Elk Valley Water Quality Plan

2019 Implementation Plan Adjustment

Annex D: Clean Water Diversion Evaluation

July 2019

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ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
AWT	active water treatment
AWTF	Active Water Treatment Facility
CWD	clean water diversion
EVO	Elkview Operations
EVWQP	Elk Valley Water Quality Plan
FRO	Fording River Operations
GHO	Greenhills Operations
IPA	Implementation Plan Adjustment
IIP	Initial Implementation Plan
LCO	Line Creek Operations
RWQM	Regional Water Quality Model
Teck	Teck Coal Limited
WLC	West Line Creek

UNITS OF MEASURE

Unit of Measure	Description
%	percent
km	kilometre
km^2	square kilometre
m	metre
m^3/day	cubic metres per day
masl	metres above sea level
µg/L	micrograms per litre

1 Introduction

1.1 Background

Clean water diversion (CWD) involves the construction of earthen dikes or other physical barriers and/or pipes or other conduits to route clean water from non-mine-impacted areas around mining activities. In the Elk Valley Water Quality Plan (EVWQP, Teck 2014), it was identified that:

- CWDs can reduce the volume of water affected by waste rock, thereby reducing the amount of water that needs to be treated.
- CWDs have a larger potential to be effective when they involve the diversion of large, upstream, undisturbed watersheds, such as Upper Line Creek at Line Creek Operations (LCO) and Upper Kilmarnock Creek at Fording River Operations (FRO).

During the EVWQP, water treatment costs were estimated based on the volume of water requiring treatment, which supported the inclusion of CWDs in the Initial Implementation Plan (IIP).

Teck Coal Limited (Teck) built and operated two gravity-flow CWDs prior to the EVWQP: one at FRO on Kilmarnock Creek and one at Greenhills Operations (GHO) on Swift Creek. Lessons learned from these projects suggest that piped CWDs may be the preferred option to reduce the risk of seepage loss and freezing, although this approach will be considered on a case-by-case basis during the design of each individual CWD project.

It was Teck's understanding during the development of the EVWQP that, by reducing the volume of clean water that comes in contact with mine waste, CWD could help stabilize and reduce selenium and other water quality concentrations in the following two ways:

- By reducing the amount of selenium and other constituents of interest downstream (i.e., when combined with an active water treatment facility [AWTF] with a fixed effluent concentration, more load can be removed from a more concentrated influent stream than one that is more dilute).
- By reducing the estimated cost of mitigation based on the understanding that hydraulic capacity was the primary cost factor in the implementation of active water treatment (AWT).

Table 1-1 shows CWDs included in the EVWQP and their respective capacities, operational dates and the AWTF to which they are associated. CWDs were planned to be commissioned at the same time as associated AWTFs. As a result, operational dates for the Kilmarnock and Erickson Creek CWDs have been updated with the operational dates for their associated AWTFs in *Environmental Management Act* Permit 107517. In the IIP, CWDs at FRO and Elkview Operations (EVO) were sized to convey freshet (May) flows in an average year, as estimated at that time. The size of the CWD at LCO reflected analyses done in support of the LCO Phase II Environmental Assessment Certificate Application (Teck 2011).

Table 1-1 Clean Water Diversions Included in the Elk Valley Water Quality Plan

Clean Water Diversion	Streams and Volume Diverted	Date Operational	Associated Active Water Treatment Facility (AWTF)
Kilmarnock Creek	Upper Brownie and Kilmarnock watersheds, estimated at 45,000 m^3/d	December 31, 2018	FRO AWTF-S
Erickson Creek	Upper Erickson watershed, estimated at 14,000 m^3/d	December 31, 2020	EVO AWTF 1
South Gate Creek	South Gate Creek, estimated at 3,500 m^3/d	December 31, 2020	EVO AWTF 1
Upper Line, Horseshoe and No Name creeks	Upper Line, Horseshoe and No Name creeks, estimated at 35,000 m^3/d	2032	WLC AWTF 2

AWTF = active water treatment facility; EVO = Elkview Operations; FRO = Fording River Operations; WLC = West Line Creek.

Management Question 3 of the Adaptive Management Plan (i.e., Are the combinations of methods for controlling selenium, nitrate, sulphate and cadmium included in the implementation plan the most effective for meeting limits and SPOs?) includes a key uncertainty around CWDs, which is as follows: is clean water diversion a feasible and effective strategy to support water quality management? This annex provides an evaluation based on current information.

1.2 Conceptual Model

The conceptual model of constituent release is that the mass of constituents released from waste rock is a function of water entering a waste rock pile via precipitation. CWDs reduce the volume of water flowing through the base of a waste rock pile. The run-on (run-off from up-gradient natural catchment areas) is understood to dominantly flow through the coarse rubble zone at the base of the waste rock piles (also referred to as rock drains) and has little interaction with the bulk of the overlying waste rock material. The conceptual model is informed and supported by research conducted by Wellen et al. (2018) and by Villeneuve et al. (2017).

