07). For these monitoring locations in Camp Creek and False Canyon Creek, water quality is not expected to change from the seasonal trends observed since 1999. The expected water quality was predicted using the monthly average concentrations.

The water quality predictions for Tributary E include monitoring locations MH-12 and MH-18. MH-12 is located downgradient of the North Tailings Dam seepage on the East Fork of Tributary E. MH-18 is located on the main stem of Tributary E and is downgradient of both the North Tailings Dam (MH-02) and Burnick Portal drainage (MH-22).

Monitoring of MH-12 and MH-18 was not required during temporary closure. Because these locations were not monitored, monthly average concentrations were predicted.

At MH-12, monthly average concentrations were predicted using:

$$C_{MH-12} = \frac{Q_{MH-12}C_{MH-08} + (QC)_{MH-02}}{Q_{MH-12}}$$

Where: C_{MH-12} is the predicted average monthly concentration at MH-12
C_{MH-08} is the average monthly concentration at MH-08
$(QC)_{MH-02}$ is the average monthly load from the North Dam seepage (MH-02)
Q_{MH-12} is the average monthly average flow at MH-12

Monthly average concentrations at MH-18 were predicted using:

$$C_{MH-18} = \frac{Q_{MH-18}C_{MH-08} + (QC)_{MH-02}}{Q_{MH-18}}$$

Where: C_{MH-18} is the predicted average monthly concentration at MH-18
C_{MH-08} is the average monthly concentration at MH-08
$(QC)_{MH-02}$ is the average monthly load from the North Dam seepage (MH-02)
Q_{MH-18} is the average monthly average flow at MH-18

3.4.2 Conservative Case Prediction Method

Estimates for receiving water locations were made using the loading equation:

$$C_{Future} = \frac{QC_{Current} + (QC)_{1380\ Portal}}{Q_{Current}}$$

Where: C_{Future} is the predicted concentration
$C_{Current}$ is the current concentration
$(QC)_{1380\ Portal}$ is the load from the 1380 Portal after attenuation in the Main Zone waste rock pile
$Q_{Current}$ is the monthly average flow.

4 Water Quality Prediction Results

4.1 Expected Case

The expected case predicts that water quality will follow the seasonal trend observed since 1999 and will not improve over time. Average monthly concentrations of zinc, lead, and cadmium for the monitoring locations in Camp Creek and False Creek are shown in Table 2. The monthly average concentrations since 1999 are the expected average monthly concentrations in the future.

The monthly average concentrations since 1999 at monitoring locations in Camp Creek and False Canyon Creek were compared to CCME water quality guidelines for the protection of aquatic life (CCME WQG PAL) for cadmium, lead, and zinc (Table 2). Only lead and zinc have long term or chronic exposure water quality guidelines. The long-term guideline for lead is a function of hardness. Cadmium has short term (acute) and long term (chronic) guidelines, which are both calculated as a function of hardness. Monthly average hardness estimates were used to calculate hardness-based guidelines. The comparison between monthly average concentrations and CCME WQG PAL showed the following:

- Cadmium most often exceeded the long term CCME guidelines at MH-04, but many of the calculated monthly averages were just slightly over the guideline.
- Average monthly lead concentration in February exceeds the CCME guideline at MH-04.
- Cadmium (short term), lead, and zinc each exceeded the CCME guideline at MH-11.
- Monthly average concentrations at MH-13 and MH-16 in False Canyon Creek and MH-08 at the headwaters of the east fork of Tributary E did not exceed CCME water quality guidelines.

In general, exceedances are less frequent farther downgradient from the mine site, as expected from the contribution of unaffected tributaries.

Table 2. Expected Case Average Monthly Concentrations and CCME Guidelines.

MH-04									
Month	**Average Hardness**	**CCME Guidelines**				**average concentrations**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	172	0.03	0.006	0.004	0.00025	0.007	0.001	0.0002	0.0002
February	174	0.03	0.006	0.004	0.00025	0.015	**0.007**	0.0004	**0.0004**
March	169	0.03	0.006	0.004	0.00024	0.007	0.002	0.0003	**0.0003**
April	185	0.03	0.007	0.004	0.00026	0.005	0.001	0.0001	0.0001
May	169	0.03	0.006	0.004	0.00024	0.006	0.002	0.0003	**0.0003**
June	130	0.03	0.004	0.003	0.00020	0.010	0.001	0.0004	**0.0004**
July	152	0.03	0.005	0.003	0.00022	0.006	0.001	0.0002	**0.0002**
August	158	0.03	0.006	0.003	0.00023	0.006	0.001	0.0003	**0.0003**
September	170	0.03	0.006	0.004	0.00025	0.007	0.001	0.0003	**0.0003**
October	174	0.03	0.006	0.004	0.00025	0.007	0.001	0.0003	**0.0003**
November	172	0.03	0.006	0.004	0.00025	0.004	0.001	0.0002	0.0002
December	153	0.03	0.005	0.003	0.00023	0.016	0.001	0.0002	**0.0002**

MH-11									
Month	**Average Hardness**	**CCME Guidelines**				**average concentrations**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	228	0.03	0.007	0.00484	0.00031	**0.035**	0.006	0.0004	**0.0004**
February	216	0.03	0.007	0.00458	0.00030	0.026	**0.008**	0.0003	0.0003
March	221	0.03	0.007	0.00469	0.00031	0.030	0.004	0.0002	0.0002
April	224	0.03	0.007	0.00477	0.00031	**0.039**	0.005	0.0004	**0.0004**
May	193	0.03	0.007	0.00410	0.00027	0.023	0.005	0.0002	0.0002
June	166	0.03	0.006	0.00350	0.00024	0.021	**0.008**	0.0002	0.0002
July	183	0.03	0.007	0.00387	0.00026	0.014	0.002	0.0002	0.0002
August	189	0.03	0.007	0.00401	0.00027	0.013	0.002	0.0002	0.0002
September	194	0.03	0.007	0.00412	0.00028	0.015	0.002	0.0002	0.0002

MH-11

Month	Average Hardness	CCME Guidelines				average concentrations			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
October	195	0.03	0.007	0.00413	0.00028	0.012	0.001	0.0001	0.0001
November	205	0.03	0.007	0.00434	0.00029	0.019	0.003	0.0001	0.0001
December	222	0.03	0.007	0.00473	0.00031	0.026	0.002	0.0002	0.0002

MH-13

Month	Average Hardness	CCME Guidelines				average concentrations			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	224	0.03	0.007	0.0048	0.00031	0.007	0.001	0.0001	0.0001
February	233	0.03	0.007	0.0050	0.00032	0.008	0.002	0.0003	0.0003
March	219	0.03	0.007	0.0047	0.00030	0.004	0.001	0.00005	0.00005
April	185	0.03	0.007	0.0039	0.00026	0.004	0.002	0.0001	0.0001
May	172	0.03	0.006	0.0036	0.00025	0.011	0.001	0.0002	0.0002
June	160	0.03	0.006	0.0034	0.00023	0.006	0.001	0.0001	0.0001
July	185	0.03	0.007	0.0039	0.00026	0.003	0.001	0.0001	0.0001
August	209	0.03	0.007	0.0044	0.00029	0.006	0.001	0.0001	0.0001
September	195	0.03	0.007	0.0041	0.00028	0.007	0.0003	0.00003	0.00003
October	199	0.03	0.007	0.0042	0.00028	0.004	0.001	0.00004	0.00004
November	207	0.03	0.007	0.0044	0.00029	0.003	0.001	0.00004	0.00004
December	209	0.03	0.007	0.0044	0.00029	0.006	0.001	0.0001	0.0001

