Elk Valley Water Quality Plan

2019 Implementation Plan Adjustment

Annex H: Assessment of Water Availability

July 2019

Teck

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
AWTF	Active Water Treatment Facility
CPX	Cougar Pit Expansion
DCWMS	Dry Creek Water Management System
ECCC	Environment and Climate Change Canada
ENV	Ministry of Environment and Climate Change Strategy
EMPR	Ministry of Energy, Mines and Petroleum Resources
EVO	Elkview Operations
EVWQP	Elk Valley Water Quality Plan
FRO	Fording River Operations
GHO	Greenhills Operations
IPA	Implementation Plan Adjustment
LCO	Line Creek Operations
MIW	Mine Influenced Water
N	North
RWQM	Regional Water Quality Model
S	South
Teck	Teck Coal Limited
WFTF	West Fork Tailings Facility
WLC	West Line Creek

UNITS OF MEASURE

Unit of Measure	Description
%	percent
km^2	square kilometre
$L/s/km^2$	liters per second per square kilometre
m	metre
mm	millimetres
m/s	metres per second
m^3/day	cubic metres per day

1 Introduction

The 2019 Implementation Plan Adjustment (IPA) is an adjustment to the Initial Implementation Plan (IIP) included in the Elk Valley Water Quality Plan (EVWQP, Teck 2014); it outlines Teck Coal Limited's (Teck's) updated mitigation plan to meet the long-term water quality Compliance Limits and Site Performance Objectives (SPOs) for selenium, nitrate and sulphate defined in *Environmental Management Act* Permit 107517. The 2019 IPA was developed using the Regional Water Quality Model (RWQM) described in Teck (2017), modified as outlined in Annex B.

Like the IIP, the 2019 IPA is based on the application of biologically-based active water treatment facilities (AWTFs) supported by clean water diversions where practical to support efficient treatment, to address selenium and nitrate water concentrations within the Elk Valley. The expected performance of active water treatment, in terms of effluent concentrations, is outlined in Annex C. Methods used to select the clean water diversions incorporated into the 2019 IPA are outlined in Annex D.

The methods used to develop mitigation in the 2019 IPA are described in Annex E, including stream prioritization, identification of hydraulic capacity, sequencing, and phasing of mitigation to meet short, medium and long-term Compliance Limits and SPOs. Assumptions used to model the projected performance of the 2019 IPA, in terms of effluent quality and the amount of water in targeted mine-affected watersheds that is available for capture and treatment are also outlined in Annex E. The latter attribute is referred to in the 2019 IPA as water availability.

The purpose of this annex is to identify if the assumed water availability can be met through the collection of water at surface, or whether collection of water at surface may need to be supplemented by the collection of mine-influenced subsurface flow. This evaluation was conducted on a tributary by tributary basis, as outlined below. This annex also includes a discussion of the follow-up activities that will be undertaken to better understand surface and subsurface flows in tributaries targeted for mitigation, and what action may be used to achieve targeted rates of water capture at each intake location. Water availability has been identified as a Key Uncertainty in the 2018 Adaptive Management Plan, and this assessment will be used to reduce that Key Uncertainty.

1.1 Background

1.1.1 Components of a Water Balance

A water balance in a watershed consists of four main components:

- Precipitation
- Surface Losses (i.e., evaporation, evapotranspiration, sublimation)
- Total Runoff (i.e., direct runoff, interflow and groundwater discharge)
- Deep Percolation (i.e., groundwater recharge to deep aquifers)

Surface losses involve the loss of water from the watershed to the atmosphere through the processes identified above (i.e., evaporation, evapotranspiration and/or sublimation). Deep percolation is a different form of water loss, involving the downward movement of water from the surface or near surface zone to deep aquifers that do not readily interact with local watercourses or waterbodies within the watershed.

The remaining component, total runoff, consists of water that effectively moves laterally downgradient through the watershed, reporting to local watercourses or waterbodies within the watershed and then to watershed outlets. Total runoff, which can also be referred to as total watershed yield, includes water traveling at surface (direct runoff), interflow and shallow groundwater flow that readily interacts with and discharges to local watercourses and waterbodies.

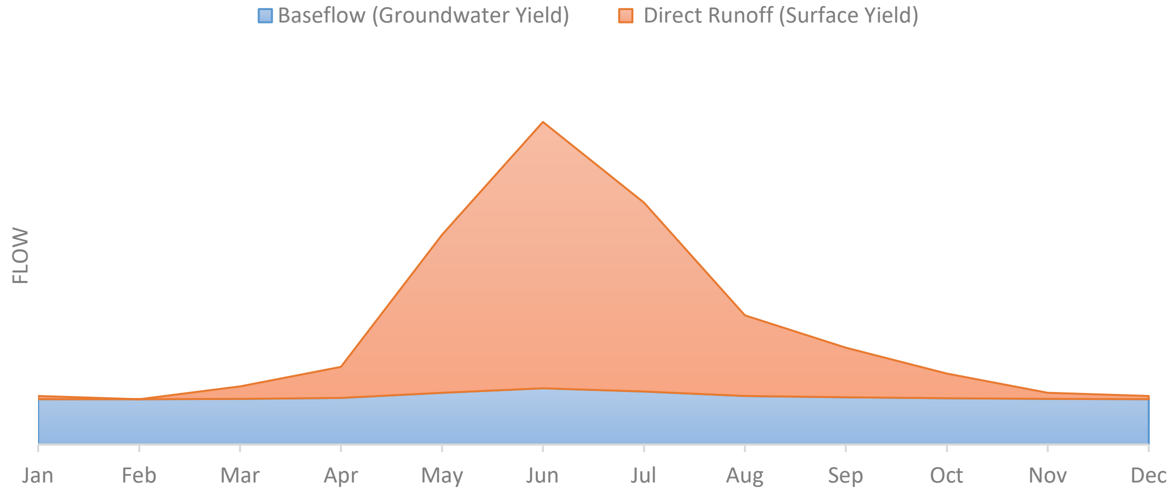
Interflow is precipitation that infiltrates the ground, flows in the vadose zone (unsaturated zone between the ground surface and the top of the groundwater table), and then discharges back to surface. The division of total runoff into direct runoff, interflow, and shallow groundwater discharge is dependent on local-scale spatial variations in slope angle, near-surface permeability, and precipitation patterns, as well as temporal variations in precipitation events.

In a watershed with mining disturbance (i.e., waste rock spoils, pits), the division of total runoff into its three sub-components follows the same principles as in an undisturbed watershed. However, it is complicated by local-scale variations introduced by mining activity, such as changes to watershed boundaries induced through pit development and changes to surface permeability related to waste rock spoiling / pit backfilling.

Contribution of Groundwater / Interflow to Total Runoff in the Elk Valley

In the Elk Valley, total runoff (or total watershed yield) computed from water balances and measured flows at regional hydrometric stations (e.g., the mouth of the Fording River) equates to approximately 50% to 60% of annual precipitation. The shallow groundwater / interflow component typically ranges between 20% and 50% of the total watershed yield (or 10% to 30% of annual precipitation). The fraction of total runoff represented by the shallow groundwater / interflow component varies notably throughout the year. Total runoff during winter months can, in many cases, be attributed almost entirely to interflow and groundwater discharge, while total runoff during freshet is comprised predominantly of direct discharge (Figure 1-1). The relative contributions of groundwater discharge / interflow and direct runoff to surface flows in a given watercourse can vary along the length of the watercourse depending on flow pathways inherent in the local watersheds and the extent of mining disturbance.

Figure 1-1 Conceptual Hydrograph Illustrating Seasonal Fluctuations in the Contributions of Groundwater Discharge / Interflow and Direct Runoff to Total Runoff (Watershed Yield)



Subsurface Flow Paths and Their Effect on Estimating Total Runoff from Measured Flows

Local tributary catchments in the Elk Valley are generally characterized by relatively shallow glacial deposits and steep gradients. Losses to deep percolation are small, and total runoff tends to report to surface watercourses either as direct runoff or as shallow groundwater / interflow moving along short travel paths. Water moves downgradient through tributary watersheds into the Fording River and the Elk River, which are regional topographical lows that generally gain flow with downstream distance (i.e., are gaining systems (Golder 2015c).

The Fording River floodplain contains permeable sediments and a valley bottom aquifer. Some of the total tributary runoff reporting to the Fording River travels subsurface and initially reports to the valley bottom aquifer. Groundwater flow in the valley bottom aquifer is directed to and eventually discharges into the Fording River, which, as previously identified, is a regional topographic low. There are small, local areas where groundwater flow is directed parallel to the river, which is referred to as an underflow-dominated section. However, on a regional basis, the direction of shallow groundwater flow is towards and into the Fording River.

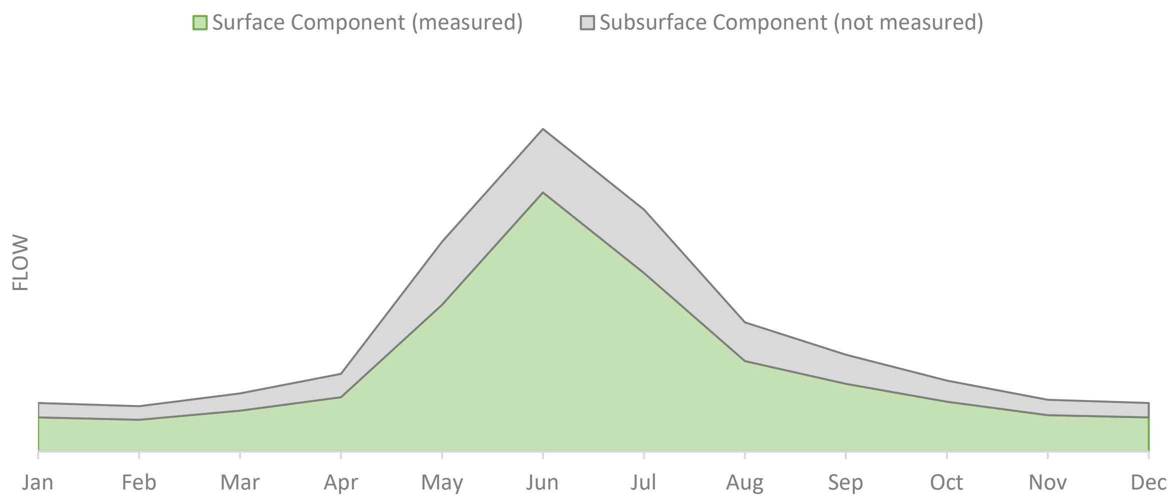
Flows into the Elk River occur in a similar fashion, particularly in the vicinity of Leask Creek, Wolfram Creek and Thompson Creek. Water moves from tributary streams into the Elk River through surface and subsurface flow paths, which discharge into the Elk River mainstem.

The presence of surface and subsurface flow paths can make it a challenge to accurately measure total runoff from tributary watersheds. Unless a monitoring station is placed in an area of local groundwater discharge (i.e., in a gaining reach), monitored water flows may underestimate total runoff from the upstream areas, because a portion of the total runoff is travelling subsurface at that particular location in the watershed. This concept is illustrated in Figure 1-2.

The subsurface flow component in Figure 1-2 is reflective of ground conditions and flow paths at a specific location along the watercourse, defined by the unique physical characteristics of the section of interest (e.g., gradient, cross-section width, substrate materials, thickness and permeability of underlying sediments). These characteristics are taken into consideration when siting and designing intake structures and quantifying flows that may not be captured by a given intake structure.

In contrast, the relative size of the groundwater / interflow components of total runoff (as illustrated in Figure 1-1) is reflective of broader watershed characteristics and the pathways by which precipitation moves through the watershed. It is defined by the physical characteristics of the watershed rather than the watercourse itself. An understanding of the relative size of these two flow components (shallow groundwater and interflow) does not directly inform intake design, but informs certain aspects of the RWQM, such as potential adjustments to representative hydrographs as one moves from one watershed to another.

Figure 1-2 Conceptual Hydrograph Illustrating Contributions of Measured Surface Flows and Unaccounted Subsurface Flows to Total Runoff (Watershed Yield)



1.1.2 Water Availability and Capture Efficiency

Water Availability

In the 2019 IPA, water availability is defined as the proportion of total watershed yield that can be captured at each intake location. It is independent of the capture efficiency of the intake and associated infrastructure that carries water from the source to the AWTF. The values assigned to water availability in the RWQM were initially set based on the proportion of total watershed yield that is assumed to be readily available as surface flow; they were increased, if and as necessary, to simulate enhanced capture of mine-influenced water to achieve downstream Compliance Limits and SPOs. Such enhancements would reflect the potential capture of some of the subsurface flow that would otherwise bypass the intake.

Teck's primary design approach is to plan for collection of surface water unless groundwater capture is required to meet Compliance Limits and SPOs. An understanding of the quantity of water flowing at surface relative to total watershed yield is therefore required at planned intake locations to identify areas where groundwater capture may be required to meet the assumed water availability.

Capture Efficiency (also known as Intake Efficiency)

Intakes are modelled to be 95% efficient for flows up to the design capacity of the intake. In other words, intakes are modelled to effectively divert and transport 95% of the water available for capture, up to the design capacity of the intake. Intake efficiency is separate from water availability and accounts for intake structure characteristics. It is an expression of the efficiency of the intake and associated conveyance infrastructure (pipeline or ditch) to capture and carry water to a treatment system. It is calculated as the ratio of the volume of water delivered to the treatment system relative to the volume of water available for capture (up to the design capacity of the intake).

The total volume of water arriving at a treatment facility is calculated by multiplying total watershed yield by water availability and capture efficiency. If the total volume of water available for treatment is higher than the hydraulic capacity of the treatment facility, then the excess water bypasses the treatment process (i.e., remains instream and is not subject to treatment).

1.1.3 Sources Targeted for Mitigation and Assumed Water Availability

Water quality mitigation as part of the 2019 IPA, as discussed in Annex C, is focused on six areas across four of Teck's five mine operations in the Elk Valley:

- Fording River Operations (FRO) – North
- FRO - South
- Greenhills Operations (GHO)
- Line Creek Operations (LCO) – Dry Creek
- LCO – Line Creek
- Elkview Operations (EVO)

Mitigation in each area will consist of the collection and treatment of mine-influenced water from one or more sources affected by active or historical mining activity. The sources targeted for treatment are outlined in Table 1-1. The rationale for their selection is outlined in Annex E.

The assumed water availability for each source targeted for mitigation is outlined in Table 1-1. Water availability was initially defined using the same information presented in the EVWQP. It was then increased in four sources at FRO. The increase in water availability at FRO was required, primarily during winter months, for projected maximum monthly average selenium concentrations to be at or below the monthly average Compliance Limit at the FRO Compliance Point after 2033.

Table 1-1 Sources Targeted for Treatment as part of the 2019 Implementation Plan Adjustment

Area	Source	Year Treatment Begins[a]	Assumed Water Availability[b]	Change to Water Availability		Assumed Intake Efficiency[b]	Water Available for Treatment[c]
				Year	Availability		
FRO North	Clode Creek	2023	80%	2033	95%	95%	76% (90% from 2033 onward)
FRO North	Swift North Spoil Drainage	2023	80%	2033	95%	95%	76% (90% from 2033 onward)
FRO North	Swift Pit	2023	80%	2033	95%	95%	76% (90% from 2033 onward)
FRO South	Swift Creek	2021	95%	-	-	95%	90%
FRO South	Cataract Creek	2021	95%	-	-	95%	90%
FRO South	Kilmarnock Creek	2021	75%	2033	95%	95%	71% (90% from 2033 onward)
GHO	Leask Creek	2031	95%	-	-	95%	90%
GHO	Wolfram Creek	2031	95%	-	-	95%	90%
GHO	Thompson Creek	2031	95%	-	-	95%	90%
GHO	Greenhills Creek	2031	75%	-	-	95%	71%
LCO Dry Creek	Dry Creek upstream of the East Tributary	2037	99%	-	-	95%	94%
LCO Line Creek	West Line Creek	2016[d]	95%	-	-	95%	90%
LCO Line Creek	Mine Services Area West	2016[d]	90%	-	-	95%	86%
LCO Line Creek	Line Creek upstream of West Line Creek	2016[d]	95%	-	-	95%	90%
EVO	Erickson Creek	2022	90%	-	-	95%	86%
EVO	Bodie Creek	2022	95%	-	-	95%	90%
EVO	Gate Creek	2022	95%	-	-	95%	90%

[a] Unless specified otherwise, dates are for 31st December of the year noted.

[b] Defined as per Annex C.

[c] Water available for treatment was calculated as assumed water availability multiplied by assumed intake efficiency. Values have been rounded to the nearest whole number.

[d] The WLC AWTF was initially commissioned on February 1, 2016. It was temporarily shut-down on November 15, 2017, because of concerns about selenium speciation. The planned re-start date for the AWTF is December 31, 2018.

AWTF = Active Water Treatment Facility; FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; EVO = Elkview Operations; WLC = West Line Creek; % = percent.

1.1.4 Feedback

On June 22, 2018, ENV, EMPR, and KNC discussed the assumed water availabilities with Teck and requested that Teck:

- provide an assessment of the percentage of total runoff at surface in sources targeted for treatment to support the assumed water availability, taking into account relevant monitoring data and local groundwater studies
- identify follow-up activities, where warranted, that will be undertaken to better characterize and understand sub-surface flows in sources targeted for treatment
- discuss feasible engineering measures that could be employed to collect surface and shallow groundwater flow to achieve the assumed water availability, where relevant

1.2 Assessment Approach

The assessment outlined herein was completed in two parts. The first part of the assessment involved an evaluation of existing information and consisted of:

- a review of available surface water and groundwater information for each source targeted for treatment
- calculation of the proportion of total watershed yield that appears to be flowing at surface at stations where data are available to do so
- a discussion of how assumed water availability compares to the proportion of water that appears to be flowing at surface, to identify if surface collection will be sufficient to achieve the capture rates assumed in the 2019 IPA

This evaluation is presented separately for each of the six areas where water quality mitigation is planned.

The second part of the assessment involved the identification of follow-up activities that will be undertaken to better understand surface water and groundwater flow paths in selected areas where there may be a need to collect additional water from subsurface flow pathways (groundwater/interflow) or that the current assumed intake location may need to be reconsidered (i.e., moved to an location where water capture can be enhanced with minimal engineering interventions). It also includes identification of potential design considerations / engineering measures that will be evaluated when siting and designing intakes in areas where the flow available at surface may be less than the assumed water availability.

1.3 Acknowledgement of Model Bias in Estimating Total Watershed Yield and Measurement Bias in Estimating Available Surface Flow

It is acknowledged that the estimates for total watershed yield and flow available at surface discussed herein may be biased. The first, total watershed yield, by model error, and the second, stream flow available at surface, by measurement error. In addition, the location where flows are measured may not be the actual location proposed for an intake structure; these factors need to be considered when interpreting the results of the comparison of measured surface flow to assumed water availability.

Teck has conducted a valley wide assessment of the hydrometric monitoring network to evaluate if the spatial extent, the quality of data, and the frequency of data collection are sufficient and appropriate to meet the intended use of the data. Improvements to the hydrometric program include:

- installing continuous monitoring stations at all discharge streams that are targeted for treatment under the EVWQP
- setting the minimum target RISC grade at grade A for all AWTF intake locations, and grade B for all other monitoring locations
- the installation of all infrastructure to allow for proper maintenance at each monitoring location to allow for grading of the data (installation of bench marks and staff gauges)
- assessing regional (or receiving environment locations) network for adequacy of monitoring locations
- verification of scaling methods used at ungauged locations
- addition of new analogue stations to improve water quality modelling (ongoing through 2019)
- incorporation of new flow measurement techniques and equipment to improve accuracy at high flows

The assessment and improvements made to Teck's hydrometric program in the Elk Valley have been completed in consultation with the ENV, KNC, and FLNRORD under Teck's Regional Surface Flow Monitoring Plan, the Teck Flow Monitoring Protocol, and in alignment with requirements outlined in EMA Permit 107517.

Similarly, during the 2017 update of the RWQM, changes were made to improve model performance with respect to projecting total watershed yield from mine-influenced tributaries. Improvements included:

- selecting appropriate analogue watersheds based on geographic factors such as proximity, elevation, aspect, and climate
- applying analogue-specific adjustments to refine the representative hydrographs (i.e., freshet timing shifts, yield adjustments and baseflow adjustments)
- applying watershed-specific yield adjustments using a calibration factor that was tied to average watershed elevation

Teck will continue to re-evaluate the model calibration to further reduce uncertainties associated with projected total watershed yield estimates. The next re-evaluation will occur as part of the 2020 RWQM Update.