The conceptual understanding of how CWDs influence AWT has changed since the EVWQP. While CWDs reduce the volume of water requiring treatment by helping concentrate streams for treatment, Teck's understanding of the primary cost factor in AWT has changed. During the EVWQP, AWTFs were modelled and costs were estimated based on the volume of water requiring treatment (further supporting the inclusion of CWDs in the IIP). Teck's current understanding of biological AWT design and associated costs is that treatment design and costs are largely dependent on the amount of nitrate and selenium removal required (e.g., the required nitrate and selenium load removal), not just the volume of water requiring treatment. Considering the conceptual model for CWDs (that the amount of selenium, nitrate and other water quality constituents released is not impacted by diversion), in most cases CWDs do not have a cost efficiency benefit to biological AWT, nor will they result in water quality improvement without treatment as the total load remains the same.

Based on this change, an evaluation of each CWD identified in the EVWQP was completed to inform CWDs included in the 2019 IPA. The evaluation was conducted with reference to technical feasibility to construct and operate the CWDs and their influence on downstream water quality.

1.3 Regulatory Context

Permit requirements related to CWDs are summarized in Table 1-2.

Table 1-2 Permit Requirements Related to Clean Water Diversions

Permit	Requirements
***Environmental Management Act* Permit 107517**	**Section 8.2 RESEARCH AND TECHNOLOGY DEVELOPMENT**
Section 8	Section 8.2.1.iii. Research areas shall include, but not be limited to, the following topics: a) geochemical release mechanisms, release rates and relationships between factors that influence contaminant release; b) saturated and unsaturated flow mechanisms in waste piles; c) mine waste rock management and dump design alternatives; d) cover systems including soil and vegetative covers, complex soil covers and geomembranes; e) water capture, diversion and conveyance systems.
FRO Permit C-3 Permit Amendment Approving Water Quality and Calcite Mitigation Strategy November 27, 2014	Section B. 2. Water Treatment and Water Conveyance Works a. General i. All mitigation, including water diversions, seepage collection and conveyance works and water treatment facilities, shall be operated and maintained for as long as is necessary to achieve the objective and timelines for water quality, consistent with the Elk Valley Water Quality Plan, and as required by the Chief Inspector. ii. Detailed design for water diversions, seepage collection and conveyance works, water treatment works, and water treatment waste management works shall be approved by the Chief Inspector prior to construction. b. Mine Specific Mitigation i. The Permittee shall ensure that all phases of water conveyance and water treatment works for Kilmarnock Creek, Swift Creek, Cataract Creek, Clode Creek, North Spoil, and Swift Pit are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. ii. The Permittee shall ensure that water diversions for Upper Brownie and Kilmarnock watersheds are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. Section B. 6. Research and Technology Development a. Research Activities iii. Research areas shall include, but not be limited to, the following topics: • Water capture, diversion and conveyance systems
GHO Permit C-137 Permit Amendment Approving Water Quality and Calcite Mitigation Strategy November 27, 2014	Section B. 2. Water Treatment and Water Conveyance Works a. General i. All mitigation, including water diversions, seepage collection and conveyance works and water treatment facilities, shall be operated and maintained for as long as is necessary to achieve the objective and timelines for water quality, consistent with the Elk Valley Water Quality Plan, and as required by the Chief Inspector. ii. Detailed design for water diversions, seepage collection and conveyance works, water treatment works, and water treatment waste management works shall be approved by the Chief Inspector prior to construction. b. Mine Specific Mitigation i. The Permittee shall ensure that all phases of water conveyance and water treatment works for Thompson, Leask, Wolfram and Greenhills Creeks are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. ii. The Permittee shall ensure that water diversions are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. Section B. 6. Research and Technology Development a. Research Activities iii. Research areas shall include, but not be limited to, the following topics: • Water capture, diversion and conveyance systems
LCO Permit C-129 Permit Amendment Approving Water Quality and Calcite Mitigation Strategy November 27, 2014	Section B. 2. Water Treatment and Water Conveyance Works a. General i. All mitigation, including water diversions, seepage collection and conveyance works and water treatment facilities, shall be operated and maintained for as long as is necessary to achieve the objective and timelines for water quality, consistent with the Elk Valley Water Quality Plan, and as required by the Chief Inspector. ii. Detailed design for water diversions, seepage collection and conveyance works, water treatment works, and water treatment waste management works shall be approved by the Chief Inspector prior to construction. b. Mine Specific Mitigation Permit condition D.1.(e) for Selenium Active Water Treatment of the July 9, 2012 Mine Act permit amendment is herby replaced with the following conditions: i. The Permittee shall ensure that all phases of water conveyance and water treatment works for West Line Creek, Line Creek and Dry Creek are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. ii. The Permittee shall ensure that water diversions for Upper Line Creek, Horseshoe Creek and No Name Creek are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. Section B. 6. Research and Technology Development a. Research Activities iii. Research areas shall include, but not be limited to, the following topics: • Water capture, diversion and conveyance systems
EVO Permit C-2 Permit Amendment, Approving Water Quality and Calcite Management Strategy, November 27, 2014	Section B. 2. Water Treatment and Water Conveyance Works a. General i. All mitigation, including water diversions, seepage collection and conveyance works and water treatment facilities, shall be operated and maintained for as long as is necessary to achieve the objective and timelines for water quality, consistent with the Elk Valley Water Quality Plan, and as required by the Chief Inspector. ii. Detailed design for water diversions, seepage collection and conveyance works, water treatment works, and water treatment waste management works shall be approved by the Chief Inspector prior to construction. b. Mine Specific Mitigation i. The Permittee shall ensure that all phases of water conveyance and water treatment works for Bodie, Gate, and Erickson Creeks are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. ii. The Permittee shall ensure that water diversions for Upper Erickson watershed and South Gate Creek are designed, constructed and operated in sufficient time and at sufficient capacity to meet objectives and timeframes for water quality consistent with the Elk Valley Water Quality Plan. Section B. 6. Research and Technology Development a. Research Activities iii. Research areas shall include, but not be limited to, the following topics: • Water capture, diversion and conveyance systems