MH-16									
Month	**Average Hardness**	**CCME Guidelines**				**average concentrations**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	212	0.03	0.007	0.005	0.00030	0.006	0.0003	0.0001	0.0001
February	224	0.03	0.007	0.005	0.00031	0.003	0.0004	0.0001	0.0001
March	202	0.03	0.007	0.004	0.00028	0.004	0.002	0.00005	0.00005
April	211	0.03	0.007	0.004	0.00029	0.003	0.0003	0.00004	0.00004
May	156	0.03	0.006	0.003	0.00023	0.003	0.001	0.0001	0.0001
June	174	0.03	0.006	0.004	0.00025	0.005	0.002	0.0001	0.0001
July	197	0.03	0.007	0.004	0.00028	0.003	0.0003	0.00005	0.00005
August	219	0.03	0.007	0.005	0.00030	0.005	0.001	0.0001	0.0001
September	209	0.03	0.007	0.004	0.00029	0.003	0.0004	0.00002	0.00002
October	211	0.03	0.007	0.004	0.00029	0.004	0.0005	0.00005	0.00005
November	219	0.03	0.007	0.005	0.00030	0.003	0.0003	0.00004	0.00004
December	218	0.03	0.007	0.005	0.00030	0.003	0.0002	0.00003	0.00003

MH-08

Month	Average Hardness	CCME Guidelines				average concentrations			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
Units	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	162	0.03	0.006	0.003	0.00024	0.009	0.001	0.00009	0.0001
February	197	0.03	0.007	0.004	0.00028	0.018	0.006	0.0002	0.0002
March	197	0.03	0.007	0.004	0.00028	0.009	0.0003	0.0001	0.0001
April	197	0.03	0.007	0.004	0.00028	0.012	0.001	0.0001	0.0001
May	147	0.03	0.005	0.003	0.00022	0.014	0.0004	0.0001	0.0001
June	136	0.03	0.005	0.003	0.00020	0.019	0.001	0.0001	0.0001
July	134	0.03	0.005	0.003	0.00020	0.016	0.0004	0.0001	0.0001
August	184	0.03	0.007	0.004	0.00026	0.012	0.001	0.0002	0.0002
September	185	0.03	0.007	0.004	0.00026	0.009	0.0004	0.0001	0.0001
October	178	0.03	0.007	0.004	0.00026	0.009	0.001	0.0001	0.0001
November	179	0.03	0.007	0.004	0.00026	0.010	0.001	0.0001	0.0001
December	185	0.03	0.007	0.004	0.00026	0.007	0.001	0.0001	0.0001

MH-12

Month	Average Hardness	CCME Guidelines				Predicted Concentration			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	162	0.03	0.006	0.003	0.00024	0.02	0.002	0.00015	0.00015
February	197	0.03	0.007	0.004	0.00028	0.02	0.007	0.00018	0.00018
March	197	0.03	0.007	0.004	0.00028	0.02	0.0007	0.00008	0.00008
April	197	0.03	0.007	0.004	0.00028	0.02	0.002	0.000088	0.000088
May	147	0.03	0.005	0.003	0.00022	0.02	0.0004	0.00010	0.00010
June	136	0.03	0.005	0.003	0.00020	0.02	0.001	0.00013	0.00013
July	134	0.03	0.005	0.003	0.00020	0.02	0.0005	0.00009	0.00009
August	184	0.03	0.007	0.004	0.00026	0.01	0.001	0.00018	0.00018
September	185	0.03	0.007	0.004	0.00026	0.01	0.0004	0.00008	0.00008
October	178	0.03	0.007	0.004	0.00026	0.01	0.0006	0.00008	0.00008
November	179	0.03	0.007	0.004	0.00026	0.02	0.001	0.00011	0.00011
December	185	0.03	0.007	0.004	0.00026	0.02	0.002	0.00009	0.00009

MH-18									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	162	0.03	0.006	0.003	0.00024	0.01	0.001	0.0001	0.0001
February	197	0.03	0.007	0.004	0.00028	0.02	0.007	0.0002	0.0002
March	197	0.03	0.007	0.004	0.00028	0.01	0.001	0.00007	0.00007
April	197	0.03	0.007	0.004	0.00028	0.01	0.002	0.00009	0.00009
May	147	0.03	0.005	0.003	0.00022	0.01	0.0004	0.00009	0.00009
June	136	0.03	0.005	0.003	0.00020	0.02	0.001	0.0001	0.0001
July	134	0.03	0.005	0.003	0.00020	0.02	0.0005	0.00008	0.00008
August	184	0.03	0.007	0.004	0.00026	0.01	0.001	0.0002	0.0002
September	185	0.03	0.007	0.004	0.00026	0.01	0.0004	0.00008	0.00008
October	178	0.03	0.007	0.004	0.00026	0.01	0.0005	0.00007	0.00007
November	179	0.03	0.007	0.004	0.00026	0.01	0.0009	0.00009	0.00009
December	185	0.03	0.007	0.004	0.00026	0.01	0.001	0.00008	0.00008

Source: \\VAN-SVR0\Projects\01_SITES\Sä_Dena_Hes\1CT008.043_Sä Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Load Data January 2014\SDH_loadcalcs_20140630_mdp_trs.xlsx

Bold values exceed CCME WQG PAL.

4.2 Conservative Case

4.2.1 Average Annual Flow Conditions

Table 3 compares predicted conservative case concentrations in Camp Creek and False Canyon Creek to CCME PAL. Predicted concentrations are greatest during base flow conditions (September to April), when surface water flow is primarily from groundwater discharge. Concentrations are lowest during freshet and on the falling limb of the annual hydrograph when surface water is primarily from snow melt. Parameters exceeding applicable CCME guidelines are summarized as follows:

- MH-04: The long term guideline for cadmium was exceeded every month. By comparison, the existing monitoring data (average monthly values) also exceed the long term cadmium guideline nine months of the year (including freshet). Predicted zinc and lead concentrations exceeded CCME WQG PAL during base flow months (October through April).
- MH-11: predicted concentrations exceeded the CCME WQG PAL for zinc during base flow conditions for lead in January, February, March, April, and June; and the long term guideline for cadmium except in May, June and July. The long term cadmium guidelines in August, September were only exceeded by 0.0001 mg/L.
- MH-13: predicted monthly average cadmium concentrations exceeded the long term guideline only in February. All measured values from which the average was calculated were below the detection limit, but one of the detection limits was relatively high (0.001 mg/L). This resulted in the observed monthly average being elevated. Predicted lead and zinc concentrations were below CCME guideline concentrations for all months.
- MH-16: predicted zinc, cadmium and lead concentrations did not exceed CCME guideline concentrations.
- Predicted zinc, lead and cadmium concentrations did not exceed CCME WQG PAL at monitoring locations MH-12 and MH-18 in Tributary E.