Nevertheless, uncertainty remains in the projected estimates of total watershed yield and measured stream flows used in the analysis presented herein. In areas where good quality flow records are available, the uncertainty in estimates of total watershed yield is considered to be higher than that relative to the stream flow estimates based on measured data; the former (total watershed yield estimates) are generated using representative hydrographs within a model framework, whereas the latter (calculated stream flows) are defined using measured data. In areas with poorer quality surface flow data or incomplete flow records, one set of information may be no more accurate than the other.

The potential influence of uncertainty on the analysis outlined herein is discussed below with reference to two potential scenarios:

1. Total watershed yield is overestimated relative to direct discharge (as estimated by water flow measured at surface at given monitoring location).
2. Total watershed yield is underestimated relative to direct discharge.

If total watershed yield is overestimated relative to measured stream flow, then the proportion of water flowing at surface will be underestimated; it will appear that the assumed water availability can only be met using intake designs that target surface and subsurface flows, or that intakes must be placed at more appropriate locations.

The converse will occur if total watershed yield is underestimated. The proportion of water flowing at surface will be overestimated, and it will appear that the assumed water availability outlined in Table 1-1 for the location in question can be met by an intake targeting only surface water collection at the monitoring location in question.

Given this uncertainty, the analysis outlined below is not considered to be definitive. It provides an indication of the degree to which the water availability assumptions outlined in Table 1-1 can be met using intakes targeting only surface water flow, and serves to identify where follow-up activities should be prioritized. Follow-up activity is planned at all prospective intake locations in support of detailed design, and potential contingency measures that could be implemented should water availabilities be lower than assumed are outlined herein.

2 Data Evaluation

2.1 Fording River North

2.1.1 Comparison of Modelled and Monitored Flows

This section, and those outlined below with reference to the other areas targeted for treatment, include a comparison of modelled and monitored flows at each of the treatment sources to Fording River North on a seasonal basis and a discussion of how the results align with the water availability inputs used to support mitigation planning. The accuracy and potential errors in both monitored data and model calibration (i.e., estimates of total watershed yield) were considered in this evaluation, as well as potential influence of pit dewatering. A map of Fording River North watersheds and potential intake locations is presented in Figure 2-1.

The comparison of modelled to monitored flows was conducted using available information from 2008 to 2017. Mean monthly flows were generated for each of the months with available data in the 10-year time period. Ratios of mean monthly monitored to mean monthly modelled flow were calculated and averaged across lower (i.e., November to February) and higher flow months (i.e., April to July), respectively.

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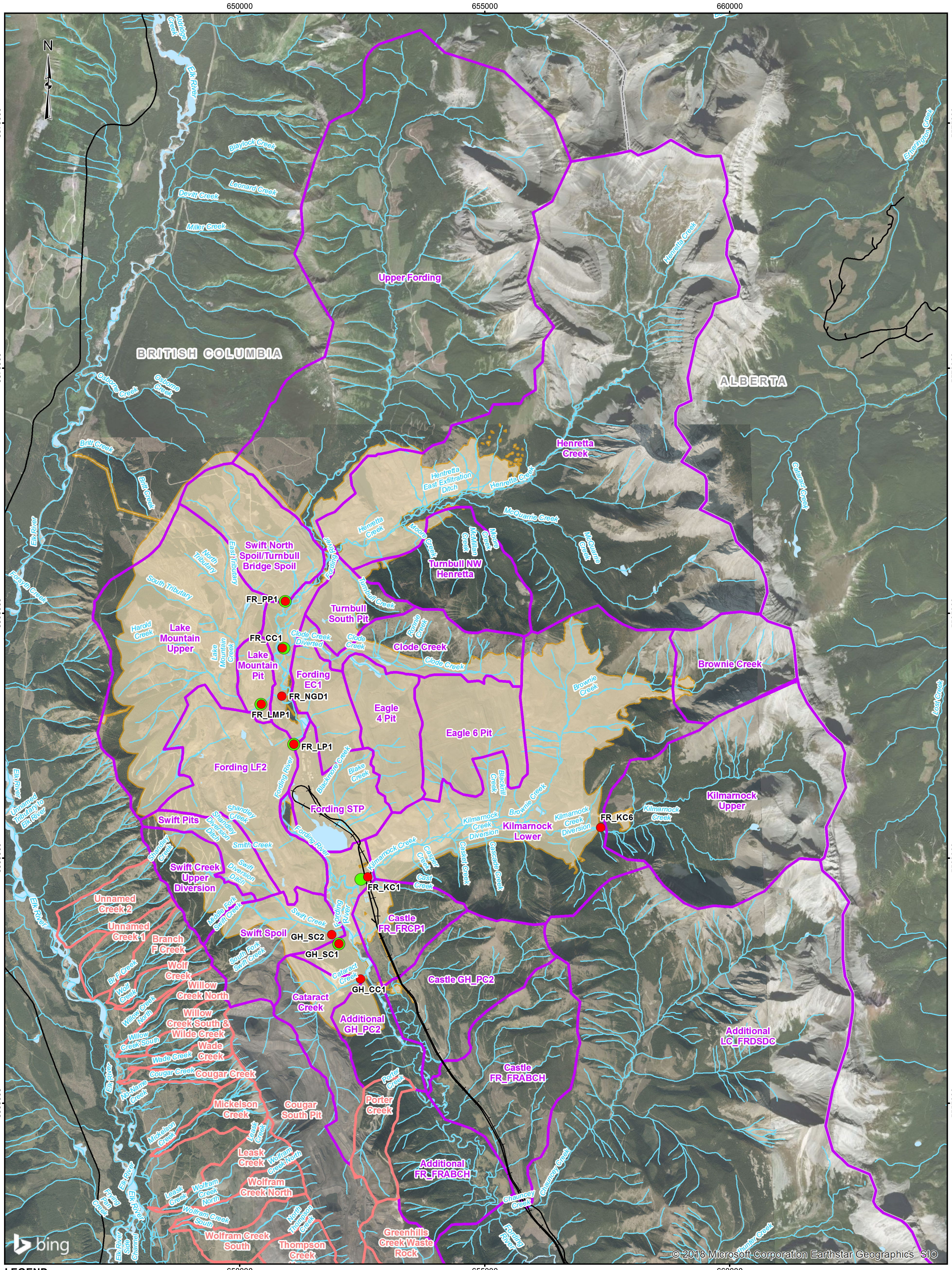


LEGEND

- APPROXIMATE INTAKE LOCATION
- SURFACE WATER LOCATION
- CITY/TOWN/COMMUNITY
- ROAD
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL BOUNDARY
- FORDING RIVER OPERATIONS C-3 PERMIT BOUNDARY
- FRO SUB-WATERSHED
- GHO SUB-WATERSHED
- BROWNIE CREEK — SUB-WATERSHED NAME

2 0 2

SCALE 1:75,000 KILOMETRES

REFERENCE

BASE DATA: CANVEC, GEOGRATIS 2017
IMAGERY: LIDAR IMAGERY PROVIDED BY TECK. ADDITIONAL IMAGERY BY MICROSOFT BING © 2017 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 11N

WATER QUALITY IMPLEMENTATION PLAN

TITLE **APPROXIMATE AWTF INTAKE LOCATIONS AND SELECTED MONITORING LOCATIONS AT FORDING RIVER OPERATIONS**

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	AS	26 Jun. 2018	SCALE AS SHOWN	REV. 0
GIS	PR/LM	02 Nov. 2018		
CHECK	AS	02 Nov. 2018	**FIGURE: 2-1**	
REVIEW	JPB	02 Nov. 2018		

2.1.1.1 Clode Creek

Watershed Conditions

The Clode Creek drainage area includes the completed, backfilled and flooded Eagle 4 pit, the active Eagle 6 pit (various phases), and historical and active waste rock spoils. Ephemeral tributaries convey runoff from undisturbed areas upstream of the Clode Creek Rock Drain to Clode Creek. The rock drain discharges into the Clode Settling Ponds, which also receive inflows through seeps at the toe of the waste rock spoil slopes to the east and southeast of the ponds. Water is withdrawn from the Clode Creek drainage for consumptive use (dust suppression) upstream of the rock drain. Pit dewatering from Eagle 6 is directed to both Clode Creek and Kilmarnock Creek. A flow monitoring station is located at the Clode Settling Ponds decant (E102481, FR_CC1). The contributing drainage area to FR_CC1 is approximately 11.9 square kilometres (km^2), and the catchment is predominantly disturbed (9.3 km^2).

Monitored Flows

Instantaneous flow measurements have been collected at FR_CC1 for over 20 years; the frequency of data collection has been weekly from April to June and monthly during other times of the year. The available dataset has few gaps (< 6% of months missing data), and measurement accuracy is good, as evaluated in the Flow Metadata Summary (KWL 2017a). Future data collected from this location are expected to be of better quality, due to the establishment of a stable rating curve and installation of a continuous monitoring stations in 2017 (KWL 2017b).

The calculated mean annual watershed yield (300 millimetres [mm]) is under-representative of the expected yield from its contributing drainage area. The discrepancy is likely due to:

- infiltration from the Clode Settling Ponds into the shallow surrounding gravels, which results in reduced surface discharge at the decant (see Section 2.1.2 for more detail)
- use of water from the Clode Creek watershed for dust suppression, and
- dewatering of parts of the Clode Creek watershed to Kilmarnock Creek.

Monitored flow information is available for consideration in the calculation of the proportion of water flowing at surface. However, it may be under-representative of direct runoff from the watershed, due to consumptive use and diversion (two activities that are independent of water flow path).

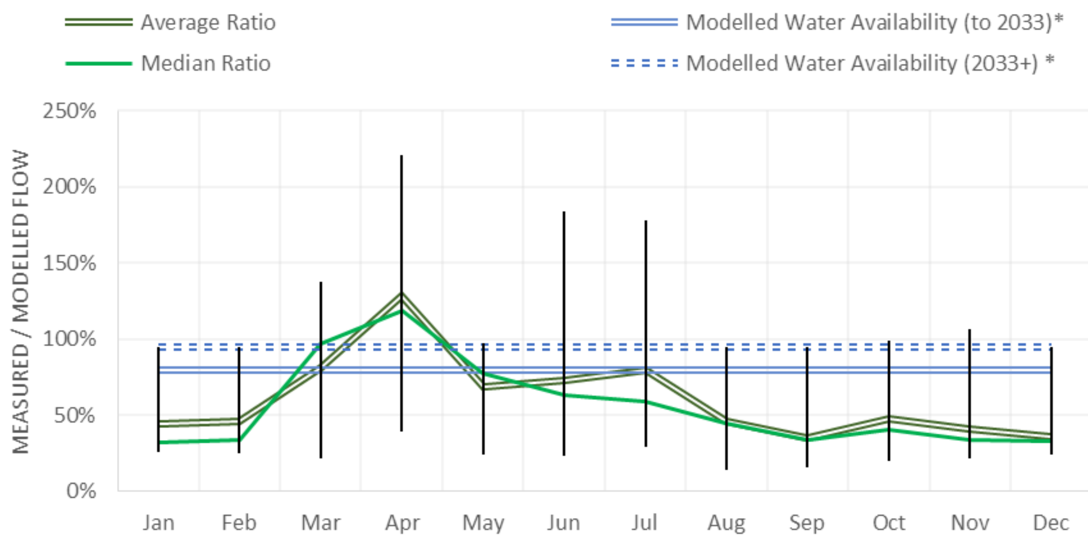
Modelled Flows

Modelled flows are generated by the 2017 RWQM using LCO Dry Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. Watershed-specific calibration adjustments were not implemented for Clode Creek in the 2017 RWQM, because model performance issues were attributed more to uncertainty in watershed conditions and historical water management practices than the analogues used. As outlined in Teck (2017), model performance in Clode Creek was rated as poor.

Comparison of Monitored and Modelled Flows

During low flow months (November to February), monitored flows were consistently lower than the modelled flows (85% of the time). On average, mean and median monthly monitored flows during this period were 42% and 33%, respectively, of the corresponding modelled flow (Figure 2-2). During high flows (between April and July), monitored flows were occasionally higher than modelled flows (i.e., 28% of the time); on average, however, mean monthly monitored flow was 86% of the corresponding modelled flow (Figure 2-2).

Figure 2-2 Clode Settling Ponds: Comparison of Mean Monthly Measured Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines were used to identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.1.1.2 Swift North Spoil Drainage and Swift Pit

Watershed Conditions

Drainage areas associated with the Swift North Spoil include the existing Turnbull West Bridge Spoil, and Lake Mountain Creek and its tributaries. Drainage areas associated with Swift Pit include several historical pits (e.g., Shandley, K-pit, I-pit, 3-pit, 2-pit). While each drainage area (i.e., Turnbull West Bridge Spoil, Lake Mountain Creek and Swift Pit) currently discharges to the Fording River at different locations, they collectively comprise the area of the Swift North Water Management System and are discussed together because of their linkages and interdependencies.

The drainage area associated with the Turnbull West Bridge Spoil is approximately 4.3 km^2, of which 1.2 km^2 are disturbed (2017 snapshot). There is no single point of discharge from the spoil to the Fording River; seepage from the spoil either discharges to an exfiltration ditch located along the toe of the spoil or directly discharges to the Fording River alluvial sediments (i.e., as shallow groundwater flow).

The drainage area associated with Lake Mountain Creek is 13.2 km^2, of which 2.5 km^2 are disturbed (2017 snapshot). Lake Mountain Creek flows through the Lake Mountain Settling Ponds (formerly the North Greenhills Diversion catch basin) before discharging to the Fording River. Future activities planned within this drainage include the construction of the Swift North Spoil, mining of Lake Mountain Pit and construction of water management infrastructure consisting of:

- non-contact water diversions that would discharge to Lake Mountain Settling Ponds
- mine-influenced water conveyance systems that would divert a portion of the watershed north to the Post Settling Ponds

Operational dewatering from Lake Mountain Pit would be directed to Lake Mountain Settling Ponds. Both the Post Settling Ponds and the Lake Mountain Settling Ponds are potential intake locations for the Fording River Operations Active Water Treatment Facility North (FRO AWTF-N).

The drainage area associated with Swift Pit is approximately 10 km^2, most of which is disturbed. Historical pits in this area are either flooded with water or backfilled. They do not typically decant to the receiving environment, as water from the pits is used as a make-up water source to the wash plant (via pumping to the South Tailings Pond). To facilitate mining of Swift Pit, the historical pits are planned to be dewatered to the Liverpool Settling Ponds, which discharge to the Fording River via a constructed channel at the north end of the inactive North Tailings Pond. While the current drainage area to Liverpool Settling Ponds is 2.6 km^2 (KWL 2017a), the Liverpool Settling Ponds are planned to serve as a settling pond for the entire Swift Pit drainage during operational dewatering and have been identified as a potential intake location for the FRO AWTF-N.

Monitored Flows

Limited flow monitoring data are available in the drainages of Swift North Spoil and Swift Pit. Instantaneous flow monitoring data were collected at the North Greenhills Diversion catch basin (FR_NGD1), which was discontinued and replaced with instantaneous flow monitoring at the Lake Mountain Settling Ponds decant (E306924; FR_LMP1) in 2016. While the location of FR_NGD1 was downstream of FR_LMP1, the flow regime is expected to be similar between the two monitoring points. Instantaneous flow monitoring was also initiated at the Liverpool Settling Ponds decant (FR_LP1) in 2016. Both monitoring locations are considered stable and suitable to produce data of acceptable quality (KWL 2017a). Flow monitoring will also be established at the Post Settling Ponds decant (FR_PP1) once construction is complete. The data currently available from these stations are not sufficient to support an evaluation of the proportion of total watershed yield that may be flowing at surface.

Modelled Flows

Modelled flows are generated by the 2017 RWQM using LCO Dry Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. Watershed-specific calibration factors were not applied for the Swift North Spoil and Swift Pit drainages in the 2017 RWQM as historical data to support specific adjustments are limited. The Swift North Water Management System includes new infrastructure that will be constructed over time.

Comparison of Monitored and Modelled Flows

A comparison of monitored and modelled flows was not completed for the Swift North Spoil and Swift Pit drainages due to limited data availability.

2.1.2 Review of Groundwater Data

Regional Data

Clode Settling Ponds and the lower Turnbull Bridge Spoil are in the Fording River floodplain. The conceptual groundwater model for the Fording River floodplain is that there is seepage from tributaries/ponds to the underlying valley bottom aquifer, due to the presence of permeable sediments within the floodplain and higher elevation of the surface water features compared to groundwater for all or part of the year. As noted in Section 1.1.1, groundwater flow in the valley bottom aquifer is directed to and eventually discharges into the Fording River, which is a regional topographic low that tends to gain flow with distance downstream (i.e., is a gaining system). There are likely small, local areas where groundwater flow is directed parallel to the river, which is referred to as an underflow-dominated section. However, on a regional basis, the direction of shallow groundwater flow is towards and into the Fording River.

The northern portions of the Swift North Spoil Drainage and Swift Pit discharge to the Fording River via the Post Settling Ponds (being constructed in 2018); the southern portions of the Swift North Spoil and Lake Mountain Pit discharge to the Lake Mountain Settling Ponds, and Swift Pit discharges via the Liverpool Settling Ponds and Smith Ponds. All four ponds are situated on the valley flanks, outside of the Fording River floodplain. The conceptual model for the valley flanks is that the majority of the overburden is thin and discontinuous; the groundwater system in the shallow bedrock is local, such that the majority of the shallow bedrock groundwater discharges to the nearest low, which is occupied by a stream/pond. In other words, water draining from the Swift North Spoil, Swift Pit, Lake Mountain Pit and South Spoil areas should largely report to the aforementioned ponds with minimal groundwater bypass or infiltration from the ponds into the local groundwater system.

Site-Specific Data

Site-specific groundwater data to verify the conceptual regional understanding of the groundwater system for the Fording River North tributaries have not yet been collected, as noted by SNC Lavalin (2018).

Geotechnical investigations at the Lake Mountain Post Ponds and North Tributary Rock Drains generally noted dry conditions at the end of test pit excavations as carried out by Amec Foster Wheeler (2018). Limited site-specific hydrogeological data, such as the hydraulic conductivity of unconsolidated sediments, are available for Swift Pit at the Liverpool Settling Ponds (formerly the North Greenhills Catch Basin Primary and Secondary Ponds) based on geotechnical investigations and numerical seepage modelling conducted by Amec Foster Wheeler (2017).

Data Gaps

As local groundwater conditions remain largely unquantified (SNC 2017), the limited site-specific groundwater data for the Clode and Lake Mountain drainages are presently not sufficient to characterize groundwater conditions and quantify potential bypass at the planned intake locations. Site-specific groundwater investigations and other follow-up activities that are planned or underway in this area are described in Section 3.

2.1.3 Discussion of Water Availability

The water availability assumption for the Clode Creek intake location is 80%, increasing to 95% in 2033, as outlined in Table 1-1. For Clode Creek, the comparison of measured to modelled flow information indicates that, if the intake is placed near the existing flow monitoring point in Clode Creek, additional water would likely need to be sourced from subsurface to achieve the water availability targets required to attain compliance. The ratio of measured to monitored flow averaged 42% and 86% in lower and higher flow months, respectively, as noted in Section 2.1.1.1. The ratio was less than the assumed water availability in 75% of the months with available data. Although limited, available groundwater information similarly supports this conclusion. The Clode Settling Ponds are in the floodplain of the Fording River, in an area of shallow groundwater recharge. Based on this information, design considerations for the intake will include evaluating other siting options.

Water availability for the Swift North Spoil drainages and Swift Pit is assumed to be 80%, increasing to 95% in 2033. For the Swift North Spoil drainages and Swift Pit, measured flow data are limited, and a comparison against modelled flows was not possible. However, the placement of the intakes on the valley flanks outside of the Fording River floodplain supports higher water availability assumptions compared to valley-bottom locations in the Fording River floodplain.

Follow-up activities are planned for the Fording River North tributaries targeted for treatment, as outlined in Section 3, to better understand water flow paths, groundwater conditions and water availability.

2.2 Fording River South

A map of Fording River South watersheds and potential intake locations is presented in Figure 2-1.