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

2 Evaluation

2.1 Methods

2.1.1 Evaluation Criteria

Two criteria were used in the evaluation:

- Technical feasibility and operability
- Potential water quality improvements

Each of these criteria and the methods by which they were evaluated are described below.

2.1.1.1 Technical Feasibility and Operability

A qualitative evaluation of the constructability and operability of CWDs to convey different flow volumes was completed. This evaluation was based on a review of site conditions (i.e., photos, geological/topographical maps, mine plans, elevations, geotechnical conditions) and incorporation of prior experience constructing and operating CWDs or similar infrastructure in the Elk Valley.

2.1.1.2 Potential Water Quality Improvements

Potential water quality benefits of including CWDs at LCO, FRO and EVO were examined using the 2017 Regional Water Quality Model (RWQM), as described in Teck (2017) and modified as outlined in Annex B. The assessment consisted of running the 2017 RWQM under the Permitted Development Scenario with different sized CWDs in place at each of the three operations and identifying how projected maximum monthly selenium concentrations at the nearest downstream compliance point changed in response to changes to the size of the CWD.

Five different CWD configurations were considered, capturing a range of possible CWD sizes in order to examine projected patterns in downstream concentrations. They were tested sequentially at each operation under low, average and high flow conditions. The five configurations consisted of the following (Table 2-1):

- A “no CWD” configuration that consisted of the 2019 IPA without CWDs (i.e., AWTFs sized and phased per the 2019 IPA, but without inclusion of CWDs).
- CWDs sized, and AWTFs sized and phased, per the 2019 IPA, with one exception; the CWD at FRO (Kilmarnock Creek) was sized at 10,000 m^3/d. At the time the evaluation was conducted, the size of the Kilmarnock Creek Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. The size was subsequently increased, initially to 45,000 m^3/d to be consistent with the EVWQP and then to 86,000 m^3/d. The larger sizing reflects additional water modelling and analysis done as part of the scoping stage of the Kilmarnock Creek CWD Project. The Kilmarnock Creek CWD Project will design, permit and construct the Kilmarnock Creek CWD and has been proceeding in parallel to the 2019 IPA. Work done in support of a larger sized CWD will be described through the Kilmarnock Creek CWD Project (and permit application) later in 2019 and into 2020.

- CWDs sized to accommodate average monthly flows in May (calculated based on average flow conditions), with AWTFs sized and phased per the 2019 IPA.
- CWDs sized to accommodate average annual flows (calculated based on average flow conditions), with AWTFs sized and phased per the 2019 IPA.
- CWDs sized to accommodate average monthly winter flows (i.e., average monthly flow from November to February, calculated based on average flow conditions), with AWTFs sized and phased per the 2019 IPA.

Table 2-1 Clean Water Diversions Considered in the Evaluation

Operation	Target Creek	Fully Effective Date in 2019 IPA	Hydraulic Capacity (m^3/d)				
			No CWD Scenario (2019 IPA without CWDs)	2019 IPA	Average Monthly Flow in May	Average Annual Monthly Flow	Average Monthly Winter Flow
FRO	Kilmarnock Creek[(a)]	31-Dec-2020	–	10,000[(b)]	40,000	22,500	5,500
LCO	Upper Line Creek (Main Line Creek and Horseshoe Creek)	31-Dec-2025	–	35,000	162,000	60,500	18,500
	No Name Creek	31-Dec-2025	–	7,000	9,000	3,500	1,000
EVO	Erickson Creek	1-Oct-2022	–	–	16,500	8,000	5,500

(a) Kilmarnock Creek Clean Water Diversion Project is ongoing and includes a more detailed assessment of the sizing and timing of the diversion, and of constructability and operability considerations. This more detailed assessment may result in changes to the sizing, timing or operational approach of the diversion.

(b) At the time the evaluation was conducted, the size of the Kilmarnock Creek clean water diversion to be included in the 2019 IPA was set to 10,000 m^3/d. It was subsequently increased to 45,000 m^3/d (to be consistent with the EVWQP) and than to 86,000 m3/d (to be consistent with additional modelling and analysis completed to date as part of the Kilmarnock Creek Clean Water Diversion Project).

CWD = clean water diversion; EVO = Elkview Operations; FRO = Fording River Operations; IPA = Implementation Plan Adjustment; LCO = Line Creek Operations.