Table 3. Conservative case water quality predictions and comparison to CCME WQG PAL

MH-04									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	172	0.03	0.006	0.004	0.00025	**0.087**	**0.016**	0.0021	**0.0021**
February	174	0.03	0.006	0.004	0.00025	**0.105**	**0.023**	0.0026	**0.0026**
March	169	0.03	0.006	0.004	0.00024	**0.115**	**0.021**	0.0028	**0.0028**
April	185	0.03	0.007	0.004	0.00026	**0.106**	**0.019**	0.0026	**0.0026**
May	169	0.03	0.006	0.004	0.00024	0.014	0.003	0.0005	**0.0005**
June	130	0.03	0.004	0.003	0.00020	0.015	0.002	0.0005	**0.0005**
July	152	0.03	0.005	0.003	0.00022	0.014	0.003	0.0004	**0.0004**
August	158	0.03	0.006	0.003	0.00023	0.022	0.004	0.0007	**0.0007**
September	170	0.03	0.006	0.004	0.00025	0.028	0.004	0.0007	**0.0007**
October	174	0.03	0.006	0.004	0.00025	**0.030**	0.005	0.0008	**0.0008**
November	172	0.03	0.006	0.004	0.00025	**0.043**	**0.008**	0.0011	**0.0011**
December	153	0.03	0.005	0.003	0.00023	**0.079**	**0.012**	0.0017	**0.0017**

MH-11									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	228	0.03	0.007	0.005	0.00031	**0.059**	**0.010**	0.0009	**0.0009**
February	216	0.03	0.007	0.005	0.00030	**0.054**	**0.013**	0.0009	**0.0009**
March	221	0.03	0.007	0.005	0.00031	**0.061**	**0.009**	0.0010	**0.0010**
April	224	0.03	0.007	0.005	0.00031	**0.060**	**0.008**	0.0009	**0.0009**
May	193	0.03	0.007	0.004	0.00027	0.025	0.005	0.0003	0.0003
June	166	0.03	0.006	0.004	0.00024	0.023	**0.008**	0.0002	0.0002
July	183	0.03	0.007	0.004	0.00026	0.016	0.003	0.0002	0.0002
August	189	0.03	0.007	0.004	0.00027	0.018	0.003	0.0003	**0.0003**
September	194	0.03	0.007	0.004	0.00028	0.021	0.003	0.0003	**0.0003**

MH-11									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
October	195	0.03	0.007	0.004	0.00028	0.018	0.002	0.0003	**0.0003**
November	205	0.03	0.007	0.004	0.00029	**0.030**	0.005	0.0004	**0.0004**
December	222	0.03	0.007	0.005	0.00031	**0.044**	0.005	0.0006	**0.0006**

MH-13									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	224	0.03	0.007	0.005	0.00031	0.015	0.003	0.0003	0.0003
February	233	0.03	0.007	0.005	0.00032	0.017	0.003	0.0005	**0.0005**
March	219	0.03	0.007	0.005	0.00030	0.014	0.003	0.0003	0.0003
April	185	0.03	0.007	0.004	0.00026	0.010	0.003	0.0002	0.0002
May	172	0.03	0.006	0.004	0.00025	0.012	0.001	0.0002	0.0002
June	160	0.03	0.006	0.003	0.00023	0.007	0.001	0.0001	0.0001
July	185	0.03	0.007	0.004	0.00026	0.004	0.001	0.0001	0.0001
August	209	0.03	0.007	0.004	0.00029	0.008	0.001	0.0002	0.0002
September	195	0.03	0.007	0.004	0.00028	0.009	0.001	0.0001	0.0001
October	199	0.03	0.007	0.004	0.00028	0.005	0.001	0.0001	0.0001
November	207	0.03	0.007	0.004	0.00029	0.006	0.002	0.0001	0.0001
December	209	0.03	0.007	0.004	0.00029	0.011	0.002	0.0002	0.0002

MH-16									
Month	Average Hardness	CCME Guidelines				Predicted Concentration			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	212	0.03	0.007	0.005	0.00030	0.009	0.001	0.0001	0.0001
February	224	0.03	0.007	0.005	0.00031	0.006	0.001	0.0001	0.0001
March	202	0.03	0.007	0.004	0.00028	0.007	0.003	0.0001	0.0001
April	211	0.03	0.007	0.004	0.00029	0.004	0.001	0.0001	0.0001
May	156	0.03	0.006	0.003	0.00023	0.003	0.001	0.0001	0.0001
June	174	0.03	0.006	0.004	0.00025	0.005	0.002	0.0001	0.0001
July	197	0.03	0.007	0.004	0.00028	0.003	0.000	0.0001	0.0001
August	219	0.03	0.007	0.005	0.00030	0.005	0.001	0.0001	0.0001
September	209	0.03	0.007	0.004	0.00029	0.003	0.0004	0.00003	0.00003
October	211	0.03	0.007	0.004	0.00029	0.005	0.001	0.0001	0.0001
November	219	0.03	0.007	0.005	0.00030	0.003	0.000	0.0001	0.0001
December	218	0.03	0.007	0.005	0.00030	0.005	0.001	0.0001	0.0001

MH-12									
Month	Average Hardness	CCME Guidelines				Predicted Concentration			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg $CaCO_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	162	0.03	0.006	0.003	0.00024	0.017	0.002	0.0002	0.0002
February	197	0.03	0.007	0.004	0.00028	0.025	0.007	0.0002	0.0002
March	197	0.03	0.007	0.004	0.00028	0.016	0.001	0.0001	0.0001
April	197	0.03	0.007	0.004	0.00028	0.017	0.002	0.0001	0.0001
May	147	0.03	0.005	0.003	0.00022	0.015	0.0004	0.0001	0.0001
June	136	0.03	0.005	0.003	0.00020	0.023	0.001	0.0001	0.0001
July	134	0.03	0.005	0.003	0.00020	0.017	0.0005	0.0001	0.0001
August	184	0.03	0.007	0.004	0.00026	0.014	0.001	0.0002	0.0002
September	185	0.03	0.007	0.004	0.00026	0.012	0.0004	0.00008	0.00008

MH-12									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
October	178	0.03	0.007	0.004	0.00026	0.013	0.001	0.0001	0.0001
November	179	0.03	0.007	0.004	0.00026	0.017	0.001	0.0001	0.0001
December	185	0.03	0.007	0.004	0.00026	0.016	0.002	0.0001	0.0001

MH-18									
Month	**Average Hardness**	**CCME Guidelines**				**Predicted Concentration**			
		Zn	Pb	Cd- Short Term	Cd- Long Term	Zn	Pb	Cd	Cd Long Term
	mg CaCO$_3$/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
January	162	0.03	0.006	0.003	0.00024	0.012	0.001	0.0001	0.0001
February	197	0.03	0.007	0.004	0.00028	0.021	0.007	0.0002	0.0002
March	197	0.03	0.007	0.004	0.00028	0.011	0.001	0.0001	0.0001
April	197	0.03	0.007	0.004	0.00028	0.014	0.002	0.0001	0.0001
May	147	0.03	0.005	0.003	0.00022	0.014	0.0004	0.0001	0.0001
June	136	0.03	0.005	0.003	0.00020	0.021	0.001	0.0001	0.0001
July	134	0.03	0.005	0.003	0.00020	0.016	0.0005	0.0001	0.0001
August	184	0.03	0.007	0.004	0.00026	0.013	0.001	0.0002	0.0002
September	185	0.03	0.007	0.004	0.00026	0.010	0.0004	0.00008	0.00008
October	178	0.03	0.007	0.004	0.00026	0.011	0.001	0.0001	0.0001
November	179	0.03	0.007	0.004	0.00026	0.013	0.001	0.0001	0.0001
December	185	0.03	0.007	0.004	0.00026	0.010	0.001	0.0001	0.0001

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Notes: Bold values exceed CCME Guidelines.
Average monthly hardness concentrations at MH-08 were used to calculate hardness based guidelines at MH-12 and MH-18.

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4.2.2 Low Flow Conditions

The 7Q20s was used to predict water quality during low flow periods. The 7Q20s is the 7-day average low flow that would occur once every 20 years during the summer. This hydrologic statistic was used because it represents low flow conditions in the summer as the result of a very dry year, opposed to the 7Q20a which represents low flow conditions from prolonged freezing. Average monthly concentrations from October were used in the estimates. Table 4 shows water quality estimates for the conservative case using low flow conditions in the summer.