2.2.1 Comparison of Modelled and Monitored Flows

2.2.1.1 Swift Creek

Watershed Conditions

The Swift Creek drainage area includes the Swift South Spoil and areas above the spoil, which discharge through the Swift Creek rock drain to the Swift Creek Settling Ponds. The Swift Creek drainage area also includes the Swift Creek Diversion, which conveys non-contact water from the upper watershed via a pipeline. Flow monitoring stations are located at the Swift Creek Settling Ponds decant (E221329, GH_SC1) and the Swift Creek Settling Pond Bypass (E105061, GH_SC2), both of which are located downstream of the Swift Creek rock drain. The Swift Creek Diversion typically discharges to lower Swift Creek below the settling ponds and flow monitoring stations, although water is routed from the diversion through the settling ponds on occasion. The contributing drainage area is approximately 3.8 km^2, and the catchment is predominantly disturbed (2.3 km^2).

The Swift South Water Management System, as described in Amec Foster Wheeler (2018), includes several changes to the Swift Creek watershed, including extensions to the Swift Creek rock drain, alterations to the Swift Creek Diversion, and commissioning of the Swift Creek Mine Influenced Water (MIW) Ponds. The MIW Ponds will receive flows from both Swift Creek and Cataract Creek.

Monitored Flows

Instantaneous flow measurements have been collected from Swift Creek for over 20 years, with weekly data from April to June and monthly monitoring at other times of the year. The available dataset has winter data gaps at GH_SC1 and summer data gaps at GH_SC2. Flow data from both stations were combined into one dataset for this analysis. Data quality at GH_SC1 is better than that at GH_SC2; they are rated as Grade C and Grade E[1], respectively. Improvements to flow monitoring in Swift Creek are planned, including a switch to a continuous monitoring station, once construction of the Swift South Water Management System is complete (KWL 2017a, KWL 2017b).

The calculated mean annual watershed yield (670 mm) for Swift Creek is over-representative of the expected yield from its contributing drainage area, despite potential infiltration from the Swift Creek Settling Ponds. The discrepancy is likely due to difficulty in tracking historical changes in the areas that discharge to the monitoring station, including:

- occasional diversion of flows from the upper Swift Creek diversion to the Swift Creek Settling Ponds
- unquantified seepage flows from the historical Bens Pit (within the Swift Pit sub-watershed) to the Swift Creek rock drain

Another factor is the potential overestimation of flows when combining measured flow datasets at GH_SC1 and GH_SC2.

Modelled Flows

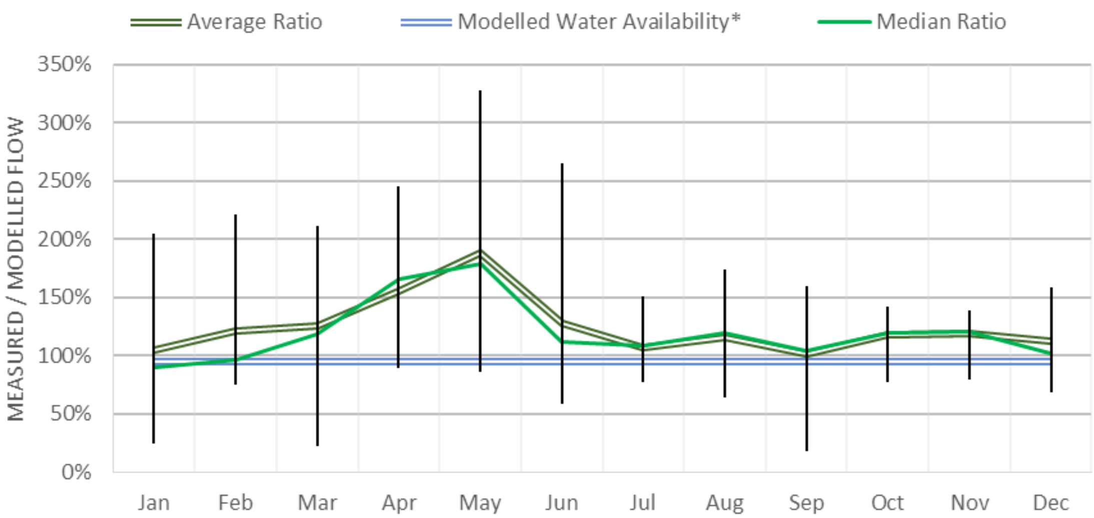
Modelled flows are generated by the 2017 RWQM using LCO Dry Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. Watershed-specific calibration adjustments were not implemented for Swift Creek in the 2017 RWQM. As outlined in Teck (2017), model performance in Swift Creek was rated as poor.

Comparison of Monitored and Modelled Flows

During low flow months, the mean monthly monitored flow was, on average, 115% of the corresponding modelled flow. For higher flow months (between April and July), the mean monthly monitored flow was, on average, 145% of the corresponding modelled flows (Figure 2-3); the median ratio under higher flow conditions was 123% of the corresponding modelled flows. Monitored flows were greater than modelled flows in approximately 70% of the months with available data.

[1] As per the data grading system described in the Manual of British Columbia Hydrometric Standards (BC MOE 2009).

Figure 2-3 Swift Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines were used to identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.2.1.2 Cataract Creek

Watershed Conditions

The current drainage area associated with Cataract Creek is approximately 3.5 km^2 and is almost entirely disturbed. It includes waste rock from both FRO and GHO. Due to the predominantly disturbed contributing drainage area, the Cataract Creek hydrograph is highly attenuated with lower freshet peaks and elevated winter base flows in comparison to predominantly natural watersheds. The historical Cougar North Pit area at GHO was dewatered to Cataract Creek up to 2008, effectively increasing the contributing drainage area to Cataract Creek by about 3 km^2. A flow monitoring station is located at the Cataract Creek Settling Pond decant (200384, GH_CC1), upstream of its discharge into the Fording River. Flows from Cataract Creek are planned to be diverted to Swift Creek as part of the Swift South Water Management System (currently scheduled for fall 2018).

Monitored Flows

Instantaneous flow measurements have been collected from Cataract Creek at GH_CC1 since 1993. Monitoring responsibility switched operations from GHO to FRO in 2016, and flows are currently measured in an open channel section, with weekly measurements from March to July and monthly measurements through the remainder of the year. Recently, minor hydraulic issues were noted at the flow monitoring station due to calcite accumulation in the open channel (KWL 2017b). Data completeness is good with only 6% of months without a flow measurement. However, data collected during 2014 and 2015 were found to have unusual patterns that could not be attributed to climate or site water management. In consideration of the historical Cougar North Pit dewatering through 2008, and potential data issues in 2014 and 2015, a separate analysis was completed excluding these three years (Figure 2-4).

The calculated mean annual watershed yield for Cataract Creek is 530 mm. While generally consistent with the contributing watershed area, this estimate may be slightly under-representative due to some infiltration from the settling pond upstream of the flow monitoring station.

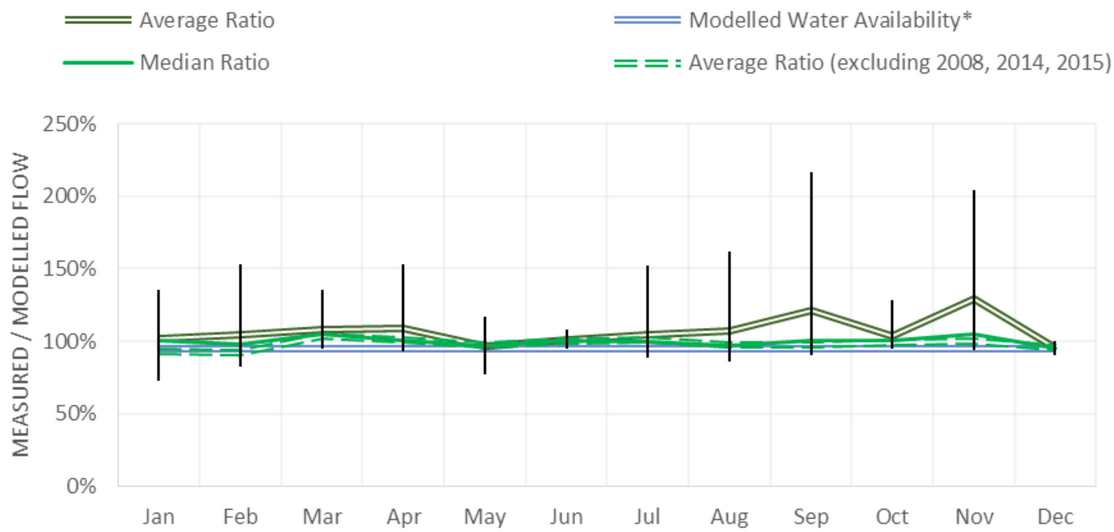
Modelled Flows

Modelled flows are generated by the 2017 RWQM using LCO Dry Creek as the analogue watershed for undisturbed areas (a small portion of the sub-watershed) and Cataract Creek as the analogue watershed for mine areas. Cataract Creek was the analogue watershed for all mine areas in the 2017 RWQM.

Comparison of Monitored and Modelled Flows

Monitored and modelled flows at Cataract Creek are often almost identical as it is the input analogue watershed in the model. During low flow months, the mean monthly monitored flow was, on average, 112% of the corresponding modelled flow. For the higher flow months (between April and July), the mean monthly monitored flow was, on average, 111% of the corresponding modelled flows (Figure 2-4). Monitored flows were greater than modelled flows in approximately 54% of the months with available data. Overall, modelled flows in Cataract Creek provide a good estimate of the measured surface flows as the median ratio of monitored to modelled flows is 100% for both low and high flow periods when periods of questionable monitored data are excluded from the analysis.

Figure 2-4 Cataract Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.2.1.3 Kilmarnock Creek

Watershed Conditions

The Kilmarnock Creek drainage area consists of three sub-watersheds: Kilmarnock Upper (undisturbed upper catchment), Kilmarnock Lower (mix of waste rock and undisturbed areas), and Brownie Creek (predominantly waste rock spoil). It has a total area of approximately 40.3 km^2, of which 9.9 km^2 is disturbed. The downstream end of Kilmarnock Creek is buried by a cross-valley waste rock spoil, which acts a rock drain.

Since about 1989, the flow path of Kilmarnock Lower has been routed through the rock drain, which is currently about 1.9 km long. Several spoil failures into the valley bottom occurred prior to completion of the cross-valley fill. Completion of the cross-valley fill included placement of coarse rock in channels that were excavated through the failed material. The failure events likely altered the internal structure of the rock drain, such that it presents greater flow attenuation than would otherwise be expected. In general, the effects of a well-constructed rock drain are to reduce the flow peaks and flatten the hydrograph on an hourly to daily scale, with limited effects on monthly scale (Piteau 1997). The Kilmarnock Creek rock drain appears to have broader effects on the hydrograph (i.e., weekly to monthly).

Monitored Flows

Environment and Climate Change Canada (ECCC) operated a seasonal hydrometric station near the mouth of Kilmarnock Creek (Station 08NK029) from 1984, switching to year-round flow monitoring in 1991. The station was discontinued in 1995 following a flood. Teck installed a gauge at Kilmarnock Lower

(FR_KC1), approximately 100 m downstream of the ECCC gauge location, and began seasonal (May 1 to August 31) spot flow monitoring in 1997. Continuous seasonal monitoring began in 2008, and year-round continuous monitoring began a few years later in 2013. Teck also operated a seasonal gauging station in upper Kilmarnock Creek (FR_KC4), which has a drainage area of approximately 16 km^2. Periodic spot flow measurements were taken year-round at both Teck stations. The upper station was discontinued after the 2013 flood and replaced with a station upstream of the Brownie Creek confluence (FR_KC6).

The calculated mean annual watershed yield at FR_KC1 is 560 mm. This estimate is in line with regional estimates. Data completeness is considered fair, as there are sufficient data on peak flows but fewer years with winter flow data.

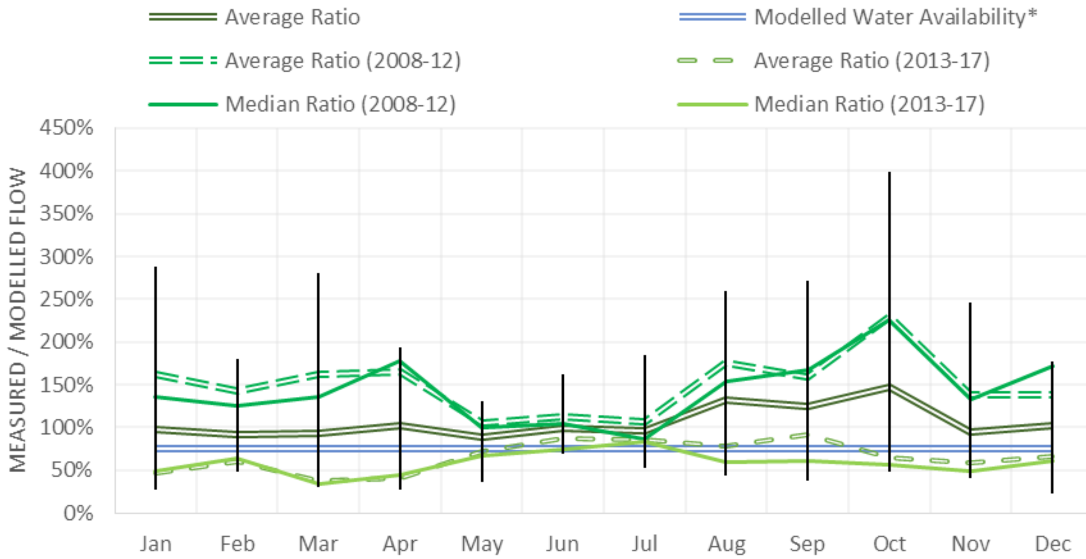
Modelled Flows

Modelled flows are generated by the 2017 RWQM using Line Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. The Line Creek analogue hydrograph was shifted (delayed) by 7 days to better match freshet timing in Kilmarnock Creek. Watershed-specific calibration factors were applied on the shifted Line Creek natural analogue to adjust flow magnitude, and a mine analogue yield adjustment factor was applied on the Cataract Creek mine analogue hydrograph. As outlined in Teck (2017), model performance in Kilmarnock Creek was rated as good.

Comparison of Monitored and Modelled Flows

A comparison of the monitored and modelled flows was completed for the 10 year period extending from 2008 through 2017, as well as two 5-year subsets (i.e., 2008 to 2012 and 2013 to 2017). The subsets were chosen to reflect distinct differences in the monitored dataset before and after 2013 (the year in which continuous monitoring began). In the winter months, the mean monthly monitored flow was, on average, 145% of the corresponding modelled flow from 2008 to 2012 (i.e., consistently higher than modelled flows), but only 58% of the corresponding modelled flow from 2013 to 2017 (i.e., consistently lower than modelled flows). For the higher flow months (between April and July), the mean monthly monitored flow was, on average, 122% and 71% of the corresponding modelled flows over the 2008 to 2012 and 2013 to 2017 periods, respectively, with median ratios of 107% and 71%, respectively (Figure 2-5). Overall, monitored flows were greater than modelled flows in approximately 44% of the months with available data. Differences in monitored flows before and after 2013 may be related to changes to the methods used to collect the flow data.

Figure 2-5 Kilmarnock Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines were used to identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.2.2 Review of Groundwater Data

Regional Data

The conceptual groundwater model for the southern portion of FRO is similar to that described above for the northern portion. Within the Fording River floodplain, there is seepage from tributaries/ponds to the underlying valley bottom aquifer, due to the presence of permeable sediments within the floodplain and higher elevation of the surface water features compared to groundwater for all or part of the year. Groundwater flow in the valley bottom aquifer is directed to and eventually discharges into the Fording River, which is a regional topographic low that tends to gain water flow with distance downstream (i.e., is a gaining system). There are likely small, local areas where groundwater flow is directed parallel to the river. However, on a regional basis, the direction of shallow groundwater flow is towards and into the Fording River.

Site-Specific Data

Site-specific investigations have been completed in the Swift-Cataract area. Bedrock is relatively shallow in the Swift Creek area, and water draining from spoils in the watershed may flow along the bedrock interface through the shallow surficial deposits, following local topography and drainage divides, as identified in SNC (2018). The surficial material is classified as gravelly silt with cobbles and hydraulic conductivity values on the order of 10^{-5} metres per second (m/s). The geology of the area of Cataract Creek is similar to that of Swift Creek (SNC 2018).

In Swift Creek and Cataract Creek, Amec Foster Wheeler (2017) completed a seepage study that included a test pitting program of the Swift-Cataract water management system area, including 43 test pits and 8 boreholes. Hydraulic conductivity values were estimated for unconsolidated sediments and bedrock, with permeability values estimated through laboratory tests. A numerical model was developed to estimate seepage rates from various components of the Swift-Cataract water management system, including ponds and diversion channels. Sensitivity analyses were completed to evaluate the effect of changes in water table elevations and overburden and bedrock hydraulic conductivity values. The efficiency of the water management system in collecting and retaining total watershed yield from Swift Creek and Cataract Creek was estimated for mean annual conditions and for low flow conditions (January). The annual system efficiency was estimated at a probable (mean) value of 99.9%, with a range from 77.3% to 99.9%. The January system efficiency was estimated at 99.8% (mean), with a range from 48.5% to 99.9%.

In Kilmarnock Creek, limited site-specific groundwater data are presently available. Groundwater flux rates were previously estimated to be in the order of 1,000 cubic metres per day (m^3/day) based on limited field data (Golder 2014). SNC (2018a) notes that the confluence of Kilmarnock Creek and Fording River is an alluvial fan that consists of fine to coarse grained sediments; groundwater recharge to the alluvial fan from the creek is known to occur. Water flow through the alluvial fan tends to be parallel to the Fording River before discharging into the river farther downstream. The material underlining Kilmarnock Creek is sand and gravel extending to bedrock, with hydraulic conductivities are on the order of 10^{-6} to 10^{-5} m/s (SNC 2018a). The depth to bedrock in the centre of the Fording River valley downstream of the Kilmarnock Creek alluvial fan remains unknown although bedrock depth is inferred to be greater than 30 m based on the total depth of existing groundwater monitoring wells (SNC 2017).

Data Gaps

There are no data gaps for the Swift-Cataract drainages as site-specific data and local-scale modelling have been collected / conducted. For Kilmarnock Creek, the limited site-specific data are presently not sufficient to adequately characterize groundwater conditions and quantify potential bypass at the planned intake location. Site-specific groundwater investigations and other follow-up activities planned for Kilmarnock Creek are described in Section 3.

2.2.3 Discussion of Water Availability

The water availability value assumed for the Swift Creek intake location (which will capture water from both Swift and Cataract creeks) is 95%, as outlined in Table 1-1. The ratio of monitored to modelled flows are often greater than 100%, suggesting that collecting water at surface should meet the water availability assumption used in the RWQM. Groundwater investigations undertaken by Amec Foster Wheeler (2017) support this assumption.

For Kilmarnock Creek, water availability at the intake location is assumed to be 75%, increasing to 95% in 2033 (discussed in Section 1.1.3). The results of the analysis suggest that the proportion of total watershed yield available as surface flow could be lower than the water availability targets required to attain compliance at certain times of the year (based on the comparison of modelled to monitored flows), depending on where the intake is positioned relative to the current flow monitoring location and the alluvial fan underlying the lower portion of Kilmarnock Creek. Further work is planned in Kilmarnock Creek to better understand water flow paths and to appropriately position the intake to maximize water capture, as outlined in Section 3.

2.3 Greenhills Operations

A map of Greenhill Operations watersheds and potential intake locations is presented in Figure 2-6.