The evaluation was conducted starting with FRO, then LCO and finally EVO. The sizing and phasing of CWDs and AWTFs at LCO and EVO were as per the 2019 IPA when conducting the CWD evaluation at FRO. Similarly, the sizing and phasing of CWDs and AWTFs at FRO and EVO were as per the 2019 IPA when conducting the CWD evaluation at LCO, and so on at EVO. The only exception was that, when evaluating conditions at LCO and EVO, the CWD at FRO (Kilmarnock Creek) was sized at 10,000 m^3/d.

The evaluation was conducted with a focus on selenium concentrations during the 20-year planning window because it was generally found to be the limiting constituent. The 20-year planning window was used to provide a reasonable temporal boundary to the evaluation.

The evaluation was also conducted assuming waters draining from undisturbed areas upstream of a CWD flow through the CWD and discharge to the receiving environment at or downstream of AWTF outfalls. This approach was consistent with the methods used to evaluate the potential benefits of CWDs in the EVWQP. It results in the isolation of the targeted undisturbed area from the rest of the watershed (i.e., non-contact runoff from this area does not interact with contact runoff from other parts of the watershed, nor is it available for use in supplementing flow into the AWTF when the AWTF is operating below its hydraulic capacity).

In response to a request from BC Ministry of Environment and Climate Change (ENV), the evaluation at Kilmarnock Creek was repeated using a different assumption. Water from mine affected and undisturbed areas upstream of the proposed intake to the FRO AWTF-S was sent to the AWTF. When the AWTF was operating at capacity (be that hydraulic capacity or its nitrate design load removal), then excess water from undisturbed areas was diverted through a CWD and discharged to the downstream environment. The purpose of this evaluation was to identify if a more active approach to the operation of a CWD would affect its influence on downstream water quality.

2.1.2 Scoring

The results of the individual evaluations completed as described in Section 2.1.1 were summarized, reviewed and assigned a colour-based score, based on the scoring system outlined in Table 2-2. Scores across the two criteria for each CWD were then reviewed to identify the relative merits of the option under consideration, as well as the merits of including a CWD of any size at the operation under evaluation. If, through the evaluation of feasibility and operability, a CWD was deemed not feasible to construct and/or operate, it was not evaluated further and not included in the 2019 IPA.

Table 2-2 Scoring Matrix Used for the Clean Water Diversion Evaluation

Criteria	Scoring System
Feasibility and Operability	Red = complex to build and operate / not likely to be feasible Yellow = challenging to construct and operate effectively Green = straightforward to construct and operate, or have sufficient in-house knowledge to overcome expected challenges
Potential to Improve Water Quality	Based on average projected changes to maximum projected selenium concentrations from the modelling scenario without CWD in place Red = ≤1 µg/L difference at nearest compliance point / Order Station Yellow = >1 and ≤ 5 µg/L difference at nearest compliance point / Order Station Green = >5 µg/L difference at nearest compliance point / Order Station

AWTF = active water treatment facility; CWD = clean water diversion.

2.2 Results

2.2.1 Fording River Operations – Kilmarnock / Brownie Creeks

2.2.1.1 Technical Feasibility and Operability

Site Conditions

The combined Brownie and Kilmarnock Creek drainages make up an estimated total area of ~44 km^2, which consists of the following:

- Brownie Creek Drainage (west/north side): ~8 km^2 of area (mine contact water).
- Brownie Creek Drainage (east/south side): ~7 km^2 of area (non-contact water).

- Upper Kilmarnock Drainage: ~16 km^2 of area with (non-contact water).
- Lower Kilmarnock Drainage (south side): ~6 km^2 of area (non-contact water).
- Lower Kilmarnock Drainage (north side): ~7 km^2 of area (mine contact water).

The non-contact water area (e.g., the area from which non-contact water would be collected for diversion) in the Brownie Creek drainage accounts for ~15% of the estimated total drainage area. The non-contact water area in the Kilmarnock Creek drainage accounts for ~50% of the estimated total drainage area.

Brownie Creek is a small stream with limited surface water flow. It flows into (and comes in contact with) the Brownie waste rock spoils at FRO. Flow in Brownie Creek is not monitored due to its remoteness and low flow. Based on observation, a minimal (~1 m wide) amount of flow is available, likely due to it being located in an area dominated by scree slopes where flows may not be confined to the surface.

Kilmarnock Creek, which consists of both the Upper and Lower Kilmarnock Creek drainages, eventually drains into the Fording River, but is subsurface for a downstream stretch prior to connecting the Fording River. A large portion of Kilmarnock Creek comes in contact with waste rock to the north.