Only the CCME long term guideline for cadmium is exceeded at MH-04, similar to the predictions for base flow conditions. The 7Q20s flow predictions are of similar magnitude as the average monthly flows predicted for base flow conditions.

Table 4. Camp Creek and False Canyon Creek Water Predictions for the Conservative Case during Low Flow Conditions

	Predicted Concentration (mg/L)				CCME WQG PAL			
Location	Zn	Cd	Pb	Minimum Monthly Hardness (mg/L CaCO3)	Zn	Cd		Pb
					Short-term	Short-term	Long-term	Short-term
MH-4	0.02	**0.0004**	0.002	130	0.03	0.003	0.0002	0.004
MH-11	0.02	0.0002	0.002	166	0.03	0.004	0.0002	0.006
MH-12	0.01	0.00009	0.0006	134	0.03	0.003	0.0002	0.005
MH-13	0.007	0.00004	0.0004	160	0.03	0.003	0.0002	0.006
MH-16	0.003	0.00002	0.0004	156	0.03	0.003	0.0002	0.006
MH-18	0.01	0.00008	0.0006	134	0.0300	0.003	0.0002	0.005

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Bold values indicate the prediction exceeds CCME WQG PAL.

4.3 Effect of Climate Change

The potential effect of climate change was evaluated using climatic models compiled by the Canadian Climate Change Scenarios Network (CCCSN). This set of models is from the United Nations Intergovernmental Panel on Climate Change's (IPCC) third and fourth assessment reports (IPCC 2001 and 2007). The models evaluate 72 climatic scenarios and predict a range of possible changes in total annual precipitation over the next 70 years. Figure 2 shows the cumulative percent distribution of climatic model predictions in mean annual precipitation. Table 5 presents a frequency table of predicted increases in mean annual precipitation. This evaluation suggests that 75% of the modeled scenarios' predicted mean annual precipitation may increase by up to 15 mm over the next ten years or at a rate 1.5 mm/year.

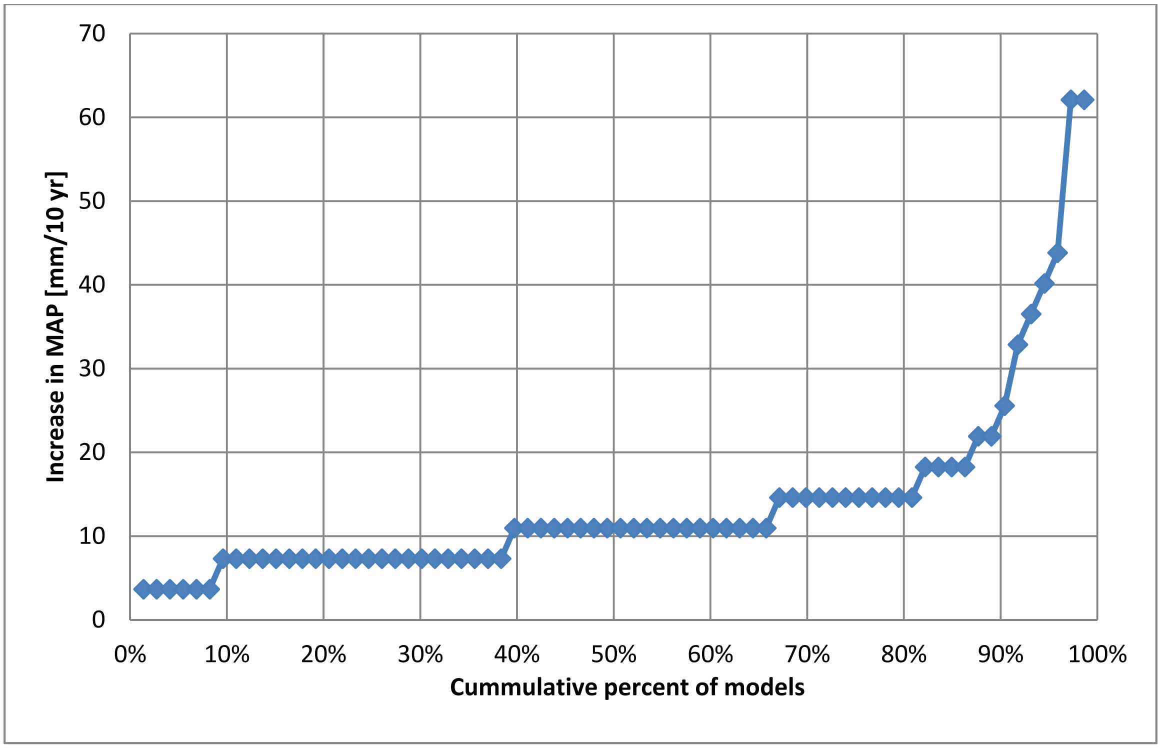

Figure 2. Cumulative percent distribution of climatic model predictions in mean annual precipitation (MAP).

Table 5. Frequency Table of Predicted Increases in Mean Annual Precipitation.

Percentage of the Models	Mean Annual Precipitation Increase (mm/10yr)
5	4
25	8
50	11
75	15
95	42

These results need to be considered in the context of the variability of total annual precipitation. Total annual precipitation at the site was estimated to be 630 mm (SRK 1990). An increase in mean annual precipitation of 15mm/10 years is less than a 2.5% increase, which is well within interannual variability.

The consequence of additional precipitation is additional runoff. Additional infiltration into source areas could potentially increase flow from source areas, which would increase the load assuming source terms remain unchanged. However, if precipitation increases, there would be a proportional in increase in runoff from unimpacted areas. Because the increase in load from sources is proportional to the increase in runoff, the likely result would be no net increase in concentration from both the expected case and conservative case predictions. This conclusion is supported by the water quality data from the site over the last 23 years, which do not show any change in loading or resulting increases in concentrations downgradient from the site.

5 Discussion of Water Quality Estimates

The current monthly average (expected case), the conservative average flow case, and Q720s low flow case water quality estimates meet the current WUL water quality limits in Camp Creek, Tributary E, and False Canyon Creek. Concentrations are higher during base flow periods (November to April) than during freshet and the summer months. Water quality estimates for a 7Q20s low flow scenario were similar to seasonal (base flow) estimates. These estimates will be used to assess potential effects to the aquatic receiving environment from site discharge after closure.

The conservative case predictions also need to be considered in context of being the maximum possible concentrations that could occur at some time in the future. This conservative case is possible only if increasing concentrations were allowed to increase without implementing any mitigation measures. Concentrations in the receiving environment would not increase instantaneously to the predicted levels. Concentrations would increase gradually over time as a function of mixing with other groundwater, dispersion, attenuation, the subsequent consumption of attenuation capacity, and the travel time between the source and discharge locations.

Constituents dissolved in water travel to groundwater as the discharge from the portals infiltrates into the ground. Dissolved constituents are attenuated by the processes described in SRK (2005a, 2007) and Day and Blowes (2005). The slug of water that infiltrates is dispersed as it advects with groundwater. Some of the water travels shorter paths of high permeability and other travels longer paths of lower permeability. This controls the average time it takes a slug of water to travel from where it infiltrates to where it discharges. This increases the time for the center of mass of a slug of infiltrated water to arrive at the discharge location. Some arrives quicker and some slower. The average time of travel is dictated by the average hydrogeologic characteristics of the media it flows through.