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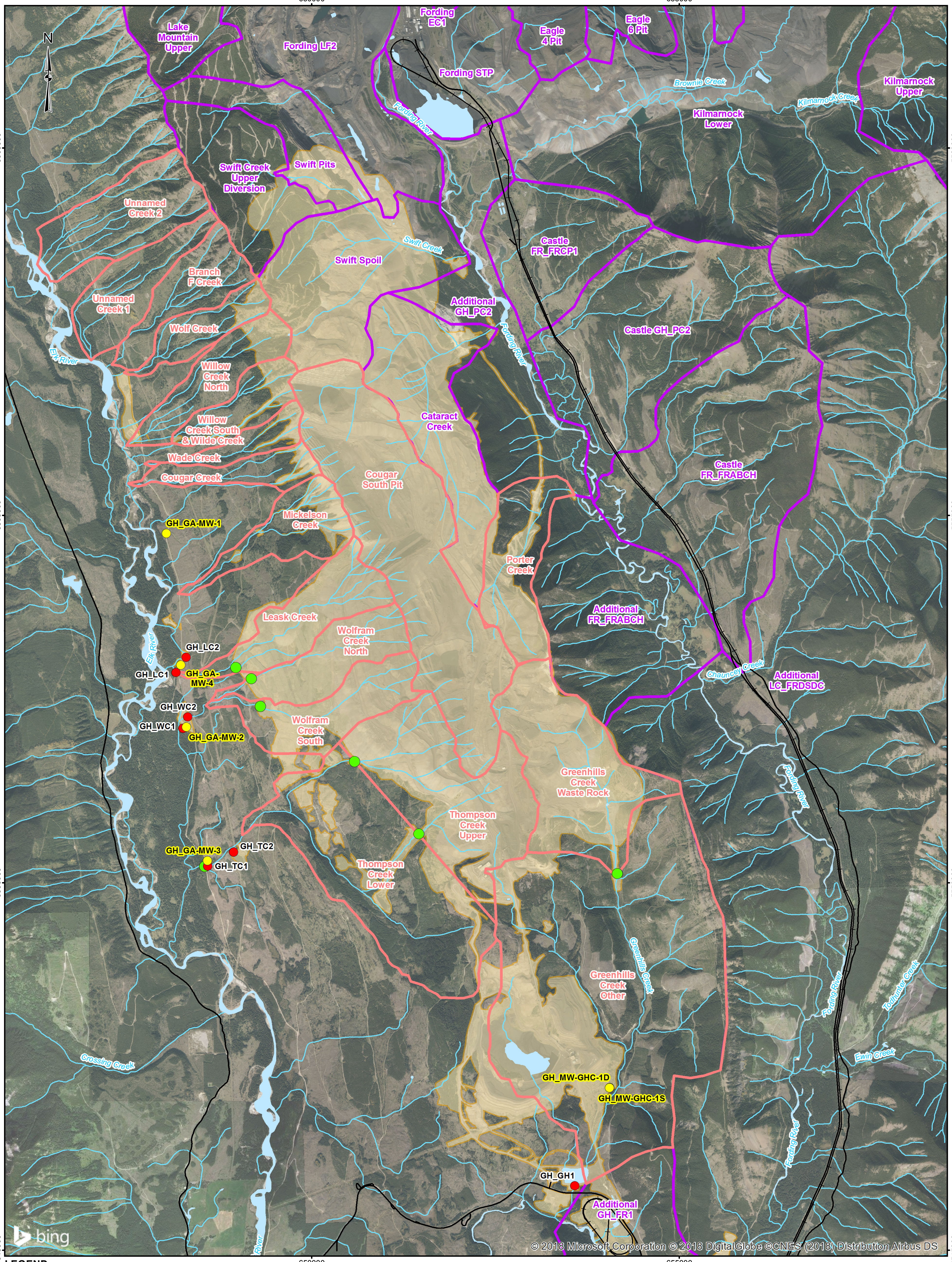


LEGEND

- APPROXIMATE INTAKE LOCATION
- GROUNDWATER LOCATION
- SURFACE WATER LOCATION
- CITY/TOWN/COMMUNITY
- ROAD
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL
- GREENHILLS OPERATIONS C-137 PERMIT BOUNDARY
- GHO SUB-WATERSHED
- FRO SUB-WATERSHED
- WADE CREEK — SUB-WATERSHED NAME

2 0 2

SCALE 1:50,000 KILOMETRES

REFERENCE

BASE DATA: CANVEC, GEOGRATIS 2017
IMAGERY: LIDAR IMAGERY PROVIDED BY TECK. ADDITIONAL IMAGERY BY MICROSOFT BING © 2017 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 11N

WATER QUALITY IMPLEMENTATION PLAN

TITLE **APPROXIMATE AWTF INTAKE LOCATIONS AND SELECTED MONITORING LOCATIONS AT GREENHILLS OPERATIONS**

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	AS	26 Jun. 2018	SCALE AS SHOWN	REV. 0
GIS	PR/LM	02 Nov. 2018		
CHECK	AS	02 Nov. 2018	**FIGURE: 2-6**	
REVIEW	JPB	02 Nov. 2018		

2.3.1 Comparison of Modelled and Monitored Flows

2.3.1.1 Leask Creek

Watershed Conditions

The Leask Creek drainage includes a waste rock spoil (i.e., the West Spoil) in its upper watershed; the lower watershed is undisturbed. The total drainage area is approximately 1.7 km^2, of which 1.3 km^2 is disturbed by the West Spoil. Surface flows typically infiltrate to ground in the lower section of Leask Creek, including through the settling pond located in the lower reach. The surface connection between Leask Creek and the Elk River is intermittent.

Pit dewatering from the Cougar South pits has historically been discharged to Leask Creek, as well as Wolfram Creek. A pipeline between the Wolfram and Leask settling ponds allows transfer and balance of spring runoff and pumped water to increase the overall settling capacity provided by the two ponds. Future activities planned in the drainage include continued waste rock placement in the West Spoil and potential dewatering / decant from the Cougar South Pit.

Monitored Flows

Spot flow measurements were collected at Leask Creek Settling Pond Decant (E257796, GH_LC1) from 1993 to 2004 and at the Leask Creek Settling Pond Inflow (GH_LC2) from 2005 onwards. Spot flow measurements were typically conducted on a weekly basis from April to July and monthly otherwise with limited winter flows before 2005. The settling pond inflow station is considered more representative of watershed yield due to infiltration from the pond. Flows at GH_LC2 were used in this analysis.

The calculated mean annual watershed yield is 370 mm. There is low confidence in this estimate, due to the influence of infiltration and pit pumping. Data completeness is considered fair, as there are data for freshet flows but few years have non-zero winter flow data (i.e., only 2015 and 2016 have non-zero flow measurements consistently between November and February).

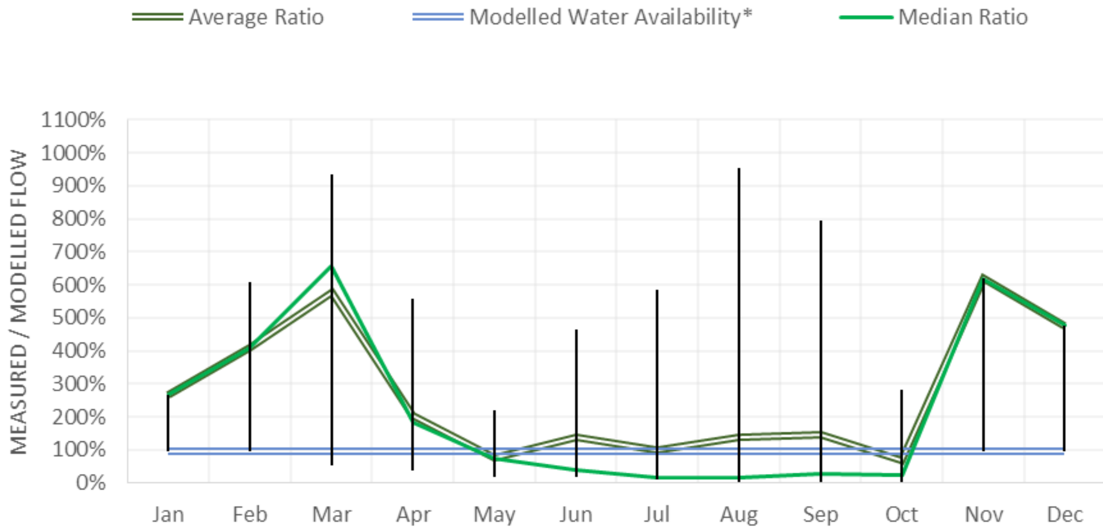
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the LCO Dry Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. As outlined in Teck (2017), the natural analogue was shifted back by three weeks to account for earlier freshet in Leask Creek and a baseflow adjustment factor of 2.5 litres per second per square kilometre ($L/s/km^2$) was applied. A yield adjustment factor was also applied to the Cataract Creek mine analogue, although a watershed-specific calibration was not carried out. Overall model performance in Leask Creek was rated as poor.

Comparison of Monitored and Modelled Flows

Based on the available data, monitored surface flows tend to be higher than modelled estimates of total watershed yield (Figure 2-7). The difference is more pronounced in winter months than at other times of the year (i.e., average ratios of 440% and 129%, respectively, and median ratios of 477% and 70%, respectively).

Figure 2-7 Leask Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.3.1.2 Wolfram Creek

Watershed Conditions

The Wolfram Creek drainage includes a settling pond and the tributaries of Wolfram North and Wolfram South. The upper watershed contains a waste rock spoil and the lower watershed is undisturbed. Wolfram Creek discharges into the Wolfram Creek Settling Pond and subsequently into the Elk River. The direct connection between Wolfram Creek and the Elk River is intermittent and active only for short durations during periods of high flow. Flow monitoring stations are located at the Wolfram Creek Settling Pond Decant (E257796, GH_WC1) and the Wolfram Creek Settling Pond Inflow (GH_WC2). The contributing drainage area to GH_WC2 is approximately 4.8 km^2, with a disturbed catchment area of approximately 3.9 km^2. Wolfram Creek has historically received operational pumping (pit dewatering) from Cougar South Pit (Phase 3). A pipeline between the Wolfram and Leask settling ponds allows transfer and balance of spring runoff and pumped water to increase the overall settling capacity. Future activities planned in the drainage include the expansion of the West Spoil.

Monitored Flows

Instantaneous flow measurements have been collected at GH_WC1 from 1993 to 2004 and at GH_WC2 from 2005 onwards. The frequency of data collection has been weekly from April to June and monthly during other times of the year. The settling pond inflow station is considered more representative of watershed yield due to infiltration from the pond. Flows at GH_WC2 were used for this analysis.

The calculated mean annual watershed yield is 310 mm. There is low confidence in this estimate, based on the same rationale as outlined above for Leask Creek. Data completeness is considered fair, as there are sufficient data on freshet flows but few years with winter flow data (i.e., only 2008, 2009 and 2015 to 2017 had non-zero flow measurements in November to February).

Modelled Flows

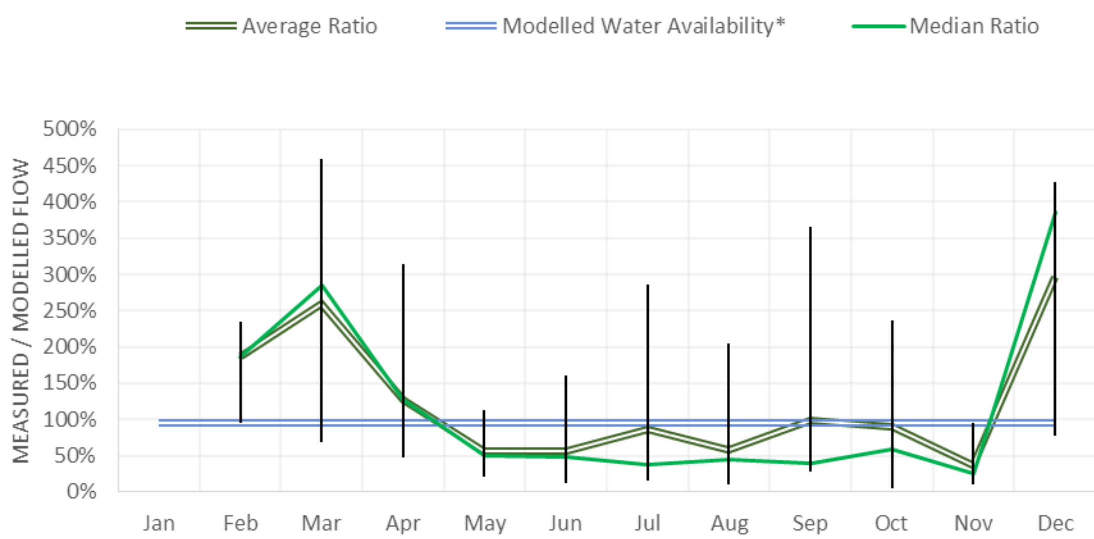
Modelled flows are generated by the 2017 RWQM using the LCO Dry Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. The natural analogue was shifted back by three weeks to account for earlier freshet in Wolfram Creek and a baseflow adjustment factor of 2.5 L/s/km^2 was applied. A yield adjustment factor was also applied to the Cataract Creek mine analogue. A watershed-specific calibration was not carried out. Model performance in Wolfram Creek was rated as poor, as outlined in Teck (2017).

Comparison of Monitored and Modelled Flows

For low flow months, monitored flows were, on average, higher than the modelled total watershed yield, with the mean monthly monitored flow being 170% of the corresponding modelled flow (Figure 2-8). This average value is skewed by a couple of high values, and the median ratio, by comparison, is 108%.

During the higher flow months, the average and median monthly monitored flow were 80% and 56% of the corresponding modelled flow, respectively. Monitored flows were greater than modelled flows in approximately 35% of the months with available data.

Figure 2-8 Wolfram Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.3.1.3 Thompson Creek

Watershed Conditions

The Thompson Creek drainage includes a settling pond, a disturbed upper watershed containing a waste rock spoil and a largely undisturbed lower watershed. Thompson Creek discharges into the Thompson Creek Settling Pond and subsequently into the Elk River. Flow monitoring stations are located at the Thompson Creek at LRP Road or Bypass (E102714, GH_TC1) and the Thompson Creek Settling Pond Decant (E207436, GH_TC2). The contributing drainage area to GH_TC2 is approximately 8.8 km^2, with a disturbed catchment area of approximately 3.0 km^2. Future activities planned in the drainage include the expansion of the waste rock spoil in upper Thompson Creek.

Monitored Flows

Instantaneous flow measurements have been collected at GH_TC1 from 2006 onwards and at GH_TC2 from 1994 onwards. The frequency of data collection has been weekly from April to June and monthly during other times of the year. The station at LRP Road or Bypass (GH_TC1) is considered more representative of watershed yield due to infiltration from the pond. Flows at GH_TC1 were used for this analysis.

The calculated mean annual watershed yield of 260 mm is low and considered to be under-representative, due to infiltration in the settling pond. Data completeness is considered good, with gaps in only 17% of months.

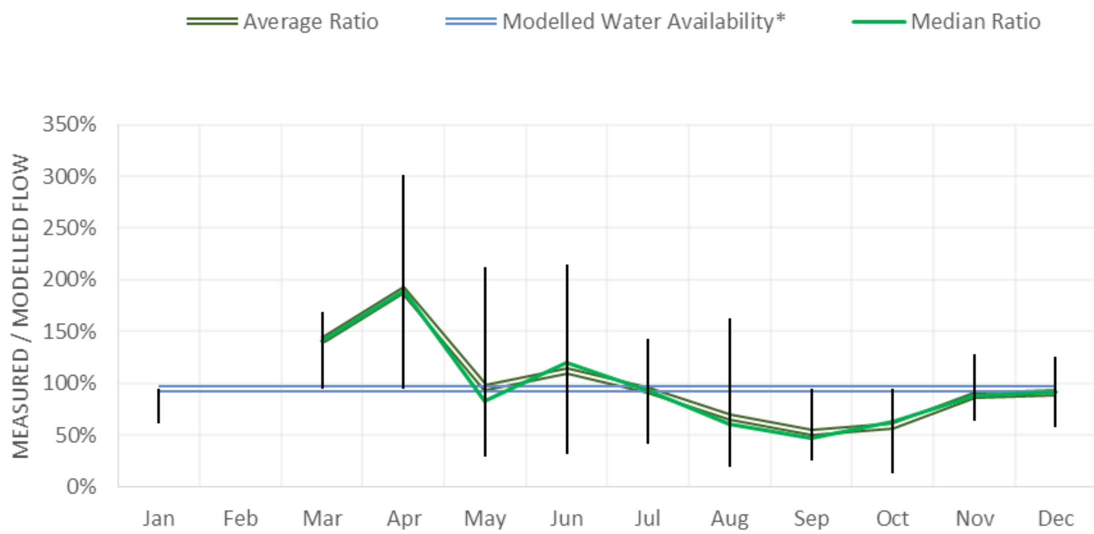
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the LCO Dry Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. A mine analogue adjustment factor was applied to the Cataract Creek mine analogue. Model performance in Thompson Creek was rated as acceptable, as outlined in Teck (2017).

Comparison of Monitored and Modelled Flows

Based on the available data, monitored flows in low flow periods were lower than modelled total watershed yield, with the mean and median monthly monitored flows being 87% and 72% of the corresponding modelled flow (Figure 2-9). During the higher flow months, the average and median monthly monitored flow were 123% and 111% of the corresponding modelled flow, respectively. Monitored flows were greater than modelled flows in approximately 37% of the months with available data.

Figure 2-9 Thompson Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.3.1.4 Greenhills Creek

Watershed Conditions

The Greenhills Creek drainage area contains a waste rock spoil in its upper watershed, and various mine features in the predominantly undisturbed lower watershed, including coarse coal reject spoils, a tailings facility and a coal wash plant. Greenhills Creek discharges into the Greenhills Creek Settling Pond and subsequently into the Fording River. A flow monitoring station is located at the Greenhills Creek Settling Pond Decant (E102709, GH_GH1). The contributing drainage area to GH_GH1 is approximately 15.2 km^2, with a disturbed catchment area of approximately 4.7 km^2. Future activities planned in the drainage include the continued operation of the tailings facility and wash plant and expansions to the coarse coal reject spoils.

Monitored Flows

Instantaneous flow measurements have been collected at GH_GH1 from 1993 onwards. The frequency of data collection has been weekly from April to June and monthly during other times of the year.

The calculated mean annual watershed yield of 320 mm is likely under-representative due to infiltration upstream of the flow monitoring station. Data completeness is considered good, with gaps in only 16% of months.

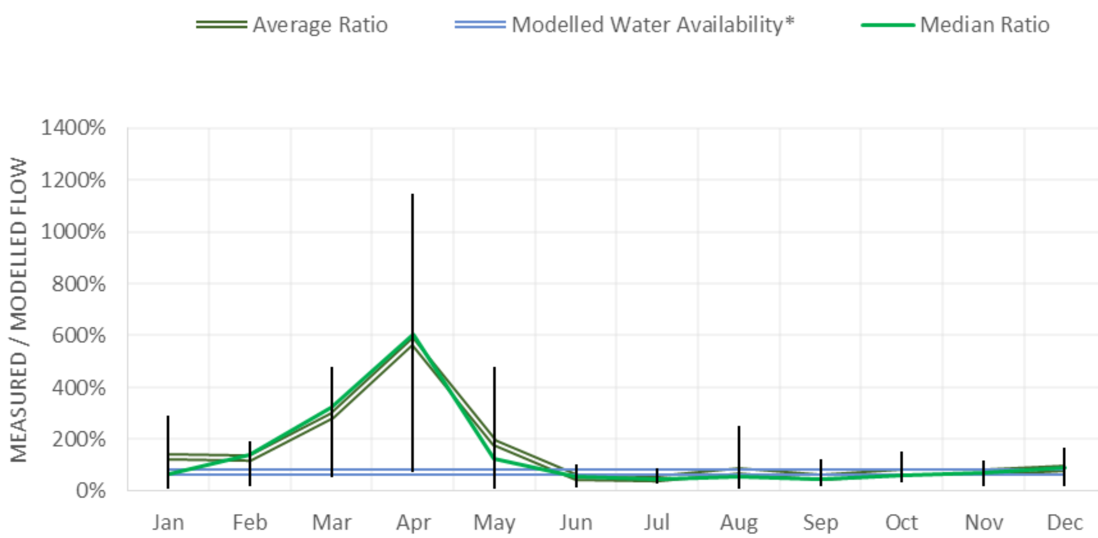
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the LCO Dry Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. A mine analogue adjustment factor was applied on the Cataract Creek mine analogue and a baseflow adjustment factor of 2.5 L/s/km^2 was applied to the LCO Dry Creek analogue hydrograph. As outlined in Teck (2017), model performance in Greenhills Creek was rated as poor.

Comparison of Monitored and Modelled Flows

During low flow months, the mean ratio of monitored to modelled flow was 104%, with the median monthly monitored flow being 96% of the corresponding modelled flow (Figure 2-10). During the higher flow months, the average and median ratios of monthly monitored to modelled flow were 223% and 73%, respectively. Monitored flows were greater than modelled flows in approximately 44% of the months with available data.

Figure 2-10 Greenhills Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.3.2 Review of Groundwater Data

Regional Data

Leask, Wolfram, and Thompson creeks are situated on the Elk River valley flanks and generally flow to the valley bottom as surface water due to low permeability till and bedrock (SNC 2017). Groundwater-surface water interactions are relatively strong in topographic lows in the Elk River valley. In general, groundwater discharge maintains stream flows outside of freshet and large storm events. These interactions result in gaining streams on a regional basis, with small-scale areas of net recharge to the underlying surficial deposits (such as that which occurs in the lower portions of Leask, Wolfram and Thompson creeks).