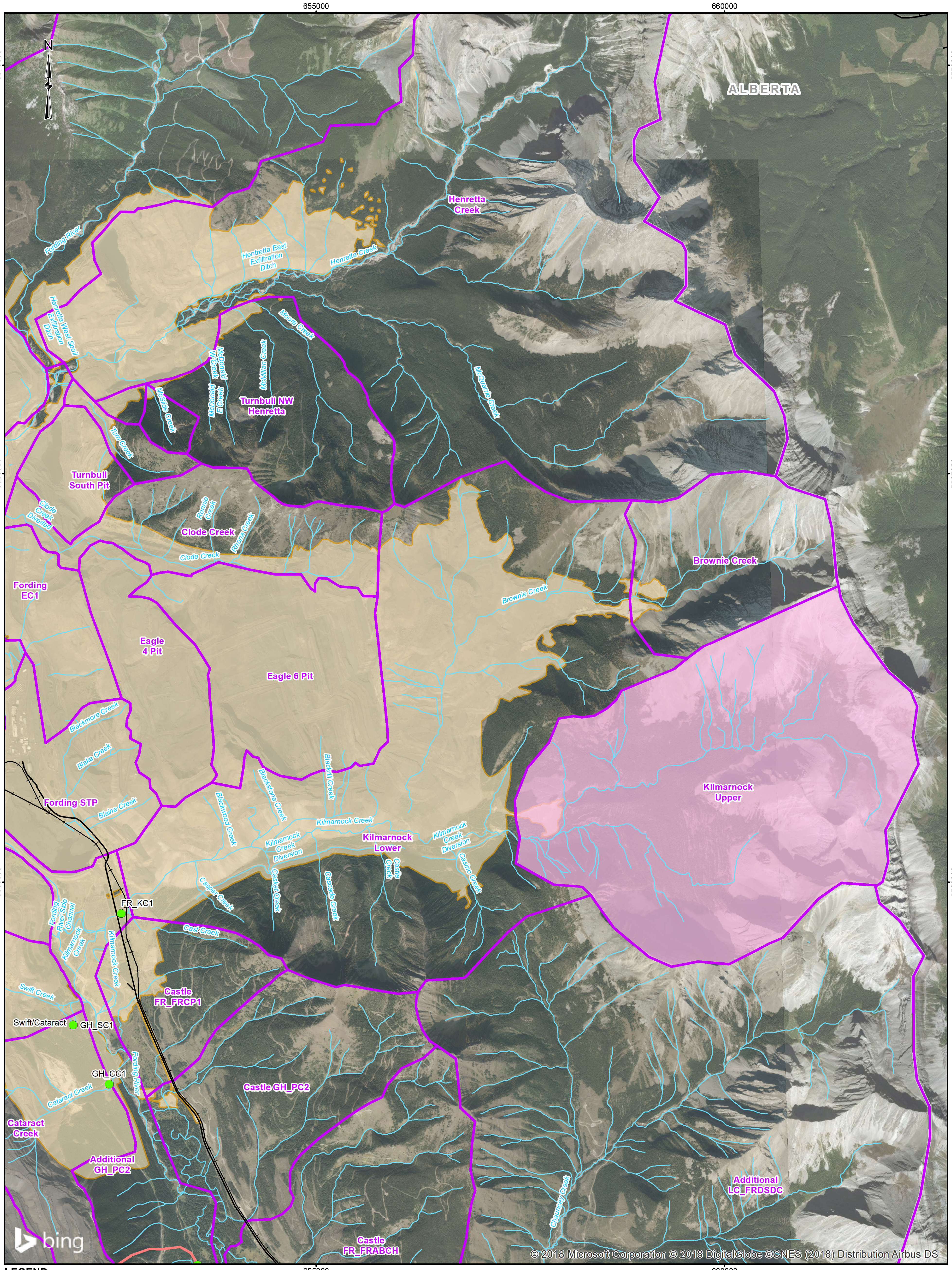
The elevation of the Brownie Creek drainage headwaters is ~2,100 metres above sea level (masl). The headwaters of the Upper Kilmarnock Creek drainage is ~1,800 masl. The estimated discharge point of the Kilmarnock Creek CWD is at ~1,600 masl; an elevation difference of ~500 m and ~200 m from the headwaters of the Brownie Creek and Kilmarnock Creek drainages, respectively. Both drainages are in narrow valleys with existing waste rock piles on one side and steep, rugged mountain terrain on the other side(s). Small streams with peaky freshet flows are scattered along the non-mine-impacted mountain side slopes in both drainages.

Access to these drainages is limited. Utilities (mainly power for potentially pumping water) are not in proximity to either drainage; the closest power for the Brownie Creek drainage is ~4 to 5 km away and a similar distance (with access challenges) away for the Upper Kilmarnock Creek drainage.

Existing access to Upper Kilmarnock Creek is available because of the previous Kilmarnock Creek Diversion project, but it would need to be upgraded. Access to Brownie Creek is available via the FRO mine site, but limited due to active mining.

A map of the Brownie and Kilmarnock Creek drainages is shown in Figure 2-1.

Document Path: S:\Clients\Teck_Resources\ElkValley\99_PROJ\1792554_Teck\40_PROD\0006_Clean_Water_Diversion_Annex\1792554-0006-CS-0001.mxd



LEGEND

- MONITORING / MODELLING NODE
- CITY/TOWN/COMMUNITY
- ROAD
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- BRITISH COLUMBIA - ALBERTA PROVINCIAL BOUNDARY
- FORDING RIVER OPERATIONS C-3 PERMIT BOUNDARY
- FRO SUB-WATERSHED
- FRO CLEAN WATER DIVERSION SUB-WATERSHED
- BROWNIE CREEK — SUB-WATERSHED NAME

2 0 2

SCALE 1:45,000 KILOMETRES

WATER QUALITY IMPLEMENTATION PLAN

TITLE

POTENTIAL CLEAN WATER DIVERSION AT FORDING RIVER OPERATIONS UNDER THE PERMITTED DEVELOPMENT SCENARIO (2037 SNAPSHOT)