Just as there is a frequency distribution of travel, attenuation capacity of individual flow paths is similarly not the same for all flow paths. Flow paths which receive more flow and mass loadings will have their attenuation capacity assumed at higher rates than flow paths that receive less flow and loadings. The flow paths do not lose attenuation capacity at the same rate or point in time.

Figure 3 shows a conceptual model of how concentrations increase over time at a downgradient location because of dispersion and loss of attenuation capacity along the flow path. There is a gradual increase as initially the flow paths with the shortest travel times (highest velocities) lose attenuation capacity. Concentrations eventually increase rapidly as the flow paths with the median travel times lose attenuation capacity. The lag time between the initial increase in concentration and the maximum predicted concentration could be tens to hundreds of years. There would be sufficient time to observe any concentration increase and implement mitigation measures if needed.

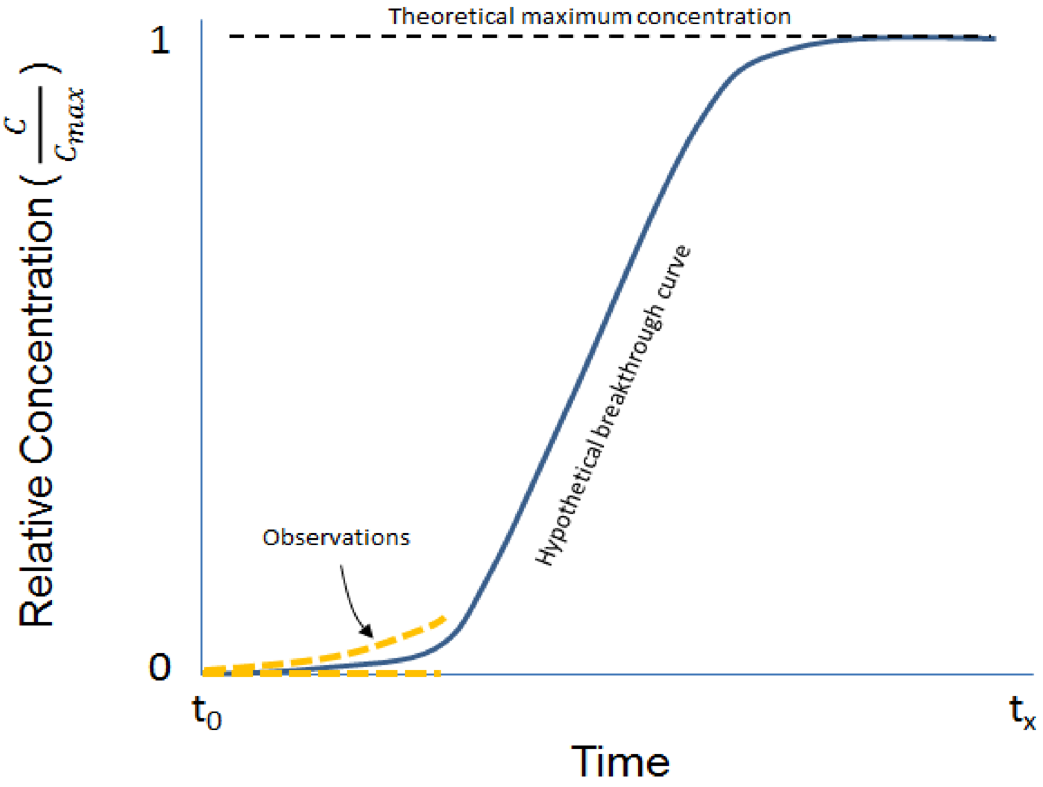

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Figure 3. Conceptual model of increasing concentration at groundwater discharge location.

6 Conclusions and Recommendations

Previous investigations have explained geochemical mechanisms that attenuate metals from loading sources. The duration of the attenuation mechanism through soils has not been defined for the 1380 Portal discharge. Attenuation of the metal load from the Burnick Portal is expected to last more than 200 years (SRK 2005b). Attenuation of the metal load from North Dam seepage has not been evaluated but the load is so small that it does not affect downgradient surface water quality. This report synthesizes anticipated metal attenuation, source loads, and site hydrology to predict water quality.

Predicted zinc, cadmium, and lead concentrations for the conservative average flow scenario (i.e., no metal attenuation in the soils downstream of the 1380 Portal) are greater during base flow conditions than during the freshet and summer. During base flow (October to November), groundwater discharge contributes a larger proportion of the flow than during freshet and the summer months, when snowmelt and runoff contribute more flow. Snowmelt and runoff dilute the mass load contributed to base flow by groundwater discharge. At MH-04, predicted levels of zinc, lead, and cadmium exceeded CCME WQG PAL during base flow. Further downstream at MH-11, predicted cadmium, zinc, and lead exceeded guidelines during base flow less frequently and by MH-13, zinc, lead, and cadmium levels were generally below CCME guidelines for the protection of aquatic life. Only predicted cadmium concentrations for the conservative case low flow conditions (7Q20s) exceeded CCME WQG PAL.

The comparison of predictions to CCME WQG PAL is for reference only. It should not be interpreted that the predicted water quality will have an effect on the community in the streams. There are many mitigating factors that influence whether elevated concentrations would affect the community. The potential effect of the predicted water quality will be assessed in the Project Proposal to Yukon Environmental and Socioeconomic Assessment Board (YESAB).

The conservative case water quality predictions are conservative and are based on an immediate and complete loss of attenuation capacity. Since groundwater is the migration pathway, the rate at which surface water concentrations change is a function of groundwater reactive transport. Concentrations in surface water will not instantaneously increase to the predicted maximum concentrations. The variation in groundwater travel times and the rate at which attenuation capacity is consumed will result in a gradual change in concentration at the groundwater discharge location. These two processes make modeling the fate and transport of water quality constituents very complex. Predictive groundwater transport model results would be highly uncertain and should not inform the development of a post-closure monitoring and mitigation program.

Developing and implementing an adaptive management plan would allow any changes in post-closure groundwater and surface water quality near the mine site to be observed through a monitoring network, which would provide sufficient time to implement appropriate mitigation measures (SRK 2013). An adaptive management plan is often the preferred alternative when predictions are uncertain. The lag time for constituents to migrate to the receiving environment is an opportunity to observe changes in concentration and provides sufficient time to implement any necessary mitigation measures to prevent impacts to surface water quality in the receiving environment.

This report, ***“Water Quality Loading Assessment of Burnick Portal and 1380 Portal Discharge, Sä Dena Hes”***, was prepared by SRK Consulting (Canada) Inc.

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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The opinions expressed in this report have been based on the information available to SRK at the time of preparation. SRK has exercised all due care in reviewing information supplied by others for use on this project. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information, except to the extent that SRK was hired to verify the data.

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Appendix A – Site Hydrology Update

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Memo

To:	File	**Client:**	Teck Resources Ltd.
From:	Pat Bryant Tom Sharp	**Project No:**	1CT008.043
Cc:		**Date:**	May 3, 2013
Subject:	Sa Dena Hes – Hydrology Update		

1 Introduction

1.1 Background

The hydrology of the Sä Dena Hes mine site was first characterized in 1990 during the permitting stage of the mine (SRK 1990). An update was prepared in 1999 in support of the 2000 Decommissioning and Reclamation Plan (Teck 2000). A further update was prepared in 2005 to incorporate site climate and flow data that had been collected over a four-year period from 2000 to 2004 (SRK 2005b).