Greenhills Creek is a Fording River tributary. Downstream of Greenhills Creek, inferred downgradient groundwater quality suggests that a down-valley groundwater pathway does not currently exist (SNC 2018b). Groundwater monitoring is ongoing as part of site-specific and regional groundwater monitoring programs, which mostly rely on wells in the Elk and Fording River valley bottoms.

Site-Specific Data

The site-specific groundwater monitoring program at GHO collects data from wells located downgradient of the West Spoil, downgradient of the Leask, Wolfram and Thompson settling ponds. Nested well pair monitoring is conducted near the upper Thompson Creek pond. These locations are downstream of assumed intake locations, which are on the valley-flanks with upland hydrogeologic conditions that are different from the valley-bottom setting downstream of the settling ponds.

Golder completed a numerical groundwater flow study in support of the GHO Cougar Pit Extension Project (CPX) in 2015 (Golder 2015a). Results of the GHO CPX modelling study were supported by groundwater flow and chemistry data collected from wells located in the lower portions of the following creeks, near their confluence with the Elk River or Fording River (Golder 2015b), including Leask Creek (GH-MW-4), Wolfram Creek (GH-MW-2), Thompson Creek (GH-MW-3S) and Greenhills Creek (GH-MW-GHC-1S & -1D).

The wells were generally drilled to the top of the bedrock, and the highest hydraulic conductivity materials (i.e. sands and gravels) were targeted for screening. Well depths ranged from 7.6 to 30 m. The alluvium at wells GA-MW-2, -3S, and -4 ranged from moderately to highly permeable (2×10^{-6} to 1×10^{-3} m/s), consistent with interpretations of good surface-groundwater connection in the floodplain of the Elk River and groundwater recharge occurring from the settling ponds located in Leask, Wolfram, and Thompson creeks. Well GH-MW-GHC-1S was installed in a glacial till unit and had a hydraulic conductivity estimate of 3×10^{-7} m/s, whereas Well GH-MWGHC-1D was completed in shallow bedrock.

Data Gaps

Limited to no groundwater data are available near assumed intake locations for the GHO tributaries targeted for treatment. The assumed intake locations are upstream of existing monitoring wells (on the valley flanks in the case of Leask, Wolfram and Thompson Creek) and in tributary valley bottom for Greenhills Creek. The lack of nested groundwater monitoring wells prevents estimation of vertical hydraulic gradients, and aquifer storativity estimates remains unknown as no pumping test data are available (SNC 2017). The available groundwater data are not sufficient to adequately characterize groundwater conditions and quantify potential bypass at potential intake locations. Site-specific groundwater investigations and other follow-up activities planned for GHO tributaries are described in Section 3.

2.3.3 Discussion of Water Availability

The assumed water availability for the GHO West Spoil drainages (Leask, Wolfram and Thompson) is 95%, as outlined in Table 1-1. The ratio of monitored surface flow to modelled total watershed yield is often at or above 95% in lower flow months for Leask Creek, Wolfram Creek and Thompson Creek. During higher flow periods, monitored surface flow to modelled total watershed yield ratios suggest that the water available at surface at the monitoring locations may be less than 95%. However, as the treatment capacity planned for GHO is relatively small (i.e., in the order of 2,500 to 5,000 m^3/d), it can likely be kept at capacity during high flow months with a target water availability of less than 95%.

Available data for Leask Creek, Wolfram Creek and Thompson Creek originate from monitoring locations in the lower valley, at or in the vicinity of the settling ponds. The data may not be representative of conditions at potential intake locations, which are likely to be positioned higher in their respective drainages. As a result, further work is planned in these three drainages to support a better understanding of water flow paths and aid in the effective siting and design of intakes.

The assumed water availability for Greenhills Creek is 75%. The comparison of monitored surface flow and modelled total watershed yield indicates that surface focused collection should be able to achieve the desired rates of water capture, noting that the monitoring location is downstream of the potential intake location. As at other locations, further work is planned in Greenhills Creek to support the detailed design of the intake and verify the conclusions of the assessment outlined herein.

2.4 Line Creek Operations – Dry Creek

A map of Line Creek Operations watersheds and potential intake locations is presented in Figure 2-11.

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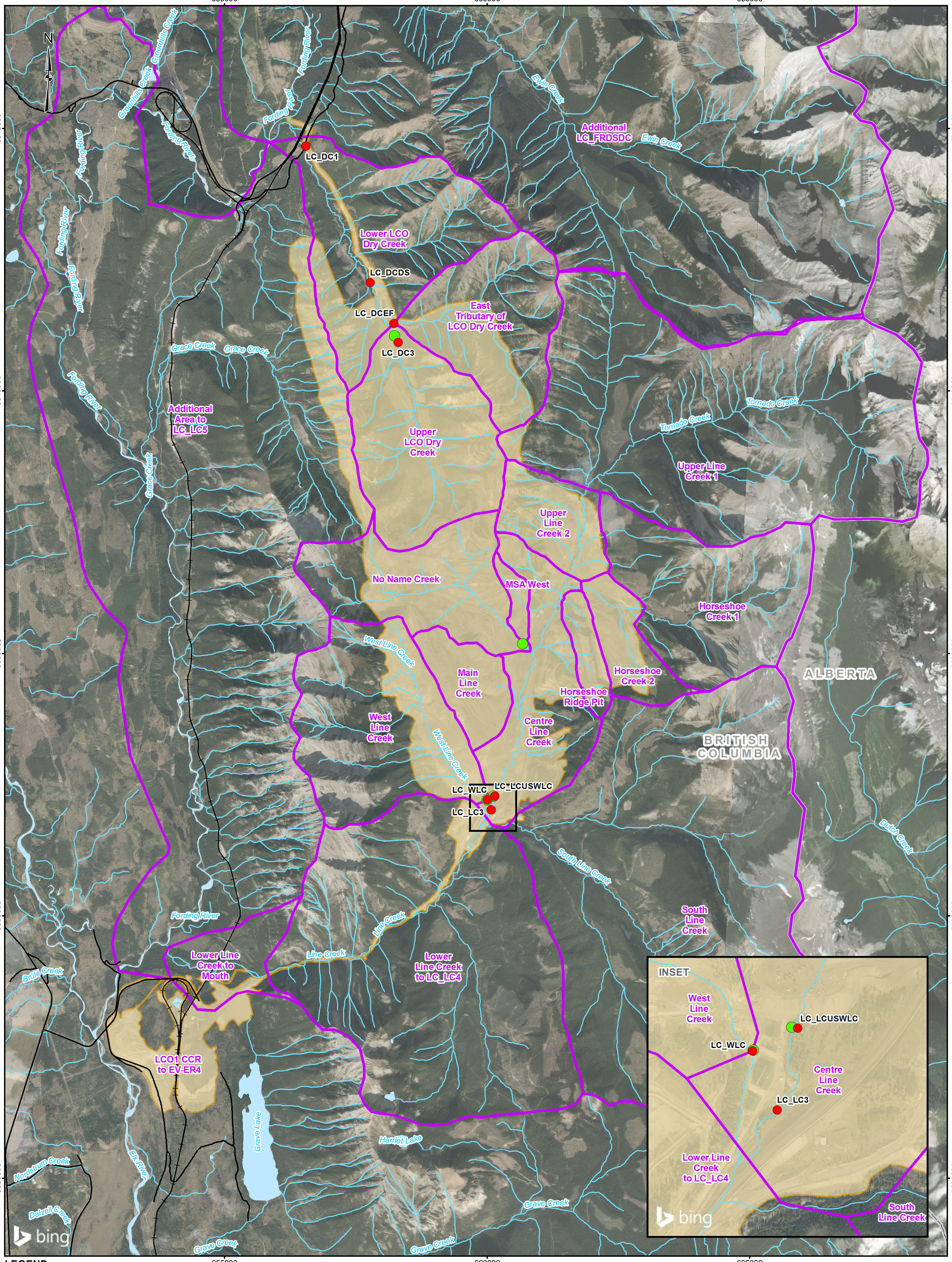


LEGEND

- APPROXIMATE INTAKE LOCATION
- SURFACE WATER LOCATION
- CITY/TOWN/COMMUNITY
- ROAD
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL BOUNDARY
- LINE CREEK OPERATIONS C-129 PERMIT BOUNDARY
- SUB-WATERSHED
- LINE CREEK — SUB-WATERSHED NAME

2 0 2

SCALE 1:70,000 KILOMETRES

REFERENCE

BASE DATA: CANVEC, GEOGRATIS 2017
IMAGERY: LIDAR IMAGERY PROVIDED BY TECK. ADDITIONAL IMAGERY BY MICROSOFT BING © 2017 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 11N

WATER QUALITY IMPLEMENTATION PLAN

TITLE **APPROXIMATE AWTF INTAKE LOCATIONS AND SELECTED MONITORING LOCATIONS AT LINE CREEK OPERATIONS**

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	AS	26 Jun. 2018	SCALE AS SHOWN	REV. 0
GIS	PR/LM	02 Nov. 2018	**FIGURE: 2-11**	
CHECK	AS	02 Nov. 2018		
REVIEW	JPB	02 Nov. 2018		

2.4.1 Comparison of Modelled and Monitored Flows

Watershed Conditions

The LCO Dry Creek drainage area includes settling ponds, a disturbed upper watershed containing a developing waste rock spoil, an undisturbed East Tributary watershed, and an undisturbed lower watershed. LCO Dry Creek discharges into the Fording River. Four flow monitoring stations are located across the watershed; they consist of:

- LCO Dry Creek near the Mouth (E288270, LC_DC1)
- East Tributary of LCO Dry Creek (E288274, LC_DCEF)
- LCO Dry Creek upstream of East Tributary Creek (E288273, LC_DC3), and
- LCO Dry Creek downstream of Ponds (E295210, LC_DCDS).

The overall contributing drainage area to LC_DC1 is approximately 26.2 km^2, with a current disturbed catchment area of approximately 0.6 km^2. Future activities planned in the drainage include expansion of the waste rock spoil in the upper watershed, mining along the ridges of upper Dry Creek (Burnt Ridge and Mount Michael pits) and associated pit dewatering.

Monitored Flows

Seasonal continuous flow measurements have been collected at LC_DC1 from 2011 onwards, LC_DCEF from 2012 onwards, and LC_DC3 from 2015 onwards. Instantaneous flow measurements have been collected at LC_DCDS from 2014 onwards. The frequency of the continuous data collection is daily with limited measurements during winter months. The frequency of the instantaneous data collection has been weekly from April to June and monthly during other times of the year.

The calculated mean annual watershed yield at LC_DC1 of 280 mm is under-representative of the expected yield from its contributing drainage area. The discrepancy is likely due to upstream infiltration and groundwater bypass of the LC_DC1 gauge station. Data completeness is considered poor, as the existing data record contains limited winter information and is missing peak flows from 2014 to 2016.

The calculated mean annual watershed yield at LC_DC3 of 400 mm is considered to be a better and more representative estimate, as it is derived from a flow station where groundwater bypass is known to be negligible.

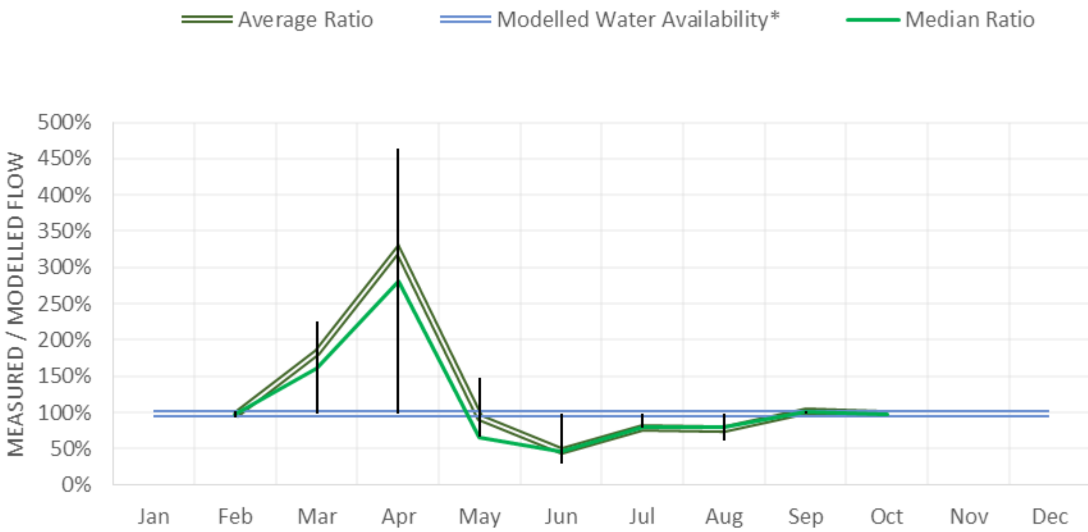
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the LCO Dry Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. A mine analogue adjustment factor was applied on the Cataract Creek mine analogue. Model performance in LCO Dry Creek was rated as acceptable, as outlined in Teck (2017).

Comparison of Monitored and Modelled Flows

For low flow months, monitored surface flows at LC_DC3 were nominally lower than modelled estimates of total watershed yield, with the mean and median monthly monitored surface flow being 97% of the corresponding modelled flow (Figure 2-12). During the higher flow months, the average and median monthly monitored flow was 150% and 79% of the corresponding modelled flow, respectively. Monitored flows were greater than modelled flows in approximately 45% of the months with available data.

Figure 2-12 Upper LCO Dry Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2015 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 3-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.4.2 Review of Groundwater Data

Regional Data

The main components of the conceptual hydrogeology model for LCO Dry Creek are the following:

- Mountainous setting with steep topography and syncline structure with axis aligned with Dry Creek valley bottom and beds dipping towards Dry Creek;
- Low to moderate bedrock hydraulic conductivity (10^{-9} to 10^{-6} m/s) with hydraulic conductivity decreasing with depth due to an increase in lithostatic pressure;
- On the flanks, the bedrock is covered with lower hydraulic conductivity till/colluvium that is a few metres thick;
- Overburden sediments up to 35 m deep underlying the Dry Creek valley-bottom;

The steep topography at LCO Dry Creek and decrease in hydraulic conductivity with depth results in nested hierarchical flow system that is commonly observed in a mountainous setting (e.g., Foster and Smith, 1988a and 1988b, Gleason and Manning, 2008, Toth 2009). The shallow flow system primarily discharges to tributaries on the valley flanks that flow into LCO Dry Creek. The observed trellis tributary pattern with flow direction perpendicular to Dry Creek develops as a result of sedimentary rock has been folded and then eroded to various degrees. The deeper flow system travels through gravel lenses overlying the bedrock in the valley-bottom and then discharges to LCO Dry Creek as seepage through valley till in areas of upward flow. Both shallow and deeper flow systems ultimately converge and discharge into LCO Dry Creek, with subsurface discharge maintaining perennial flow even during periods of no or limited surface runoff. However, LCO Dry Creek has both gaining and losing stretches (i.e., areas of net groundwater discharge and recharge, respectively), as a result of local geology, stream morphology and connected aquifer water levels.

Site-Specific Data

Several groundwater investigations have been completed in the LCO Dry Creek watershed in support of the Dry Creek Water Management System (DCWMS), the results of which are detailed in Golder (2013, 2014, 2016). A summary of this work is outlined below.

A local groundwater study was performed in 2013 within the sediments near and within the footprint of the DCWMS to support the design (Golder 2013). The program consisted of installing 10 monitoring wells, water quality sampling, water level monitoring, hydraulic testing, pump testing and the development of a conceptual groundwater flow model. Drilling in 2013 occurred primarily in areas to the east of Dry Creek due to access issues, with additional wells installed in 2014 on the west side of Dry Creek (Golder 2014).

The lithologic sequence of the valley fill sediments is as follows (from shallowest to deepest):

- colluvium and surficial till, which ranges from 2 to 10 m thick
- highly consolidated basal till, which ranges from 15 to 33 m thick
- discontinuous lens with relatively high gravel content
- bedrock

Around the DCWMS and to the north, depth to bedrock is generally 25 to 35 m. A discontinuous lens with relatively high gravel content was encountered in boreholes on the east side of Dry Creek during the 2013 hydrogeology program. The same feature was not encountered on the west side of Dry Creek, indicating that it is a local feature of limited geographic extent. The interval between ground surface and the top of the dense, consolidated till consists of less consolidated colluvium and surficial till. The lower hydraulic conductivity of the till (geometric mean of 1×10^{-7} m/s) near the Dry Creek Diversion Structure confines the underlying lenses or patches of gravel of higher hydraulic conductivity (geometric mean of 3×10^{-5} m/s) that are observed overlying the bedrock.

Artesian conditions are present in the spring and at other times of the year in the vicinity of the DCWMS, based on water level data analysis. The flowing artesian head conditions in the gravel lenses is consistent with convergence of the intermediate and deeper bedrock flow systems in the discharge area underlying Dry Creek with a resultant upward hydraulic gradient. Measured water levels in the six wells installed adjacent to the head pond were all above 1,706 metres above sea level, the operational elevation of the head pond. These results indicate that the hydraulic pressure of the head pond is less than the hydraulic pressure in the underlying geology, which creates upward groundwater flow paths into the DCWMS.

Flow accretion studies were completed in November 2018 and results similarly indicate that the area of LCO Dry Creek between the waste rock spoil and the DCWMS is a zone of net groundwater discharge. Over the period of measurement, surface flow was observed between the waste rock footprint and the diversion structure that conveys water into the DCWMS, including periods where most of the flow can be attributed to groundwater discharge. No dry stretches were observed.

The prediction for seepage bypass around and under the Dry Creek Diversion was performed with two numerical models. First, a 3D numerical groundwater flow model was constructed and calibrated to evaluate changes in hydraulic heads underlying LCO Dry Creek due to mining on top of the adjacent ridges. The open pit mines will encounter the groundwater table that will be lowered to allow mining to proceed. As a result, the upward hydraulic gradient under LCO Dry Creek will also be reduced. The 3D numerical model was used to set the boundary conditions for hydraulic heads at the base of the 2D vertical numerical models used to estimate the bypass.

2.4.3 Discussion of Water Availability

Water availability for LCO Dry Creek is assumed to be 99%. The minimal seepage bypass predicted to date is consistent with the hydrogeologic setting and designed intake structure that includes the following components:

- Moderate to low hydraulic conductivity (geometric mean of 1×10^{-7} m/s) till underling the footprint of the head pond;
- Upward vertical gradient; and
- Double liner system under the head pond.

The analysis of recently collected monitoring data indicate increasing trends in selenium, sulphate and nitrate in surface water while there is no change in concentrations in groundwater through the end of 2017. These data are considered preliminary in the sense of characterizing the influence of the recent start of deposition of waste rock in the headwaters of LCO Dry Creek. That said, they are supportive of the assumption that mine-influenced water will be largely at surface at the diversion structure, as are the findings of the detailed groundwater studies completed in the LCO Dry Creek area. No specific follow-up activities are planned in LCO Dry Creek to quantify groundwater bypass, beyond continuation of currently established hydrometric, groundwater and water quality monitoring programs. Monitoring data that are collected as part of the site-specific monitoring program will be used to check and, if needed, update conceptual and numerical groundwater flow models.

2.5 Line Creek Operations – Line Creek

A map of Line Creek Operations watersheds and existing and potential intake locations is presented in Figure 2-11.

2.5.1 Comparison of Modelled and Monitored Flows

2.5.1.1 West Line Creek

Watershed Conditions

The West Line Creek drainage area consists of a waste rock spoil on its eastern slopes and undisturbed areas on its western slopes. West Line Creek is a tributary of Line Creek, which discharges into the Fording River. A flow monitoring station is located near the mouth of West Line Creek (E261958, LC_WLC). The contributing drainage area to LC_WLC is approximately 10.0 km^2, with a disturbed catchment area of approximately 2.7 km^2. No specific future mining activities are planned in this drainage area.

Monitored Flows

Seasonal instantaneous flow measurements have been collected at LC_WLC from 1995 onwards, with a switch to continuous flow monitoring in 2009. The frequency of the instantaneous data collection has been weekly from April to June and monthly during other times of the year, while the frequency of the continuous data collection has been daily (including adequate measurements during the winter months).

The calculated mean annual watershed yield at LC_WLC of 230 mm is low and considered under-representative. The cause of the under-representation is not yet fully understood. Work conducted in relation to the development and calibration of the 2017 RWQM suggests that water from undisturbed areas may be discharging from the watershed through flow paths that bypass the flow monitoring station and are outside of the influence of loads released from waste rock in the West Line Creek watershed. Data completeness is considered good, with the continuous data collected since 2009 being more reliable than older information.