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	PR	27 Aug. 2018	SCALE AS SHOWN	REV. A
GIS	PR	28 Aug. 2018		
CHECK	ES	28 Aug. 2018	**FIGURE: 2-1**	
REVIEW	JPB	28 Aug. 2018		

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

Assessment of Technical Feasibility and Operability

Brownie Creek Drainage

As identified above, the Brownie Creek drainage is a relatively small, isolated drainage area in the upper watershed. This drainage:

- Has a non-contact water area (e.g., the area from which non-contact water would be collected for diversion) that accounts for ~15% of the estimate total Brownie and Kilmarnock Creek drainage area.
- Has limited access via the FRO mine site due to active mining.
- Is located in steep, mountainous terrain.
- Is remote from utilities (mainly power). The closest power is ~4 to 5 km away.
- Would require pumping (and associate power for pumping) of Brownie Creek up and over mountainous terrain to Upper Kilmarnock Creek.

Consequently, constructing, operating and maintaining a diversion of Brownie Creek is anticipated to be extremely difficult. These factors, coupled with the relatively small non-contact drainage area, removed the Brownie Creek diversion from further consideration and evaluation.

Kilmarnock Creek Drainage

In 2011, Teck built and operated a gravity-flow, open channel, diversion of Kilmarnock Creek as described in Section 1.1. This diversion experienced operational challenges and was shut down following a regional flood event in 2013 for the following reasons:

- Waters from the slope flowed sub-surface for the majority of the year, bypassing the channel and limiting effective collection.
- Ice anchoring in the winter months resulted in water over-topping the diversion channel, limiting collection and increasing geotechnical risks.

Some portions of the existing diversion remain intact. Experience from the previous Kilmarnock Creek diversion will influence the design, construction, operation and maintenance of subsequent diversions.

The potential of moving from an open channel to a closed pipeline design will be considered for CWDs, maximizing gravity flow and collecting only upstream flows, but reducing the risk of slope water flow bypassing (and/or damaging) the CWD and ice causing water to over-top a diversion channel.

As identified above, the Upper Kilmarnock, non-contact water, drainage area plus the Lower Kilmarnock, non-contact water, drainage area, accounts for ~50% of the estimated total Brownie and Kilmarnock Creek drainage area. Through operation of the 2011 diversion, it was shown that most of the water from the non-contact water area of the Lower Kilmarnock Creek drainage (south side of the Lower Kilmarnock Creek with ~6 km^2 of area) is surficial during freshet but runs sub-surface during the rest of the year. Taking into account this sub-surface flow path results in a reduction of the non-contact water drainage area (and water from this area) to ~35% of the total drainage area that could be diverted during all times of the year except for freshet, regardless of whether the diversion is constructed as an open channel or as a pipeline.

In terms of constructability, existing access to Upper Kilmarnock Creek is available because of the previous diversion project, but it would need to be upgraded. Similar to Brownie Creek, this diversion is located in steep, mountainous terrain, making construction, operation and maintenance challenging. Another constructability challenge is that both the previous diversion alignment and the conceptual alignment for the next conceptual diversion are located across the narrow valley from active waste rock piles (i.e., waste rock continues to be added to these piles). This poses a constructability, operability and maintainability risk with respect to access considering the required safe working distance from these waste rock piles (i.e., outside the run-out zone). It also poses a risk to the design of the diversion as the diversion may be required to be placed farther up the slope, increasing the geotechnical risk.

2.2.1.2 Potential Water Quality Improvements

Results of the modelling exercise indicate that inclusion of a CWD in the Kilmarnock drainage should result in improved water quality at the FRO compliance point. Reductions in projected maximum monthly selenium concentrations between 2021 and 2037 were between 1 to 4 µg/L, regardless of the approach used to represent the operation of the diversion (i.e., isolation of water draining from the targeted undisturbed area or diversion of non-contact water once the AWTF was operating at capacity) (Table 2-3 and 2-4).

Between 2021 and 2030, projected reductions achieved with a 10,000 m^3/d CWD were, on average, 1 µg/L more than with a smaller diversion sized to average winter flows (Table 2-3 and 2-4). Incremental benefits of moving beyond a 10,000 m^3/d CWD (i.e., one sized to average annual or average May flows) were negligible, in terms of further reductions to projected maximum monthly selenium concentrations.

Although the larger diversions reduce the volume of water contacting waste rock, the volume of mine contact water that enters an AWTF is constrained by two factors: the hydraulic capacity of the facility and its nitrate design load removal. Thus, the larger CWDs are projected to yield negligible additional benefit to downstream water quality because the volume of contact water being treated is constrained by the nitrate design load removal of the AWTF. In other words, although the larger CWDs result in lower volumes of mine contact water, the selenium load receiving treatment remains the same because influent flow rates to the AWTF are limited by the nitrate load that the AWTF can these accept and still operate effectively.

After 2030, the incremental benefits of larger CWDs become more meaningful (Table 2-3 and 2-4) because nitrate concentrations in mine contact waters are projected to be lower (as explosive residuals are eliminated from waste rock spoils). As a result, nitrate design load removal becomes less of a constraint, and a greater proportion of the mine contact water can be directed into the AWTF relative to that prior to 2030 and relative to that which can be treated after 2030 with a smaller CWD in place.