1.2 Mean Annual Runoff

Mean annual runoff (MAR) is defined here as the total annual yield of a catchment (i.e., the sum of the overland, interflow and groundwater components of runoff that are shed from the catchment). The technique presented in this section estimates total yield. As was done in the previous hydrological investigations, MAR was estimated by using the well-established observation that elevation explains a significant amount of the variation of yield within mountainous terrain. **Figure 1** presents the plot that was used to explore the relationship between MAR and elevation. The vertical axis shows MAR expressed as an equivalent depth (i.e., the depth that would be achieved if the average annual runoff volume was distributed uniformly over the contributing catchment area). The horizontal axis provides the measurement used to quantify the elevation characteristics of a given catchment. It is known as the catchment median elevation and represents the contour that divides a catchment exactly into two halves, with half of the catchment area being at elevations above the contour level and half below.

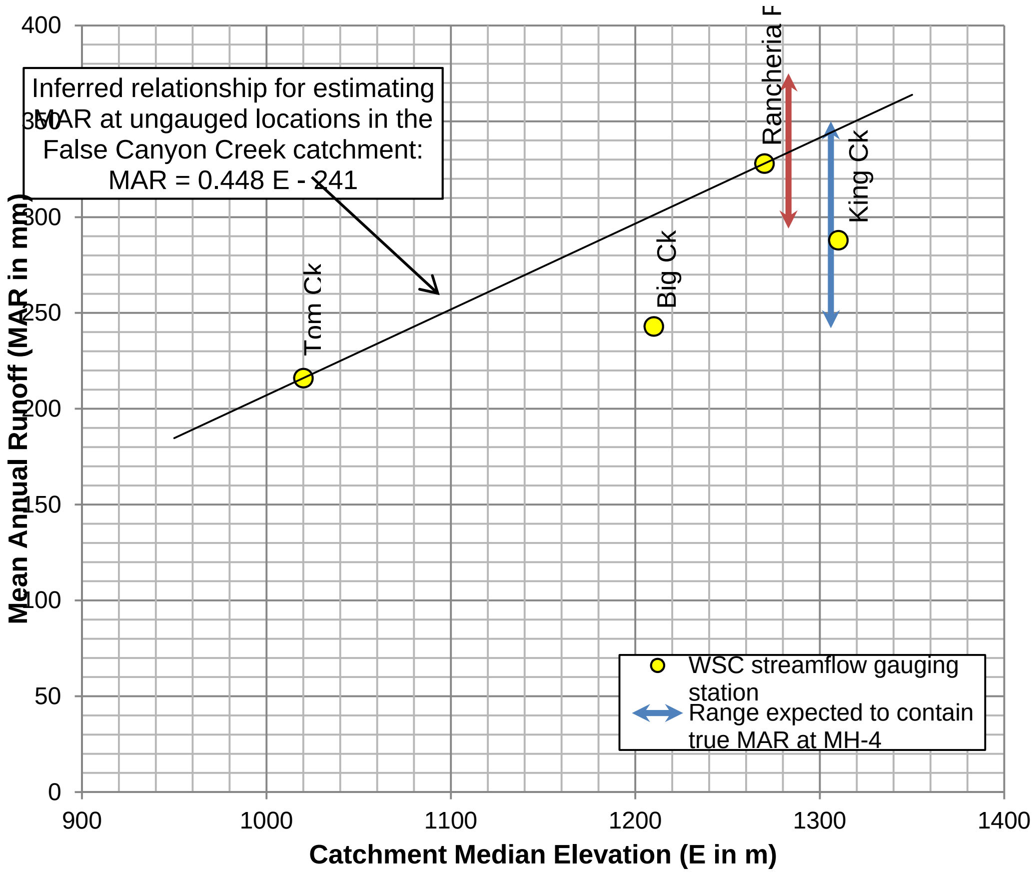


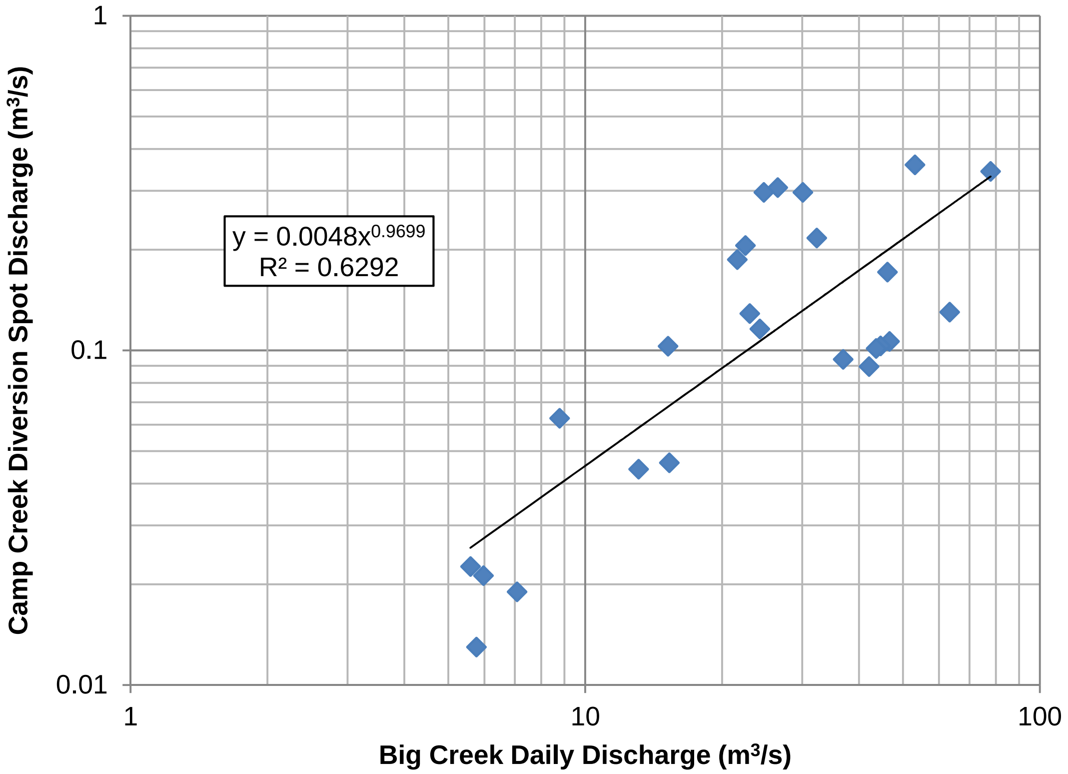
Figure 1. Mean annual runoff versus median catchment elevation.

To develop an empirical relationship between MAR and median elevation, a search was made of the WSC network of streamflow gauging stations to identify stations that: i) are in close proximity to the mine; and ii) control catchments that have comparable elevation characteristics as the catchments of the streams draining the mine. This search identified four suitable candidates (Tom Cree, Big Creek, Rancheria Creek and King Creek), two of which are of particular note. One is located in the catchment of Tom Creek, which shares part of its drainage divide with False Canyon Creek. The other WSC station is located some 80 km north of the mine on King Creek, which drains a small, high-elevation catchment.