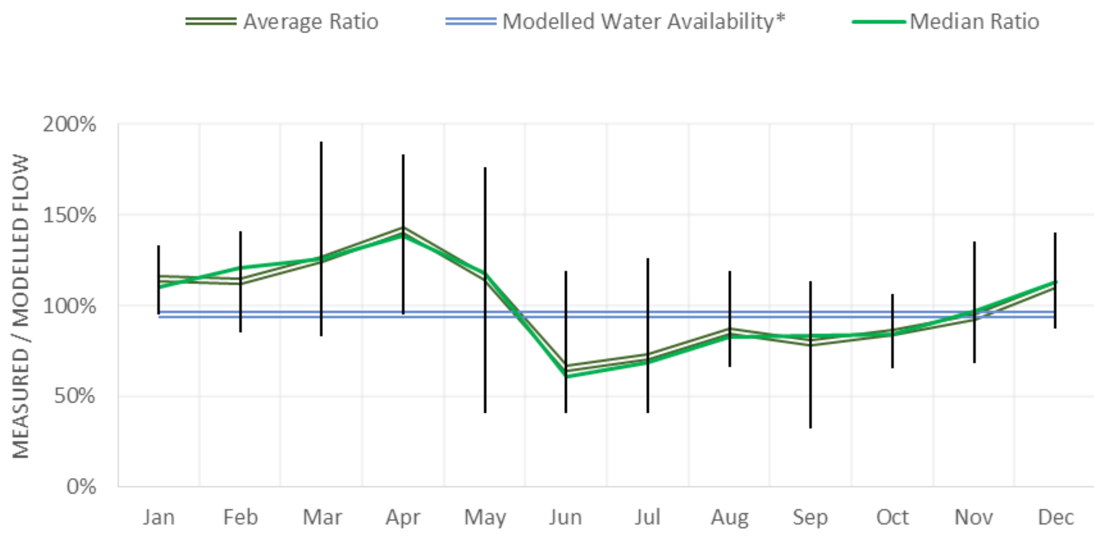
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the Line Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. A watershed-specific calibration factor was applied to the natural analogue hydrograph. A yield adjustment factor was also applied to the Cataract Creek mine analogue. As outlined in Teck (2017), model performance in West Line Creek was rated as poor.

Comparison of Monitored and Modelled Flows

For low flow months, monitored surface flows were nominally higher than modelled estimates of total watershed yield; the mean and median monthly monitored surface flows were 108% and 105%, respectively, of the corresponding average modelled flow (Figure 2-13). During higher flow months, the average and median monthly monitored surface flows were 97% and 86% of the corresponding modelled flow, respectively. Monitored surface flows were greater than modelled flows in approximately 44% of the months with available data.

Figure 2-13 West Line Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2010 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 8-year period

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.5.1.2 Mine Services Area West

Watershed Conditions

The Mine Services Area West drainage area includes No Name Creek and three mine area: Burnt Ridge Extension, North Line Extension and the Mine Services Area West Pit. Watershed runoff discharges into Centre Line Creek, before joining Line Creek and then the Fording River. The contributing drainage area to Mine Services Area West is approximately 7.5 km^2, with a disturbed catchment area of approximately 4.7 km^2. Future activities include waste rock placement in No Name Creek and the Mine Services Area West Pit, and pit dewatering from Burnt Ridge North.

Monitored Flows

No flow monitoring stations are located in Mine Services Area West.

Modelled Flows

Modelled flows are generated by the 2017 RWQM using Line Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. As outlined in Teck (2017), watershed-specific calibration adjustments were not implemented, and an evaluation of model performance was not undertaken due to an absence of monitored flow data.

Comparison of Monitored and Modelled Flows

A comparison of monitored and modelled flows was not completed due to an absence of monitored flow data.

2.5.1.3 Line Creek upstream of West Line Creek

Watershed Conditions

The Line Creek upstream of West Line Creek drainage area includes: Upper Line Creek, Horseshoe Creek, Horseshoe Ridge Pit, Main Line Creek, and Centre Line Creek. Flow discharges into Line Creek and subsequently into the Fording River. Instream flows are not directly measured at Line Creek upstream of West Line Creek (E293369, LC_LCUSWLC). Instead, they are estimated using information collected from other locations, as explained below. The overall contributing drainage area to LC_LCUSWLC is approximately 60.6 km^2, with a disturbed catchment area of approximately 14.2 km^2. Future planned activities include expansion of existing waste rock spoils.

Monitored Flows

Instream flows at LC_LCUSWLC are calculated based on measured flow from LC_LC3 (Line Creek downstream of West Line Creek, 0200337) and LC_WLC, where,

$$LC\_LCUSWLC = LC\_LC3\ - LC\_WLC$$

This approach is expected to provide an adequate estimate of flow at this location, as discussed in the Regional Surface Flow Monitoring Plan (KWL 2017).

The calculated mean annual watershed yield at LC_LCUSWLC is 530 mm. This value is likely a slight over-estimate owing to the fact that the West Line Creek annual watershed yield is under-representative.

Data completeness is considered fair; there are few winter data gaps in the datasets used in the calculation.

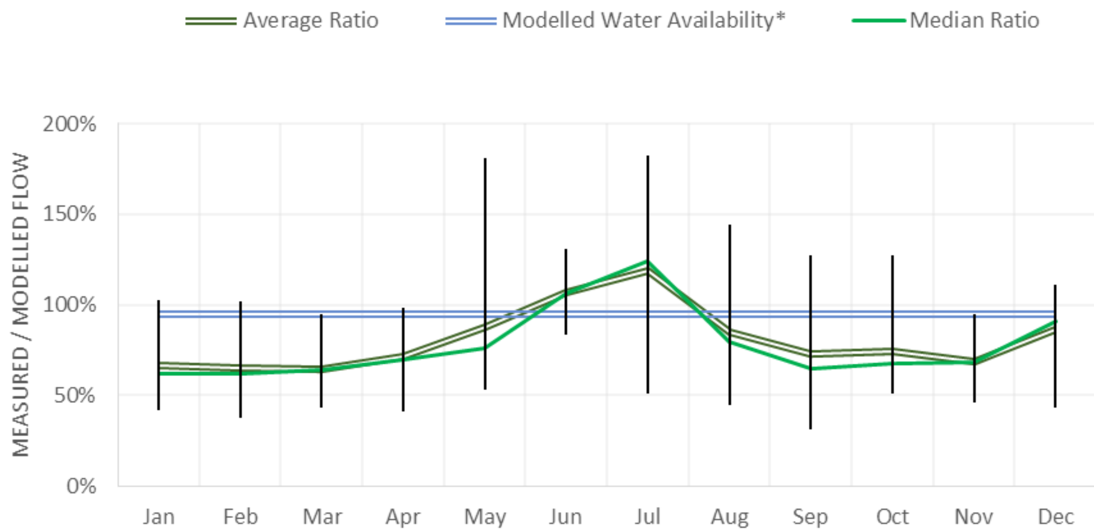
Modelled Flows

Modelled flows are generated by the 2017 RWQM using the Line Creek hydrograph as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. A yield adjustment factor was applied to the Cataract Creek mine analogue. As outlined in Teck (2017), model performance was rated as very good.

Comparison of Monitored and Modelled Flows

For low flow months, monitored surface flows were typically lower than modelled estimates of total watershed yield, with the mean and median monthly monitored surface flows being 71% and 69%, respectively, of the corresponding average modelled flow (Figure 2-14). During higher flow months, the average and median monthly monitored surface flow were 97% and 89% of the corresponding modelled flow, respectively. Monitored surface flows were greater than modelled flows in approximately 23% of the months with available data.

Figure 2-14 **Line Creek upstream of West Line Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2010 to 2017**



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 8-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.5.2 Review of Groundwater Data

Regional Data

Groundwater monitoring at LCO has been ongoing since 2013 with the objective to characterize the groundwater system and connectivity to surface water. As detailed in the 2017 LCO Site Wide Annual Groundwater Monitoring Report (Golder 2017a), groundwater monitoring occurs via the Regional Groundwater Monitoring Program, LCO Site-Wide Groundwater Monitoring Plan, and work completed in support of the West Line Creek Active Water Treatment Facility (WLC AWTF) and associated landfill (Golder 2017b). Results of these activities indicate that local sediments are characterized by a high degree of lateral and vertical heterogeneity with interbedded fines and coarse material. Groundwater flow patterns are consistent with topography, modified in some areas by geology. Overall, there are downward vertical gradients toward more laterally continuous permeable zones that act as drains, directing groundwater flow toward valley side outcrops or to shallow subsurface flow systems that drain into Line Creek.

Site-Specific Data

The Line Creek/West Line Creek (LC/WLC) collection works were constructed in 2013. The LC/WLC intake works consist of sheet pile/concrete structures with twin intake screens that straddle the creeks and divert flow as it is conveyed through the structure. The intakes were constructed at the foot of large spoils. They are intended to capture surface water only, noting that capture efficiency was not a design or performance criterion for the LC/WLC collection works. The LC/WLC intakes were designed and constructed before the EVWQP. They were designed to meet LCO requirements, which included stabilizing and reducing the selenium trend at LCO and supporting the permitting of LCO Phase II.

The first phase of the WLC treatment facility was sized by considering the surface flow measured at LC_WLC, and the system does not attempt to intercept subsurface flow. Data suggests that a portion of the non-mine-affected (clean) water yield from the WLC catchment does not surface at the WLC intake location. There appears to be a separate subsurface pathway for this flow, which may be towards the Main Line Creek backfilled pit or to Line Creek and so is not part of the “total flow”. The proportion of the mine-affected flow that comes to the surface upstream of the intakes in this case has not been estimated through groundwater investigations.

Data Gaps

A detailed site-specific characterization of groundwater conditions and potential groundwater bypass near the LC/WLC intakes is not presently available. This data gap is not considered to be a limitation for the existing WLC AWTF facility, which is sized to capture surface water alone. Future treatment in the Line Creek watershed would require additional groundwater studies to support design modifications to existing intakes or siting of new intakes, as discussed in Section 3.

2.5.3 Discussion of Water Availability

Assumed water availability at the West Line Creek intake is 95%, as outlined in Table 1-1. The comparison of measured surface flow to modelled estimates of total watershed yield indicates that collection of surface flow should be sufficient to meet the water availability assumption used in the RWQM, with average ratios of measured surface flow to modelled flow being 108% and 97% in lower and higher flow months, respectively. The watershed has a lower than expected yield, but watershed-specific calibration results in suitable model performance.

Data are unavailable to evaluate the assumed water availability at Mine Services Area West. Further study in this area is planned, as outlined in Section 3.

Assumed water availability at the Line Creek upstream of West Line Creek intake is 95%. Comparisons between monitored surface flow and modelled estimates of total watershed yield indicate that, during higher flow periods, collection of surface flow should be sufficient to meet the water availability assumption used in the RWQM, with the average ratio of monitored surface flow to modelled flows being 97%. During lower flow periods, the average ratio of monitored surface flow to modelled flow was 71%, indicating that achieving water availability targets in winter may require groundwater interception. Further study in this area is planned, as outlined in Section 3. Planned follow-up activities include the continuation of established hydrometric, groundwater and water quality monitoring programs in the Line Creek watershed, with new information being incorporated into the operation of the future phases of the WLC AWTF following Teck’s Adaptive Management Plan.

2.6 Elkview Operations

A map of Elkview Operations watersheds and potential AWTF intake locations is presented in Figure 2-15.

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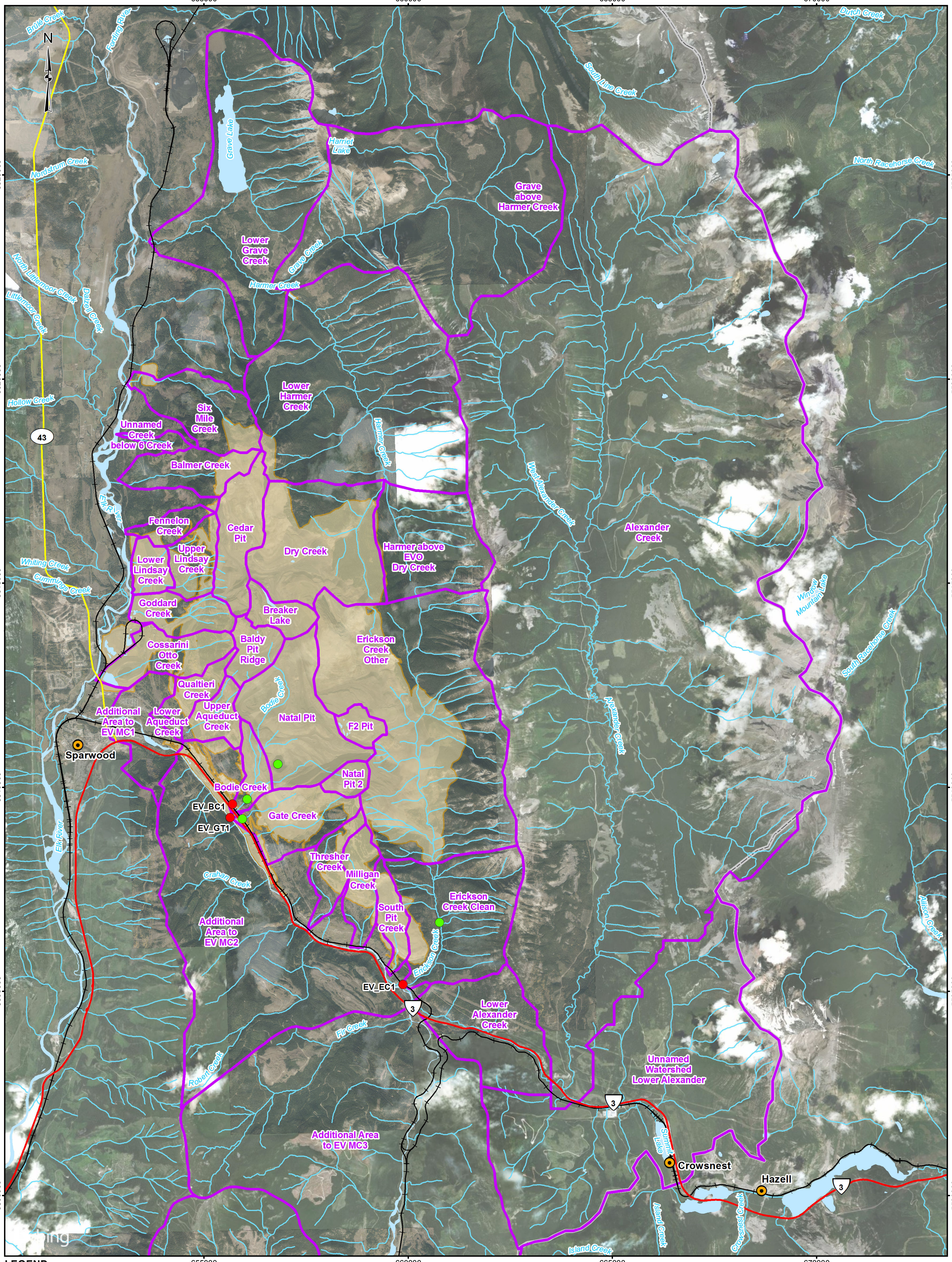


LEGEND

- APPROXIMATE INTAKE LOCATION
- SURFACE WATER LOCATION
- CITY/TOWN/COMMUNITY
- PRIMARY HIGHWAY
- SECONDARY HIGHWAY
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL
- ELKVIEW OPERATIONS C-2 PERMIT BOUNDARY
- SUB-WATERSHED
- GRAVE CREEK SUB-WATERSHED NAME

2 0 2
SCALE 1:90,000 KILOMETRES

REFERENCE

BASE DATA: CANVEC, GEOGRATIS 2017
IMAGERY: LIDAR IMAGERY PROVIDED BY TECK. ADDITIONAL IMAGERY BY MICROSOFT BING © 2017 MICROSOFT CORPORATION AND ITS DATA SUPPLIERS.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 11N

WATER QUALITY IMPLEMENTATION PLAN

TITLE **APPROXIMATE AWTF INTAKE LOCATIONS AND SELECTED MONITORING LOCATIONS AT ELKVIEW OPERATIONS**

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	AS	26 Jun. 2018	SCALE AS SHOWN	REV. 0
GIS	PR/LM	02 Nov. 2018		
CHECK	AS	02 Nov. 2018	FIGURE: 2-15	
REVIEW	JPB	02 Nov. 2018		

2.6.1 Comparison of Modelled and Monitored Flows

2.6.1.1 Erickson Creek

Watershed Conditions

The Erickson Creek drainage area includes a waste rock spoil, the West Fork Tailings Facility (WFTF) and Erickson Dam in its upper watershed, along with undisturbed headwater areas and undisturbed areas along the eastern valley slopes and in the lower watershed. Erickson Creek discharges to Michel Creek. A flow monitoring station is located at the mouth of Erickson Creek (E200097, EV_EC1). The contributing drainage area to EV_EC1 is approximately 32.7 km^2, with a disturbed catchment area of approximately 11.1 km^2. Erickson Creek includes an area of groundwater recharge (i.e., a losing reach) downstream of the waste rock spoil. Surface flows have not been observed in this reach during site visits in recent years. Future planned activities include continued waste rock placement in the upper watershed, mining of Adit Ridge Pit and continued operation of the WFTF (including discharge into Erickson Creek).

Monitored Flows

Instantaneous flow measurements have been collected at EV_EC1 since 1996. The frequency of data collection was monthly and changed to weekly from April to June in 2009. Since 2013, continuous daily flow measurements have been recorded.

Measured flows in EV_EC1 have a relatively flat annual distribution that is unlike other watersheds in the Elk Valley. Freshet flows tend to be lower than those observed elsewhere, whereas winter flows tend to be higher than in other watersheds. The cause of this unique hydrological pattern is not yet fully understood, but may be related to water movement through the aforementioned losing reach. The calculated mean annual watershed yield is 240 mm, which is low in a regional context.

Data completeness is considered fair; there are gaps and missing years from 1996 to 2004, but recent data are more consistent. High flows in 2011 were not measured due to safety concerns.

Modelled Flows

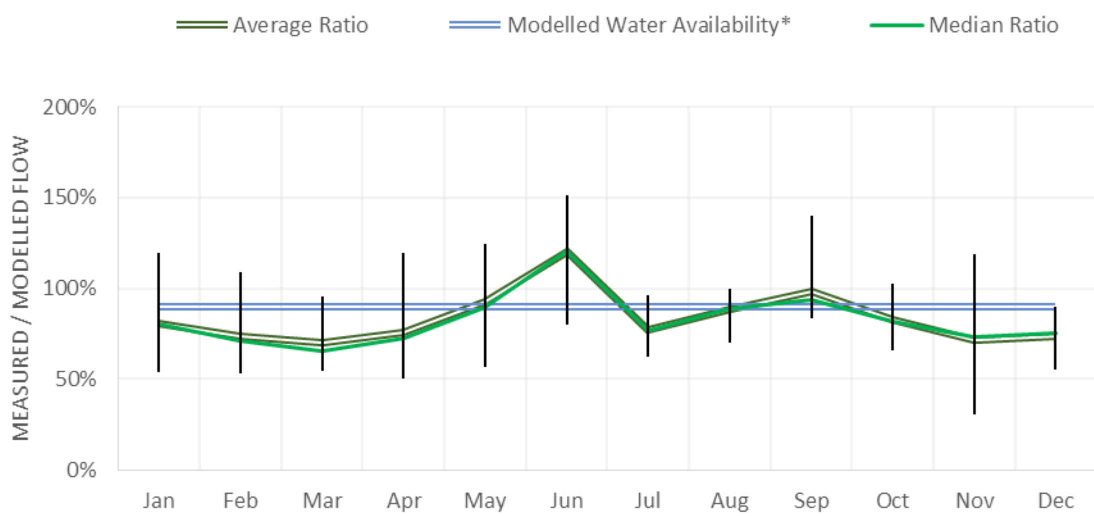
Modelled flows are generated by the 2017 RWQM using Hosmer Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas (Teck 2017). The natural analogue was shifted (delayed) by eight days to account for the later observed freshet in Erickson Creek. A yield adjustment factor was applied on both the natural and mine analogues, and a watershed-specific calibration was undertaken.

As outlined in Teck (2017), model performance in Erickson Creek was rated as poor. However, as part of the 2019 IPA, improvements to the flow calibration at Erickson Creek were conducted using adjustment factors that were derived by reallocating the modelled surplus during freshet over the remainder of the rest to better match the shape of the “flat” measured hydrograph. The changes were applied uniformly to natural and disturbed areas within the watershed (i.e., were applied to both the Hosmer Creek and Cataract Creek representative hydrographs). Further details on these changes are provided in Annex B.