The potential benefit of larger CWDs after 2030 may be overestimated in this evaluation because the modelling exercise was conducted using the Permitted Development Scenario. This evaluation does not, as a result, account for additional waste rock deposition into the Kilmarnock watershed that may occur over time as part of planned activities. The deposition of additional waste rock would result in the introduction of additional explosive residue, which would affect the rate at which nitrate concentrations decline and the time at which the nitrate design load removal may become less of a constraint.

Table 2-3 Projected Maximum Monthly Average Selenium Concentrations at the FRO Compliance Point for Each of the Five Modelled Clean Water Diversion Scenarios between 2021 and 2037, Considering Isolation of Water Draining from the Targeted Undisturbed Area[(a)]

Year	Projected Maximum Monthly Average Selenium Concentrations (µg/L)					Differences in Projected Maximum Monthly Average Selenium Concentrations from No CWD Scenario (µg/L)			
	No CWD Scenario	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May
	(0 m^3/d)	(5,500 m^3/d)	(10,000 m^3/d)[(b)]	(22,500 m^3/d)	(40,000 m^3/d)	(5,500 m^3/d)	(10,000 m^3/d)[(b)]	(22,500 m^3/d)	(40,000 m^3/d)
2021	118	117	117	117	117	1	1	1	1
2022	71	69	68	68	68	2	2	2	2
2023	74	72	70	70	70	2	4	4	4
2024	61	61	60	60	60	1	1	1	1
2025	63	62	61	61	61	1	1	1	1
2026	65	63	61	61	61	2	3	3	3
2027	61	59	58	58	58	2	4	4	4
2028	62	60	59	59	59	2	3	3	3
2029	62	61	59	59	59	2	3	3	3
2030	61	59	58	57	57	3	4	4	4
2031	62	60	59	58	58	3	3	4	4
2032	62	60	59	58	58	2	3	4	4
2033	63	61	61	59	59	2	3	4	4
2034	62	62	61	59	58	1	1	3	4
2035	63	63	62	60	59	1	1	3	4
2036	56	55	55	54	53	<1	1	1	3
2037	57	57	56	55	54	<1	1	2	3

(a) Flows from targeted undisturbed areas upstream of the proposed intake to the FRO AWTF-S were diverted through a CWD and discharged to a location downstream of the AWTF, without consideration of the degree to which the AWTF was operating at its hydraulic capacity.

(b) At the time the evaluation was conducted, the size of the Kilmarnock Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. It was subsequently increased to 45,000 m^3/d to be consistent with the EVWQP.

Note: Differences in projected maximum monthly average selenium concentrations were calculated by subtracting the projected maximum monthly average selenium concentrations of each clean water diversion modelling scenario from those of the No Clean Water Diversion Scenario. Calculated values were rounded to the nearest whole number.

CWD = clean water diversion; IPA = Implementation Plan Adjustment; µg/L = micrograms per litre; m^3/d = cubic metres per day.

Table 2-4 Projected Maximum Monthly Average Selenium Concentrations at the FRO Compliance Point for Each of the Five Modelled Clean Water Diversion Scenarios between 2021 and 2037, Without Isolation of the Targeted Undisturbed Area[(a)]

Year	Projected Maximum Monthly Average Selenium Concentrations (µg/L)					Differences in Projected Maximum Monthly Average Selenium Concentrations from No CWD Scenario (µg/L)			
	No CWD Scenario	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May
	(0 m^3/d)	(5,500 m^3/d)	(10,000 m^3/d)[(b)]	(22,500 m^3/d)	(40,000 m^3/d)	(5,500 m^3/d)	(10,000 m^3/d)[(b)]	(22,500 m^3/d)	(40,000 m^3/d)
2021	118	117	117	117	117	1	1	1	1
2022	71	69	68	68	68	2	2	2	2
2023	74	72	70	70	70	2	4	4	4
2024	61	61	60	60	60	1	1	1	1
2025	63	62	61	61	61	1	1	1	1
2026	65	63	61	61	61	2	3	3	3
2027	61	59	58	58	58	2	4	4	4
2028	62	60	59	59	59	2	3	3	3
2029	62	61	60	59	59	2	2	3	3
2030	61	59	58	57	57	3	4	4	4
2031	62	60	59	58	58	3	3	4	4
2032	62	60	59	58	58	2	3	4	4
2033	63	61	61	59	59	2	3	4	4
2034	62	62	61	59	58	1	1	3	4
2035	63	63	62	60	59	1	1	3	4
2036	56	55	55	54	53	<1	1	1	3
2037	57	57	56	55	54	<1	1	2	3

(a) Flows from targeted undisturbed areas upstream of the proposed intake to the FRO AWTF-S were diverted through a CWD and then directed into the AWTF until it was operating at capacity; at that point, waters remaining in the CWD were discharged to a location downstream of the AWTF.

(b) At the time the evaluation was conducted, the size of the Kilmarnock Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. It was subsequently increased to 45,000 m^3/d to be consistent with the EVWQP.