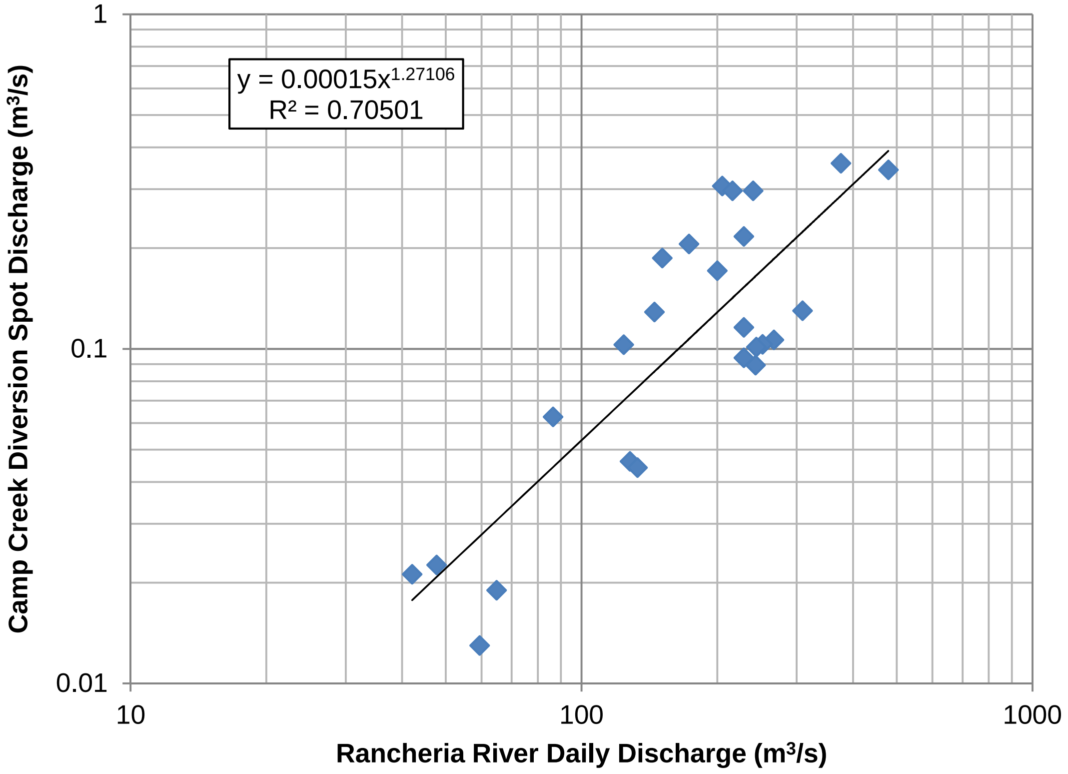
The MAR and median elevations for the four selected WSC stations were plotted on **Figure 1**. The data demonstrate that MAR tends to increase with elevation, but they also show that elevation alone does not fully explain the variations in MAR between the stations. Interpretation of the data was made by adopting a relationship that probably overestimates flows at high elevation and underestimates flows at low elevation. The relationship was generated by fitting a line through the data points for Tom Creek and Rancheria River with a slope of 45 mm per 100 m of elevation. The relationship of MAR with elevation in the False Canyon Creek is probably less than indicated by this slope. A relationship using all four data points would result have a lower slope and would probably provide more accurate estimates of MAR for the streams draining the mine site.

Data collected at two sites on Camp Creek were used to validate the adopted relationship between MAR and elevation. One site is Station MH-04 located at a road crossing of Camp Creek some 300 m upstream of the entrance to the Camp Creek Diversion. The other site is CC-3 located in the Camp Creek Diversion above the emergency spillway of the Reclaim Dam. Direct measurements of flow were made at MH-04 using current meters and bucket and stopwatch methods. Supplemental indirect estimates were made by making depth measurements in the culvert at the MH-04 road crossing. All direct flow measurements at CC-3 were based on current meterings.

Estimates of MAR at the MH-04 and CC-3 were made by correlating the site data and coincidental flows at regional WSC stations. **Figure** a and 2b presents the correlations used to estimate the MAR at the most downstream site (CC-3). **Figure** a shows the correlation between CC-3 and Big Creek. **Figure** 2b shows the correlation with Rancheria Creek flows. Log-log plots were prepared in recognition of the differing hydrological regimes of small and large streams. Small streams tend to exhibit a flashier nature than do large streams (i.e. experience a larger ratio between annual high daily flow and annual low daily flow). A power regression was fitted to each plot to capture this difference in hydrological regime. If the small stream is flashier than the larger stream, then the exponent of the power regression is expected to be greater than one (assuming the data for the small stream are treated as the dependent variable).



a.) Camp Creek Diversion discharge versus Big Creek discharge.



b.) Camp Creek Diversion discharge versus Rancheria River discharge.

Figure 2: Camp Creek Diversion discharge versus Big Creek and Rancheria River discharge.

To make an independent estimate of MAR at CC-3, the power regression of Figure 2a was used to transpose the full daily flow record of the Big Creek WSC gauging station to CC-3 (i.e., the power regression was applied to each daily value in the Big Creek record). The average of the transposed flows was then computed to estimate the MAR of CC-3. This procedure was repeated using the Rancheria River data (Figure 2b). The correlation with the Big Creek data resulted in a MAR estimate of 375 mm, while the correlation with the Rancheria River (higher r^2) resulted in an estimate of 294 mm. The median elevation of the CC-3 station is 1283 m. The relationship between MAR and elevation is in the middle of this range on Figure 1.

Figures 3a and 3b presents a similar analysis performed using the MH-04 site data and Big Creek and the Rancheria River, respectively. The full flow database for MH-04 is presented, but only data by SRK in 2012 and 2013 was used for fitting of the power regressions. This approach was adopted because the recent flow data were all based on direct flow measurements (either current meter or bucket and stopwatch), whereas much of the remaining data were estimated by application of the Manning's equation to depth measurements in a culvert. The direct flow measurements are generally more accurate than estimates made indirectly with the Manning's equation. The correlations between MH-04 and regional WSC data indicate that the true MAR of Station MH-04 likely falls in the range of 242 mm to 350 mm. **Figure 1** shows the inferred relationship between MAR and elevation runs through the upper end of the range believed to contain the true MAR of Station MH-04. Together with the data points for Big Creek and King Creek, the assessment of MAR at MH-04 suggests that the inferred relationship may overestimate the true yields of high-elevation catchments in the False Canyon Creek catchment.

Figure 3: \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\hydrology\Copy of Estimated Flows in Receiving Environment.xlsx **use tabs figure 3a and 3b**

1.3 Seasonal Runoff Distribution

The monthly runoff for streams in and around the Sä Dena Hes Mine was estimated by examining the average monthly hydrographs of regional WSC stations. Figure 4 presents the monthly distributions for the two WSC stations in the region most representative of hydrological conditions at the mine, namely the stations on Tom Creek and King Creek. The distributions have been expressed as percentages of the mean annual runoff. Figure 4 indicates what proportion of the annual runoff volume each month typically contributes. The distributions are characterized by high spring and early summer flows during snowmelt and low winter flows during prolonged freezing conditions. The distributions are dependent on elevation. The distribution for the higher King Creek catchment has a later snowmelt peak than the Tom Creek catchment.

Insert figure on tab "figure 4" Number appropriately. Include caption. \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Copy of Estimated Flows in Receiving Environment.xlsx

Figure 4

The catchments controlled by the Tom Creek and King Creek WSC stations have estimated median elevations of 1020 m and 1310 m, respectively. The median elevations of the mine site catchments fall within an almost identical range and, accordingly, the seasonal discharge patterns for the Tom Creek and King Creek stations come close to bracketing the expected runoff distributions for mine area streams. The pattern from interpolation of the Tom Creek and King Creek distributions was used to estimate the runoff pattern for any given ungauged location. For example, if flows were being estimated for a catchment with an elevation exactly halfway between the elevations of the two WSC stations (i.e., (1020 + 1310)/2 = 1165 m), then the seasonal pattern would be the average of the Tom Creek and King Creek patterns. Catchments with median elevations of around 1300 m closely resemble the King Creek pattern, while catchments with median elevations of about 1000 m closely match the Tom Creek pattern.