Comparison of Monitored and Modelled Flows

During low flow months, monitored surface flows were lower than modelled flows at EV_EC1; on average, mean monthly monitored surface flow was 75% of the corresponding modelled flow (Figure 2-16). During high flow months (between April and July), mean and median monthly monitored surface flows were 92% and 87%, respectively, of the corresponding modelled flows (Figure 2-16). Monitored surface flows were greater than modelled flows in approximately 19% of the months with available data.

Figure 2-16 Erickson Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.6.1.2 Bodie Creek

Watershed Conditions

The Bodie Creek drainage area consists of a waste rock spoil and a small undisturbed catchment in the lower watershed. Most of the flow in Bodie Creek in recent years originates from Natal West Pit, with pit dewatering flows being pumped to the Bodie Rock Drain. Bodie Creek discharges into the Bodie Creek Sedimentation Ponds, although it can be diverted to the Gate Creek Sedimentation Ponds at an upstream control pond located above the Michel Creek floodplain.

A flow monitoring station is located at the decant of the Bodie Creek Sedimentation Ponds (E102685, EV_BC1), which are in the Michel Creek floodplain. The contributing drainage area to EV_BC1 is approximately 1.2 km^2 (excluding Natal West Pit), with a disturbed catchment area of approximately 0.9 km^2. Future planned activities include further reduction in watershed area due to mining of Baldy Ridge and Natal pits and continued pit dewatering from Natal Pit.

Monitored Flows

Instantaneous flow measurements have been collected at EV_BC1 since 1992. The frequency of data collection has been weekly from April to June and monthly during other times of the year.

The calculated mean annual watershed yield is 430 mm. Confidence in this estimate is low, due to uncertainty in historical pit water management practices and loss of water to infiltration through the settling pond. Data completeness is considered fair, as there are limited data gaps in the available record (i.e., missing winter data from 1997 to 1999, and missing 2008 data).

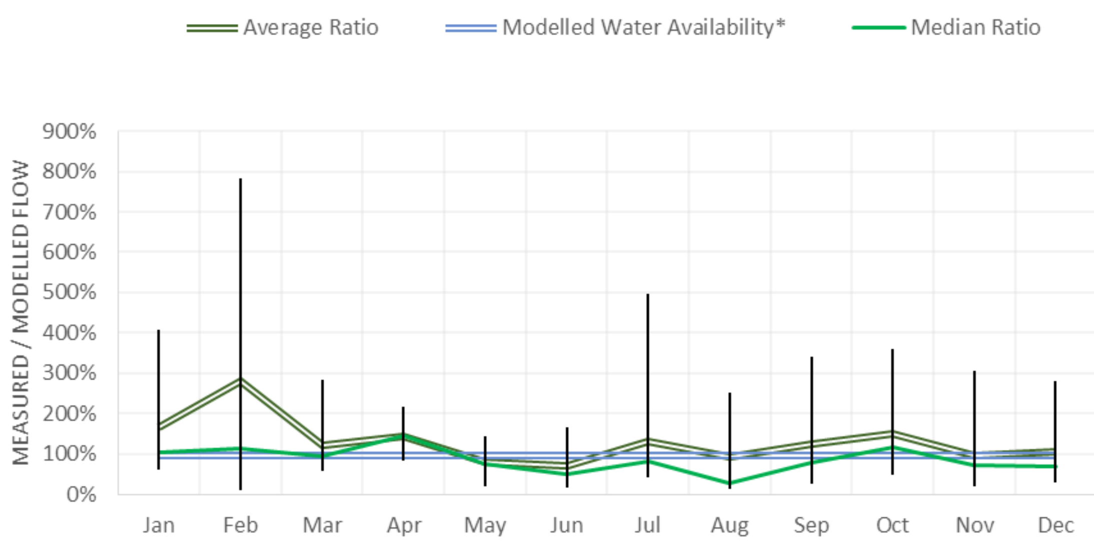
Modelled Flows

Modelled flows are generated by the 2017 RWQM using Hosmer Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. The natural analogue was shifted (delayed) by eight days for improved freshet timing in Bodie Creek. Natural and mine yield adjustment factors were also applied. As outlined in Teck (2017), model performance in Bodie Creek was rated as poor.

Comparison of Monitored and Modelled Flows

During low flow months, monitored surface flows were consistently higher than modelled estimates of total watershed yield; on average, mean monthly monitored surface flow was 172% of the corresponding modelled flow, with the median ratio being 90% (Figure 2-17). During higher flow months (between April and July), the average and median monthly monitored surface flows were 103% and 85% of the corresponding modelled flows, respectively (Figure 2-17). Monitored surface flows were greater than modelled flows in approximately 42% of the months with available data.

Figure 2-17 Bodie Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2008 to 2017



Notes:

Vertical high/low lines identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.6.1.3 Gate Creek

Watershed Conditions

The Gate Creek drainage area includes a waste rock spoil and some undisturbed areas. Tributaries of Gate Creek are Main Gate Creek and South Gate Creek, which discharge into the Gate Creek Sedimentation Ponds. A flow monitoring station is located at the decant of the ponds (E102685, EV_GT1). The contributing drainage area to EV_GT1 is approximately 4.2 km^2, with a disturbed catchment area of approximately 2.4 km^2. Gate Creek has been used as an alternate to Bodie Creek for the release of pit dewatering waters from Natal and Baldy Ridge pits, although the timing and rates of pit water discharge have not been tracked until recently. Future planned activities include a gradual reduction in watershed area due to continued mining in Natal Pit.

Monitored Flows

Instantaneous flow measurements have been collected at EV_GT1 in 1994, 1995, and from 2004 onwards. The frequency of data collection has been weekly from April to June and monthly during other times of the year.

The calculated mean annual watershed yield is 340 mm. Confidence in this estimate is low, due to uncertainty in historical pit water management practices and loss of water to infiltration through the settling pond. Data completeness is considered poor, as recorded flows prior to 2005 are uncharacteristically low or missing altogether.

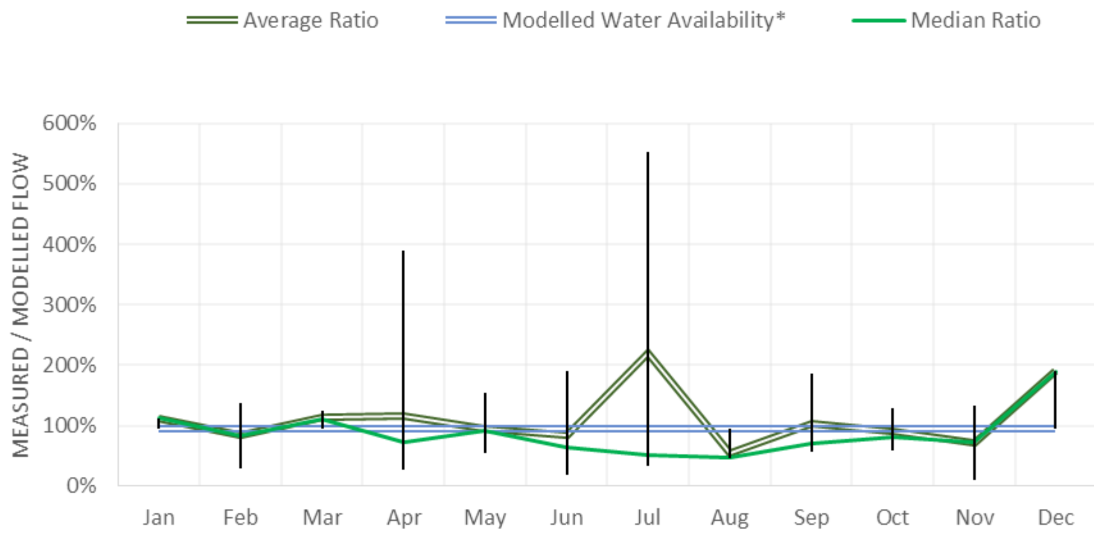
Modelled Flows

Modelled flows are generated by the 2017 RWQM using Hosmer Creek as the analogue watershed for undisturbed areas and Cataract Creek as the analogue watershed for mine areas. The natural analogue was shifted (delayed) by eight days for improved freshet timing in Gate Creek. Natural and mine yield adjustment factors were also applied. Model performance in Gate Creek was rated as poor, as outlined in Teck (2017).

Comparison of Monitored and Modelled Flows

During low flow months, monitored surface flows were similar to modelled estimates of total watershed yield, with the mean monthly monitored surface flow being 102% of the corresponding average modelled flow; the media ratio was 123% (Figure 2-18). During higher flow months, the average and median monthly monitored surface flows were 124% and 72% of the corresponding modelled flows, respectively. Monitored surface flows were greater than modelled flows in approximately 42% of the months with available data.

Figure 2-18 Gate Creek: Comparison of Mean Monthly Surface Flow, Expressed as a Proportion of Modelled Total Watershed Yield, to Assumed Water Availability, 2010 to 2017



Notes:

Vertical high/low lines were used to identify the range observed in measured to modelled flow ratios over the 10-year period.

* The ratio of measured surface flow to modelled total watershed yield is being used to evaluate if water collection focused at surface can achieve the water availabilities assumed in the RWQM. In practice, water flowing at surface will always be less than 100% of total watershed yield. Ratios of greater than 100% reflect model and/or measurement error.

2.6.2 Review of Groundwater Data

Regional Data

The conceptual groundwater flow model for EVO similar to that outlined above for other areas in the Elk Valley. Regional groundwater flow velocities are lower through bedrock compared to surficial materials. Bedrock hydraulic conductivity ranges between 10^{-9} and 10^{-6} m/s whereas surficial materials (alluvial and glacial deposits) ranges between 10^{-8} to 10^{-4} m/s. Groundwater originating in upland areas, including from mine areas, waste rock and coarse coal rejects, generally flows to the valley-bottom where discharge to surface water is expected. Localized losing stream conditions are known to occur further down-valley in tributaries at EVO, particularly in Erickson Creek (SNC 2018b).

Site-Specific Data

Teck has a site-specific groundwater monitoring program in place at EVO. Eleven monitoring wells have been installed around EVO, typically within tributary drainages that flow to either Michel Creek or the Elk River, as outlined in Golder (2015c). One of the wells was placed alongside Erickson Creek (EV_ECgw), upgradient of the confluence with Michel Creek and south of Erickson spoil to monitor groundwater quality and levels in the shallow overburden. Another well was placed alongside Michel Creek near the confluence of Bodie Creek (EV_BCgw) to monitor groundwater quality and levels in the valley fill sediments downgradient of Bodie and Gate creeks. No wells have been placed in the Gate Creek drainage area.

The wells intersect a variety of materials, ranging from gravelly sand to clayey silt depending on local site conditions (Golder 2015c). Local, direct groundwater quality effects have been observed near the confluences of Bodie, Gate, and South Gate creeks with Michel Creek. Selenium concentrations up to approximately 200 µg/L have been observed in the wells near the edges of the floodplain near the affected tributaries. Concentrations decrease downgradient due to a combination of dilution by mixing with non-contact water and discharge to Michel Creek.

Groundwater levels across all 11 wells tend to follow a similar pattern. Water levels decrease throughout the fall and winter, increase in late April or early May (as freshet occurred), and then decreased again during the later summer (Golder 2015c). Slug tests identified hydraulic conductivities ranging from 10^{-8} and 10^{-3} m/s, depending on location and local geology. The range reflects the heterogeneity in local geology.

Surface geophysical surveys have been conducted in Erickson, Gate, South Gate and Bodie creeks. The purpose of the surveys was to delineate depth to bedrock and characterize lithology of the overburden soils to identify favourable locations for water diversion structures. A total of five lines were completed in Erickson Creek, three in South Gate Creek, two in Gate Creek, and one in Bodie Creek. Each line was several hundred metres in length, positioned perpendicular to and straddling each creek. Analysis of the collected information is ongoing and will be combined with borehole data that is scheduled to be collected in relation to an upcoming geotechnical drilling program. The final combined dataset will be used to guide selection of intake locations by identifying areas with more favourable characteristics (e.g. less hydraulically conductive overburden soil, shallow bedrock, downstream of gaining stretches).

Data Gaps

Limited to no groundwater data are available near potential intake locations for the three EVO tributaries targeted for treatment, although groundwater investigations are underway in Erickson Creek to characterize groundwater bypass and support intake design. Groundwater flows in the valley-bottom area downgradient of Erickson Creek and the South Pit Decant Pond remain unknown as there are no wells installed in this area (SNC 2017). Site-specific groundwater investigations and other follow-up activities are planned or underway and are described in Section 3.

2.6.3 Discussion of Water Availability

Assumed water availability at the Erickson Creek intake is 90%, as outlined in Table 1-1. The comparison of measured surface to modelled total flows suggests that this value is appropriate for high flow periods, when the ratio of monitored to modelled flows is, on average, 92%. During lower flow periods, the average ratio of monitored surface to modelled flow was less (i.e., 75%), which indicates that additional water may need to be sourced from groundwater to achieve the target water availability during these periods.

Assumed water availability in Bodie Creek and Gate Creek is 95%. Available flow data for both creeks originate from the decant of sedimentation ponds, which are located in the Michel Creek floodplain. The available flow data are also influenced by pit dewatering activity. Even so, the comparison of measured surface to modelled estimates of total watershed yield indicates that surface flows are, on average, higher than modelled flows during low flow periods. During higher flow periods, water available at surface may be less than the targeted value.

Surface water and groundwater investigations are currently underway in Erickson Creek, Bodie Creek and Gate Creek. They include analysis of geophysical survey data, collection of surface flow measurements near the planned intakes, and completion of flow accretion studies and drilling programs. These follow-up activities will support an improved understanding of surface water and groundwater flow partitioning and support the development of intake designs to achieve target water capture rates and downstream water quality compliance.

2.7 Summary of Data Evaluation

A summary of the data evaluations outlined above is provided in Table 2-1. In general, collection of surface flow should be sufficient to meet the water availability assumptions used in the RWQM in areas where site-specific groundwater evaluations have been done. In other areas, results of the analysis indicate that additional studies and potential design considerations may be required so that the relevant intakes are able to access as much of the total watershed yield as assumed in the RWQM, at least at certain times of the year. Consequently, follow-up activities are planned with a particular focus on collecting site-specific information at potential intake locations, since existing flow monitoring locations tend to be located downstream of where potential intakes will be constructed.

Table 2-1 Summary of Data Evaluation based on Review of Flow Monitoring Data and Groundwater Information

Tributary / Area Targeted for Treatment	Waste Rock Position in Watershed		Intake Location		Flow Monitoring Data			Groundwater Information			Field Program Status?	Mean (median) Ratios - Measured Flow to Modelled Total Yield	
	Location	Status	Established Location?	Assumption used in RWQM	Long-term Flow data available in Watershed?	Available Flow Data at or near Assumed Intake Location	Are Flow Data Representative of Assumed Intake Location?	Local Setting for Assumed Intake Location	Subsurface Conditions (presumed if no data available)	Site-specific Data Available?		Under Low Flows	Under High Flows
Swift	Lower Valley Flanks	Active	Yes	At Swift mine-influenced water ponds upstream of Fording confluence (Cataract Creek diverted from existing ponds)	Yes	Spot flows at GH_SC1, GH_SC2	Yes	Lower valley flanks, outside main floodplain	Thin to moderate colluvium, shallow bedrock	Yes	Complete	>100% (>100%)	>100% (>100%)
Cataract	Lower Valley Flanks	Active	Yes		Yes	Spot flows at GH_CC1	Yes	Lower valley flanks, outside main floodplain	Thin to moderate colluvium, shallow bedrock	Yes	Complete	>100% (100%)	>100% (100%)
Kilmarnock	Valley Flanks, Valley-bottom	Active	No	At control pond upstream of settling ponds	Yes	Spot and continuous flows at FR_KC1	Yes	In alluvial floodplain / valley bottom	Moderate to thick colluvium, alluvial deposits	No	Ongoing	58% (54%)	71% (71%)
Swift North Spoil (Turnbull Bridge Spoil)	Valley-bottom, Main Floodplain	Active	No	Below Post Ponds	No	No data	n/a	In Fording River floodplain	Thick alluvial deposits	No	Ongoing	n/a	n/a
Swift North Spoil (Post and Lake Mountain)	Mid-Valley Flanks (some in-pit)	Active	No	Near Post/Lake Mountain Ponds	No	Some spot flows at FR_LMP1 – not sufficient for evaluation	n/a	Lower valley flanks, outside main floodplain, valley bottom	Thin colluvium, shallow bedrock	No	Ongoing	n/a	n/a
Swift Pit (Liverpool)	In-pit	Active	No	Near Liverpool Ponds	No	Some spot flows at FR_LP1 – not sufficient for evaluation	n/a	Lower valley flanks, near main floodplain	Thin colluvium, shallow bedrock	No	Ongoing	n/a	n/a
Clode	In-pit Valley-bottom, Floodplain	Active	No	At Clode Ponds	Yes	Spot flows at FR_CC1	Yes, intake assumed at ponds	In main Fording River floodplain	Thick alluvial deposits	No	Ongoing	42% (33%)	86% (74%)
Leask	Upper/mid Valley Flanks	Active	No	Below West Spoil (upper drainage)	Yes	Spot flows at GH_LC1/LC2	No, flows near ponds but assumed intake is further upstream	Valley flanks, outside main floodplain	Thin colluvium, shallow bedrock	No	Scoping stage	>100% (>100%)	>100% (70%)
Wolfram	Upper/mid Valley Flanks	Active	No		Yes	Spot flows at GH_WC1/WC2	No, flows near ponds but assumed intake is further upstream	Valley flanks, outside main floodplain	Thin colluvium, shallow bedrock	No	Scoping stage	>100% (>100%)	80% (56%)

Table 2-1 Summary of Data Evaluation based on Review of Flow Monitoring Data and Groundwater Information

Tributary / Area Targeted for Treatment	Waste Rock Position in Watershed		Intake Location		Flow Monitoring Data			Groundwater Information			Field Program Status?	Mean (median) Ratios - Measured Flow to Modelled Total Yield	
	Location	Status	Established Location?	Assumption used in RWQM	Long-term Flow data available in Watershed?	Available Flow Data at or near Assumed Intake Location	Are Flow Data Representative of Assumed Intake Location?	Local Setting for Assumed Intake Location	Subsurface Conditions (presumed if no data available)	Site-specific Data Available?		Under Low Flows	Under High Flows
Thompson	Upper/mid Valley Flanks	Active	No		Yes	Spot flows at GH_TC1/TC2	No, flows near ponds but assumed intake is further upstream	Valley flanks, outside main floodplain	Thin colluvium, shallow bedrock	No	Scoping stage	87% (87%)	>100% (>100%)
Greenhills	Headwater Valley Flanks Valley Bottom	Active	No	Below spoil (upper drainage)	Yes	Spot flows at GH_GH1	No, assumed intake is further upstream in watershed	Valley bottom, outside main floodplain	Moderate colluvium and thickness to bedrock	No	Scoping stage	>100% (96%)	>100% (73%)
LCO Dry	Headwater Valley Flanks, Valley Bottom	Active	Yes	At head pond (upper Dry Creek)	Yes	Spot flows at LC_DC3	Yes	Valley bottom, outside floodplain	Moderate colluvium and thickness to bedrock	Yes	Complete	97% (97%)	>100% (79%)
Mine Services Area West (MSAW)	In-pit Lower Valley Flanks	Active	No	Below No Name Creek rock drain	No	No data	-	Alluvial floodplain / valley bottom	Moderate colluvium and thickness to bedrock	No	Scoping stage for future phases	n/a	n/a
West Line	Lower Valley Flanks	Inactive	Yes	Near confluence with Line Creek	Yes	Continuous flows at LC_WLC	Yes	Alluvial floodplain / valley bottom	Moderate colluvium and thickness to bedrock	No	Scoping stage for future phases	>100% (>100%)	97% (86%)
Line upstream of West Line	Valley-bottom, (some in-pit and valley flanks)	Active	Yes	Below Line Creek rock drain (upstream of West Line Creek)	No	Flows are estimated as (LC_LC3 – LC_WLC)	Yes	Alluvial floodplain / valley bottom	Moderate to thick colluvium and thickness to bedrock	No	Scoping stage for future phases	71% (69%)	97% (89%)
Erickson	Valley Flanks, Valley Bottom	Active	No	Near bridge in lower Erickson (near EV_ECgw)	Yes	Continuous flows at EV_EC1	No, assumed intake is further upstream in watershed	Alluvial floodplain / valley bottom	Moderate colluvium and thickness to bedrock	No	Ongoing	75% (74%)	92% (87%)
Bodie	In-pit Lower Valley Flanks	Active	No	At Bodie Control Pond	Yes	Spot flows at EV_BC1	No, flows at pond decant but assumed intake is upstream	Valley flanks, outside floodplain	Thin colluvium, shallow bedrock	No	Ongoing	>100% (90%)	>100% (85%)
Gate	In-pit, Lower Valley Flanks	Active	No	Upstream of Gate Creek Ponds	Yes	Spot flows at EV_GT1	No, flows at pond decant but assumed intake is upstream	Valley flanks, outside floodplain	Thin colluvium, shallow bedrock	No	Ongoing	>100% (>100%)	>100% (72%)

n/a = not available; insufficient data to determine

3 Follow-up Activities, Potential Design Considerations and Contingency Options

Follow-up activities that will be undertaken to better understand surface water and groundwater flow paths in relevant source tributaries (i.e., where water flow at surface may be less than the modelled water availability) are identified in this section. Potential design modifications / mitigation measures that will be considered and pursued as appropriate when siting and designing intakes in areas where water flows at surface at the monitoring location may be less than water availability assumed in the 2019 IPA (and downstream compliance may consequently be impacted) are also identified in this section. This section also includes contingency options that may be considered if follow-up activities and implementation of design modifications are insufficient to achieve the loading reductions required to meet Compliance Limits and SPOs as outlined in the 2019 IPA.

3.1 Follow-up Activities

The generalized workflow of follow-up activity is outlined in Figure 3-1, with the understanding that it will be modified on a site-by-site basis in reflection of data already collected and results of the evaluation outlined herein. The work flow consists of nine tasks. Tasks 1 to 6 are typically completed in support of intake siting and design; Tasks 7 and 8 are completed during detailed design and construction, and Task 9 is completed during operations. As outlined in Figure 3-1, the tasks involve the following activities:

1. Additional analysis of available groundwater information, including, as appropriate, use of 3D visualization tools and development of geological cross-sections to characterize and better understand:
   - local hydrogeology beneath waste rock and other source materials;
   - flow paths for mine-affected water between source materials and the receiving environment, including the sources targeted for treatment;
   - sediment thickness, permeability and potential for groundwater bypass at selected intake locations.
2. Additional water level and flow monitoring near potential intake locations, particularly in areas where intakes may be placed some distance from existing monitoring locations, to better define the proportion of total watershed yield that is flowing at surface at the location of the intake.
3. Flow accretion studies to understand and map gaining and losing reaches to support siting of intake structures in areas of groundwater discharge, where possible.
4. Geophysical surveys to characterize sediment thickness, permeability and support siting of intake structures.
5. Sediment sampling from settling ponds for permeability and particle size analysis to better define exfiltration rates from the ponds.
6. Drilling and installation of groundwater wells and subsequent water quality sampling and monitoring to understand heads, vertical gradients, potential seepage pathways and depth to bedrock to support siting and design of intake structures.

7. Groundwater modelling, where appropriate and warranted, to simulate seepage and quantify potential bypass of selected intake locations under varying flow conditions.
8. Analysis of groundwater monitoring data collected via site-specific and regional programs to validate and refine groundwater models.
9. Monitoring and modelling data used interactively to evaluate intake performance and identify if additional management actions are required.

Figure 3-1 Generalized Workflow of Follow-up Activity Related to Intake Design and Operation

1) Use visualization platform as an integrator of existing geologic, hydrogeologic, mine plan, topography, site features and engineering designs

2) Develop conceptual models for the local surface water - groundwater system

3) Identify data required to estimate bypass at selected sites (potential intake locations)

4) Perform field programs to obtain required information (e.g., geophysics, drilling, flow accretion, water quality sampling, hydraulic testing)

5) Update visualization and conceptual models based on results from the field programs

6) Develop numerical models to estimate bypass at selected sites (potential intake locations)

7) Update conceptual and numerical models based on inputs from design consultant (e.g., results of geotechnical surveys)

8) Update groundwater bypass predictions / Verify bypass estimates for final design (as-built) conditions - Finalize intake location

9) Conduct monitoring and modelling during operations to check performance and identify adjustments are required

Note: Points of potential interaction with the Regional Water Quality Model occur (1) between Tasks 6 and 7 wherein expected rates of bypass are used in the model and potential requirements for reduced bypass are given to the intake design team, (2) between Tasks 8 and 9 wherein expected rates of bypass from refined intake designs are used in the model and (3) as part of Task 9 wherein observed data are compared to projected concentrations.

The status of follow-up activity in each area targeted for treatment is presented in Table 3-1:

Table 3-1 Status of Follow-up Activities on Areas Targeted for Treatment

Areas Targeted for Treatment	Status of Follow-up Activities
FRO North (i.e., Clode Creek, Swift North Spoil and Swift Pit drainages)	• Tasks 1 through 4 are in progress • Tasks 5 and 6 are planned for 2019 • Tasks 7 and 8 will be completed in conjunction with design engineering in 2020 / 2021
FRO South – Swift and Cataract Creeks	• Tasks 1 to 6 are complete • Task 7 and 8 are in progress
FRO South - Kilmarnock Creek	• Tasks 1 to 5 are complete • Task 6 is in progress • Tasks 7 and 8 are planned for 2019
GHO (i.e., Leask, Wolfram, Thompson and Greenhills creeks)	• Scoping study is planned for 2019 and will involve the completion of Tasks 1 to 3, leading to recommendations for Task 4 • Schedule for subsequent tasks will be determined based on the outcome of the scoping study
LCO Dry Creek	• Tasks 1 to 8 are complete • Task 9 is on-going
LCO Line Creek (i.e., West Line Creek, Line Creek and MSAW)	• Intakes for existing facility are in place • Scoping study is planned for 2019, with a focus on understanding what will be required to support further mitigation in this drainage • Scoping study will involve the completion of Tasks 1 to 3, leading to recommendations for Task 4 • Schedule for subsequent tasks will be determined based on the outcome of the scoping study
EVO (i.e., Erickson, Bodie and Gate drainages)	• Tasks 1 to 4 are in progress • Tasks 5 and 6 are planned for 2019 • Tasks 7 and 8 are planned to be completed in conjunction with the design engineering in 2020 / 2021

Notes: EVO = Elkview Operations; FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; MSAW = Mine Services Area West.

3.2 Design Considerations and Mitigation

Optimal locations to capture mine-affected water are generally as follows:

- Downgradient of spoils and spoil runout zones, and up-gradient of floodplain sediments or disturbed areas with high expected infiltration rates.
- In areas where direct runoff (or the water at surface) represents a high percentage of the total watershed yield (i.e., a high percentage of the mine-affected water requiring collection and treatment).

Collection systems in valley flank settings will ideally be sited between the source and the floodplain sediments. Where possible, the collection system will be sited within gaining stretches of the stream, that is, where groundwater is discharging to surface water. This latter attribute is important in areas with thick sediments that could otherwise require cutoff walls or other interventions to attain target water capture rates. Collection systems within the floodplains will be avoided where possible. Capture of mine-influenced water within the main valley floodplain sediments is challenging because of the thickness of the sediments (up to 50 m) and the multiple potential pathways associated with the inherent high degree of heterogeneity. Collection systems downgradient of waste rock spoils overlying the floodplain, or waste rock spoils that are laterally connected to main valley floodplains, have a lower probability of intercepting mine-affected water once the water is in these sediments.

Recognizing that ideal conditions do not always exist, potential design considerations and/or additional mitigation measures that may be considered and evaluated when siting and designing intakes and supporting water management infrastructure include:

- Lining settling ponds where infiltration to ground may be a concern.
- Construction of earth berms with shallow cut-off trenches or upstream liners to increase groundwater capture.
- Installation and operation of shallow groundwater capture wells to reduce groundwater bypass.
- Designing intakes that are appropriate for the physical setting of the site, to achieve the required collection efficiency. For example:
    - Pumping from open water surfaces, such as a pit, to enhance capture. In-pit intakes could use a floating pump station, or another practical configuration. Capture rates of greater than 95% can be achieved with such designs, based on prior pit dewatering experience at Teck sites.
    - An earth berm with a shallow (up to 10 m) cutoff trench to impervious stratum may be suitable for tributary creeks where colluvium is shallow.
    - An earth berm with upstream liner may be suitable for tributary valley bottoms where colluvium is deep (e.g., > 10 m) and favourable groundwater conditions are available.
    - An earth berm with cutoff wall (e.g., slurry wall) anchored to bedrock or basal till may be suitable for tributary valley bottoms where colluvium is deep.
    - Groundwater wells may be suitable for main valley floodplains where colluvium is deep and significant mine-affected water flows subsurface.

Table 3-2 Follow-up Activities Related to Water Availability Assumptions in Sources Targeted for Treatment in the 2019 IPA

Area	Source	Year Treatment Begins	Results of Screening-Level Review	Follow-up Activity	Design Modifications and Mitigation Measures for Evaluation (if required)	Rationale
FRO North	Clode Creek	2023	• If the intake is situated near the existing flow monitoring point, flow at surface likely insufficient to meet target water availability. • Surface water and groundwater programs are underway or complete.	• Geophysics survey to better define local geology • Sediment sampling to characterize permeability of pond bottom • Potential installation of groundwater monitoring wells in the lower Clode Creek watershed to define water levels in the shallow groundwater system • Numerical modelling to identify dominant flow paths and better quantify potential bypass at a chosen intake location • On-going surface water and groundwater monitoring during operations to evaluate intake performance	• Placement of the intake in or upstream of the settling pond, rather than downstream of the pond • Evaluate lining and deepening the settling pond to reduce water loss to infiltration • Evaluate direct pumping of contact water from Eagle 4 pit and Eagle 6 pit to treatment to avoid loss to ground as waters flow through Clode Creek • If necessary, install shallow groundwater capture wells in Clode Creek floodplain downstream of the existing spoil to capture bypass	• Ponds are in main valley floodplain where colluvium is deep. Floodplain is an area of shallow groundwater recharge, with water moving from the floodplain to the river mainstem • Intake cannot be placed in an area outside of the river floodplain, due to spatial constraints • Better understanding of shallow groundwater flow in lower Clode Creek is required to inform intake design • Capture wells may be necessary if changes to pond configuration and direct pumping of water to treatment are insufficient to capture enough contact water for treatment
	Swift North Spoil Drainage and Swift Pit	2023	• Limited monitoring data are available to evaluate water availability. Placement of intakes on the valley flanks outside of the Fording River floodplain support higher water availability than locations in the floodplain • Surface water and groundwater programs are underway or complete.	• Geophysics survey to better define local geology • Sediment sampling to characterize permeability of pond bottoms • Potential installation of groundwater monitoring wells to define water levels in the shallow groundwater system • Numerical modelling to identify dominate flow paths and quantify potential bypass at selected intake locations • On-going surface water and groundwater monitoring during operations to evaluate intake performance	• Pump water directly from Swift Pit or Lake Mountain Pit to treatment • If necessary, consider installing shallow groundwater capture wells downstream of disturbed areas that drain directly to Fording River floodplain, bypassing the aforementioned settling ponds	• Lake Mountain, Liverpool and Post settling ponds are located above the floodplain in areas of limited groundwater recharge; lining is therefore considered unlikely to be required • Turnbull Bridge Spoil is in main valley floodplain where colluvium is deep (likely more than 30 m); spoil drainage may bypass intakes placed farther upstream • Better understanding of shallow groundwater pathways in lower portions of the two watershed areas is required to inform intake design and identify potential groundwater bypass
FRO South	Swift Creek and Cataract Creek	2021	• Flow at surface likely sufficient to meet target water availability • Groundwater bypass has been estimated with 2D numerical model (Amec Foster Wheeler 2017) • Surface water and groundwater programs are underway or complete.	• Continue with existing and planned monitoring	• None	• Not applicable
	Kilmarnock Creek	2021	• If the intake were situated near the existing flow monitoring point, flow at surface likely insufficient to meet target water availability, particularly during lower flow months. • Surface water and groundwater programs are underway or complete.	• Geophysics survey to better define local geology • Numerical modelling to quantify potential bypass at selected intake locations • Evaluations are underway to move the intake.	• Relocating the Kilmarnock intake further upstream where groundwater bypass component may be smaller. • Based on results of operational monitoring, potential use of trenching or cut-off walls to limit the flow of contact water into the alluvial fan that underlies the lower portion of Kilmarnock Creek within the Fording River floodplain	• Estimates of instream flow decreased notably following change to flow monitoring methods • Limited opportunity to relocate the intake further upstream for safety concerns (close to spoils) • If necessary, may be able to limit infiltration into the alluvial fan through the use cut-off trenches and/or cut-off walls near the downstream end of the Kilmarnock Creek rock drain • Better understanding of local geology and shallow groundwater pathways downstream of the Kilmarnock Creek rock drain is required to support mitigation planning if a suitable intake location outside of the floodplain cannot be identified

Table 3-2 Follow-up Activities Related to Water Availability Assumptions in Sources Targeted for Treatment in the 2019 IPA

Area	Source	Year Treatment Begins	Results of Screening-Level Review	Follow-up Activity	Design Modifications and Mitigation Measures for Evaluation (if required)	Rationale
GHO	GHO Elk River Tributaries (Leask Creek, Wolfram Creek and Thompson Creek)	2031	• Monitored to modelled flow ratios often at or above 95% in lower flow months • During higher flow periods, monitored to modelled flow ratios suggest that flow at surface likely insufficient to meet target water availability. However, the treatment capacity planned for GHO is relatively small (i.e., in the order of 2,500 to 5,000 m^3/d). As a result, it can likely be kept at capacity during high flow months at a water availability of less than 95% • Winter flow data are limited, and the lower reaches of Leask, Wolfram and Thompson creeks are known areas of groundwater recharge	• Geophysics survey to better define local geology • Flow accretion studies to identify areas of groundwater recharge upstream of existing settling ponds • Additional modelling to better define dominant flow paths and quantify potential bypass at chosen intake locations • On-going surface water and groundwater monitoring during operations to evaluate intake performance	• Line existing settling ponds to limit infiltration • Place intakes upstream of lined ponds, in areas of groundwater discharge • Pump water directly from Cougar Pit South to treatment to avoid loss to groundwater during travel through tributary streams • Potential use of groundwater capture wells if required to meet Compliance Limits and SPOs	• Sedimentation ponds are located in areas of known groundwater recharge • Topographical constrains may result in intakes being positioned in the lower portions of each watershed, in or near the existing settling ponds • Use of pond liners should provide an effective means of limiting infiltration across the ponds; however, evaluation needs to consider how liners and reduction in infiltration may affect pond performance with respect to TSS control • Better understanding of groundwater conditions in lower watershed areas will allow for more refined modelling and better estimation of potential bypass at selected intake locations
	Greenhills Creek	2031	• Monitored to modelled flow ratios comparable to assumed water availability in lower flow months • Limited information near assumed intake location to verify the assumed water availability	• Geophysics survey to better define local geology • Flow accretion studies to identify areas of groundwater recharge upstream of existing settling ponds • Additional modelling to better define dominate flow paths and quantify potential bypass at chosen intake locations • On-going surface water and groundwater monitoring during operations to evaluate intake performance	• None	• Have not yet identified a need for potential mitigation or design modification
LCO – Dry Creek	Dry Creek upstream of the East Tributary	2037	• Flow at surface likely sufficient to meet target water availability • Bypass to groundwater has been estimated with 3D numerical model (Golder 2016) • Surface water and groundwater programs are underway or complete.	• None beyond monitoring already planned	• None	• Not applicable
LCO – Line Creek	West Line Creek	2016	• Flow at surface likely sufficient to meet target water availability	• None beyond monitoring already planned	• None	• Not applicable
	Mine Services Area West	2018	• No monitoring data are available to evaluate water availability near the potential intake location	• Collect surface flow data in the vicinity of the potential intake location • Compare monitored and modelled information to assess water availability	• Design modifications, if required, to be determined once follow-up activities are complete	• Do not have sufficient monitoring data for the location in question upon which to identify if design modifications are required and what form they may take
	Line Creek upstream of West Line Creek	2016	• Monitored to modelled flow ratios suggest flow at surface may be insufficient to meet target water availability in lower flow months • Limited groundwater information near assumed intake location to verify the assumed water availability.	• Continue monitoring already planned • Additional groundwater investigations for future phases as per work flow identified in Figure 3-1	• Design modifications, if required to support future phases of the WLC AWTF, to be determined once follow-up activities are complete	• Existing intakes are sufficient to meet the needs of the current configuration of the WLC AWTF • Require more groundwater information to identify if and how the existing intakes may need to be modified to support the assumed water availability as the AWTF expands

Table 3-2 Follow-up Activities Related to Water Availability Assumptions in Sources Targeted for Treatment in the 2019 IPA

Area	Source	Year Treatment Begins	Results of Screening-Level Review	Follow-up Activity	Design Modifications and Mitigation Measures for Evaluation (if required)	Rationale
EVO	Erickson Creek	2022	• Available information flow at surface may be insufficient to meet target water availability; however, comparisons are based on a location that may not be representative of conditions at the planned intake where no data are available • Surface water and groundwater investigations are currently underway.	• Analysis of geophysical survey data, • Collection of surface flow measurements near the planned intakes, • Completion of flow accretion studies • Drilling programs	• Locate intake in section of Erickson Creek where groundwater discharge occurs (i.e., position intake in a gaining reach, but outside of the Michel Creek floodplain) • If necessary, consider use of a cut-off wall or trench in lower areas of Erickson Creek where valley becomes constricted and water travelling subsurface in upper areas comes to surface	• Immediately downstream of the spoil, surface flows are largely absent and subsurface flow paths dominate • Further downstream, groundwater discharge occurs and surface flows are present • Positioning the intake in this lower reach will help to minimize groundwater bypass, while maintaining the intake outside of the influence of the Michel Creek floodplain • The natural constriction of the Erickson Creek valley may be supportive of cut-off technology, should additional mitigation be required to achieve desired levels of contact water capture
	Bodie Creek and Gate Creek	2022	• Available information suggests flow at surface may be insufficient to meet target water availability during high flow months. • Surface water and groundwater investigations are currently underway.	• Analysis of geophysical survey data, • Collection of surface flow measurements near the planned intakes, • Completion of flow accretion studies • Drilling programs	• Line existing settling ponds to limit infiltration or place intakes upstream of the Michel Creek floodplain • Pump water directly from Natal Pit to treatment to avoid loss to groundwater during travel through Bodie and/or Gate Creek • Consider use of groundwater capture wells downstream of sediment ponds if groundwater bypass is higher than desired	• Existing settling ponds are located within the Michel Creek floodplain and are subject to infiltration • Use of pond liners should provide an effective means of limiting infiltration across the ponds • Better understanding of ground conditions in lower watershed areas will allow for more refined modelling and better estimation of potential bypass at selected intake locations

FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; EVO = Elkview Operations

3.3 Potential Contingency Options

The 2019 IPA was developed based on an approach of prioritizing mine-influenced tributaries, targeting those with the highest selenium concentrations and largest loads for treatment, and identifying the treatment necessary to produce, to the extent possible, concentrations that meet the Compliance Limits and SPOs outlined in Permit 107517. The projected effect of treatment on concentrations in the receiving environment is dependent on assumed effluent quality and the amount of water that can be effectively captured and directed to treatment. As outlined in Annex C, assumptions concerning effluent quality are supported by data collected from the WLC AWTF. Design modifications and mitigation measures that will be evaluated, if and as required, to achieve necessary rates of water capture at intake locations within tributaries targeted for treatment are identified in Table 3-2. As a result, the 2019 IPA should result in concentrations that meet Compliance Limits and SPOs as detailed in Annex F.

Should monitoring results indicate that the measures currently outlined in the 2019 IPA are insufficient to achieve projected rates of compliance, Teck will evaluate and implement contingency options, as appropriate. Potential contingency options include:

- Relocating intakes within targeted tributaries to more effective locations, if the design modifications and mitigations measures prove to be insufficient and on-going monitoring identifies more suitable locations.
- Using multiple intakes within a targeted tributary to increase water capture rates (e.g., combining in-pit intakes with those positioned further downstream to optimize capture rates amongst backfilled pits and aboveground spoils).
- Targeting additional sources for treatment, such as:
  - Sources in Henretta Creek at FRO,
  - Mickelson Creek and/or Willow Creek at GHO, and
  - EVO Dry Creek at EVO.

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