1.4 Low Flows

Two statistics were used to characterize the low flow regimes of the streams draining the Sä Dena Hes mine:

- 20-year annual minimum 7-day flow (7Q20a); and,
- 20-year summer minimum 7-day flow (7Q20s).

The first statistic is the average flow during the lowest part of an annual hydrograph of an extremely dry year. More specifically, 7Q20a represents the annual lowest 7-day flow with a return period of 20 years. If a station has a streamflow record of 20 years, then the lowest 7-day flow in that record would approximate the 7Q20a. In the Yukon, the lowest annual flows will typically occur in the winter after a prolonged period of freezing. As a result, for a given return period, there is very little difference between low flow statistics over a range of durations from one day to several months. In other words, the 1Q20a, 7Q20a and 30Q20a are very similar in magnitude for a given stream in the Yukon.

The second statistic describes the lowest flow over the summer (June 1 to September 30). Specifically, 7Q20s represents the average flow over the driest 7 consecutive days in the period June 1 to September 30 during a 20-year drought. Similar to the annual statistic, if the lowest 7-day flow was extracted for each summer in a 20-year-long record, then the lowest value could be used to approximate the 7Q20s.

The low flow statistics for streams draining the Sä Dena Hes mine were inferred from low flow data collected at five regional WSC stations. The stations employed for this purpose were the four stations selected for the MAR analysis, together with the WSC station located on Frances River some 40 km downstream of where False Canyon Creek enters this river.

The streamflow record from each of the five WSC stations was subjected to the following tasks:

1. Extract the annual series of annual minimum 7-day flow;
2. Fit the annual series from Step 1 to a theoretical frequency distribution (Log-Pearson Type III) to estimate the annual 7-day low flows for a range of return periods from 2 years to 20 years;
3. Extract the annual series of summer minimum 7-day flow;
4. Fit the annual series from Step 3 to a Log-Pearson Type III distribution to estimate the summer 7-day low flows for a range of return periods; and,
5. Express the results of the frequency analyses in normalized units of $L/s/km^2$.

The results of the above-described analyses are presented in **Table 1** and **Table 2** the annual period (June 1 to May 31) and the summer period (June 1 to September 30).

Table 1: Annual Minimum 7-Day Flows at Regional WSC Stations

Streamflow Gauging Station		Drainage Area (km^2)	Mean Annual Runoff (mm)	Annual Minimum 7-Day Discharge (m^3/s) for a Return Period of:				Annual Minimum 7-Day Discharge (L/s/km^2) for a Return Period of:			
ID No.	**Name**			**2 Years**	**5 Years**	**10 Years**	**20 Years**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
10AB003	King Creek at km 20.9 Nahanni Range Road	13.7	288	0.014	0.008	0	0	1.0	0.6	0.0	0.0
10AA002	Tom Creek at km 34.9 Robert Campbell Highway	435	216	0.383	0.244	0.182	0.137	0.9	0.6	0.4	0.3
10AA005	Big Creek at km 1084.8 Alaska Highway	1010	243	2.30	1.74	1.43	1.19	2.3	1.7	1.4	1.2
10AA004	Rancheria River near the mouth	5100	328	12.0	9.1	7.1	5.5	2.4	1.8	1.4	1.1
10AB001	Frances River near Watson Lake	12800	395	21.9	18.8	17.4	16.3	1.7	1.5	1.4	1.3

Source: \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Low Flow Analysis.xlsx

Note: The annual series used in this low flow analysis were based on a climate year spanning the period June 1 to May 31

Table 2: Summer Minimum 7-Day Flows at Regional WSC Stations

Streamflow Gauging Station		Drainage Area (km^2)	Mean Annual Runoff (mm)	Summer Minimum 7-Day Discharge (m^3/s) for a Return Period of:				Summer Minimum 7-Day Discharge (L/s/km^2) for a Return Period of:			
ID No.	**Name**			**2 Years**	**5 Years**	**10 Years**	**20 Years**	**2 Years**	**5 Years**	**10 Years**	**20 Years**
10AB003	King Creek at km 20.9 Nahanni Range Road	13.7	288	0.079	0.060	0.052	0.046	5.8	4.4	3.8	3.4
10AA002	Tom Creek at km 34.9 Robert Campbell Highway	435	216	1.64	1.22	1.03	0.88	3.8	2.8	2.4	2.0
10AA005	Big Creek at km 1084.8 Alaska Highway	1010	243	6.2	4.9	4.2	3.7	6.1	4.8	4.2	3.7
10AA004	Rancheria River near the mouth	5100	328	42.7	34.0	30.1	27.2	8.4	6.7	5.9	5.3
10AB001	Frances River near Watson Lake	12800	395	149	119	105	95	11.6	9.3	8.2	7.4

Source: \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Low Flow Analysis.xlsx

Note: Summer is defined here as period June 1 to September 30.

After completion of the frequency analyses, the low flow statistics at the WSC stations were transposed to the mine site drainages. Examination of the data revealed two trends: low flows tend to increase with both MAR and catchment area. However, the sample provided by the five streamflow gauging stations was deemed insufficient to definitively assess the relative importance of these two independent variables in predicting low flow values, particularly for the 7Q20a statistic.

The approach assumed the streams draining the Sä Dena Hes mine behave similarly to the regional WSC station with the most extreme low flow regime. Tables 1 and 2 show Tom Creek fits this description for summer low flows for all return periods, and annual low flows for the 2-year and 5-year low events. It is noted that King Creek is expected to go completely dry during the winter at a return period of about 10 years, but the potential exists for flow to still be passing through the channel substrate at this station.

For the purpose of constructing the load balance model, all streams were assumed to experience the same unit low flows as Tom Creek during a 20-year drought. The appropriate values for the 7Q20a and 7Q20s events are 0.3 L/s/km^2 and 2.0 L/s/km^2, respectively.

The records of spot measurements at CC-3 and MH-04 were used as a partial validation of the estimated low flows for the mine site streams. This validation was implemented by using the correlations presented earlier (Figures 2 and 3) to transpose the Big Creek and Rancheria River estimates of 7Q20a and 7Q20s to the two gauged locations on Camp Creek. The results of the analysis are summarized in **Table 3**. The transposed low flows from Rancheria River agree reasonably well with the estimates based on the Tom Creek unit flows. The transposed flows from Big Creek suggest that the true low flows may be higher than those based on Tom Creek data. In general, the correlations with Rancheria River are better than the ones with Big Creek, and therefore more credence can be placed on the validation data provided by Rancheria River.

Table 3: Comparison of 7Q20a and 7Q20s Estimates for MH-4 and CC-3

Station	Estimation Method	Estimated 7Q20a (L/s)	Estimated 7Q20s (L/s)
MH-4	Assumed same unit low flows as estimated for Tom Creek	**0.7**	**4.2**
	Transpose Big Creek 7Q20 values using the MH-4/Big Creek correlation	1.4	6.8
	Transpose Rancheria River 7Q20 values using the MH-4/Rancheria River correlation	0.5	4.6
CC-3	Assumed same unit low flows as estimated for Tom Creek	**0.9**	**5.9**
	Transpose Big Creek 7Q20 values using the CC-3/Big Creek correlation	5.7	17
	Transpose Rancheria River 7Q20 values using the CC-3/Rancheria River correlation	1.3	10

Source: \\VAN-SVR0\Projects\01_SITES\Sa_Dena_Hes\1CT008.043_Sa Dena Hes Water Licence Support 2014\!080_Deliverables\F&T Report\Low Flow Analysis.xlsx