Note: Differences in projected maximum monthly average selenium concentrations were calculated by subtracting the projected maximum monthly average selenium concentrations of each clean water diversion modelling scenario from those of the No Clean Water Diversion Scenario. Calculated values were rounded to the nearest whole number.

CWD = clean water diversion; IPA = Implementation Plan Adjustment; µg/L = micrograms per litre; m^3/d = cubic metres per day.

The dynamic approach to operating the CWD did not result in an incremental improvement in downstream water quality, relative to the static approach, because the same nitrate and selenium loads are being subject to treatment, with the load originating almost exclusively from mine contact areas. The difference between the two operational approaches is the amount of water that travels through the AWTF when flows from mine contact areas are less than the hydraulic capacity of the AWTF. In other words, the dynamic approach does not result in the treatment of more selenium or nitrate load, but it does result in the AWTF operating at or more closely to its hydraulic capacity than achieved using the static approach (Figure 2-2). Consequently, it also results in less non-contact water being diverted around the AWTF (Figure 2-3).

The influence of the dynamic approach to flow through the AWTF is similar between differently-size CWDs (Figures 2-4 and 2-5 vs Figures 2-2 and 2-3, respectively).

Differences in projected effluent flows between the Dynamic CWD and No CWD scenarios (Figures 2-2 and 2-4) relate to the order in which water available for treatment is distributed to meet modelled water demands. Modelled water demands consist of:

- the minimum hydraulic requirement of the FRO-S AWTF, which was set to a constant value of 6,700 m^3/day
- make-up water for the FRO coal wash plant
- remaining hydraulic capacity at the FRO-S AWTF

Under the No CWD scenario, the 2017 RWQM was configured to meet the minimum hydraulic requirement of the FRO AWTF-S first before any other water demand, using water from Cataract and Swift creeks and then, if needed, water from Kilmarnock Creek. Water from the aforementioned creeks was then used to meet the make-up water demand from the coal wash plant, with remaining water directed to the FRO AWTF-S for treatment until the facility was at hydraulic or nitrate capacity, or all remaining water had been used.

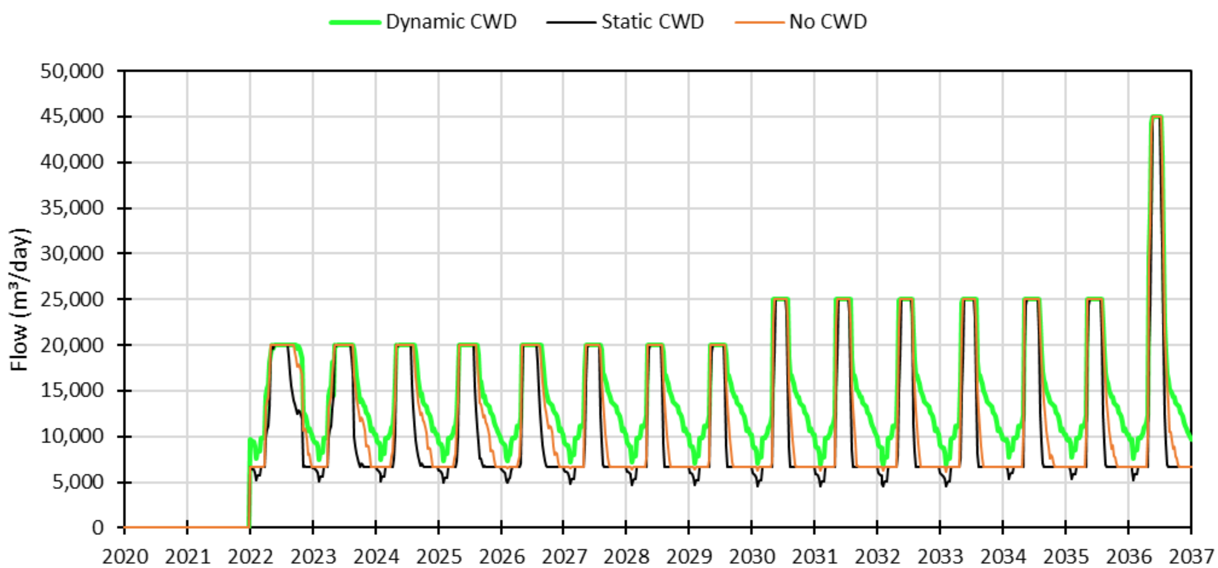
A similar configuration was used for the Dynamic CWD scenario with one exception; water in the diversion channel was modelled as being unavailable to be used to meet the make-up water demands from the coal wash plant. As a result, at certain times of the year, more water was available under the Dynamic CWD scenario to be directed into the FRO AWTF-S than under the No CWD scenario; hence, effluent flows from the FRO AWTF-S were projected to be higher at those times of the year than under the No CWD scenario, when the make-up demand from the coal wash plant restricted the amount of water remaining to be treated in the FRO AWTF-S.

In the Static CWD scenario, water in the diversion channel was modelled as being unavailable for use in meeting any of the above-noted water demands. Demands had to be met, to the extent possible, using collected water from Swift Creek, Cataract Creek and the mine-influenced portions of Kilmarnock Creek. Consequently, less water was available to meet the demands, and, as a result, effluent flows from the FRO AWTF-S were projected to be less than those under the No CWD during certain times of the year.

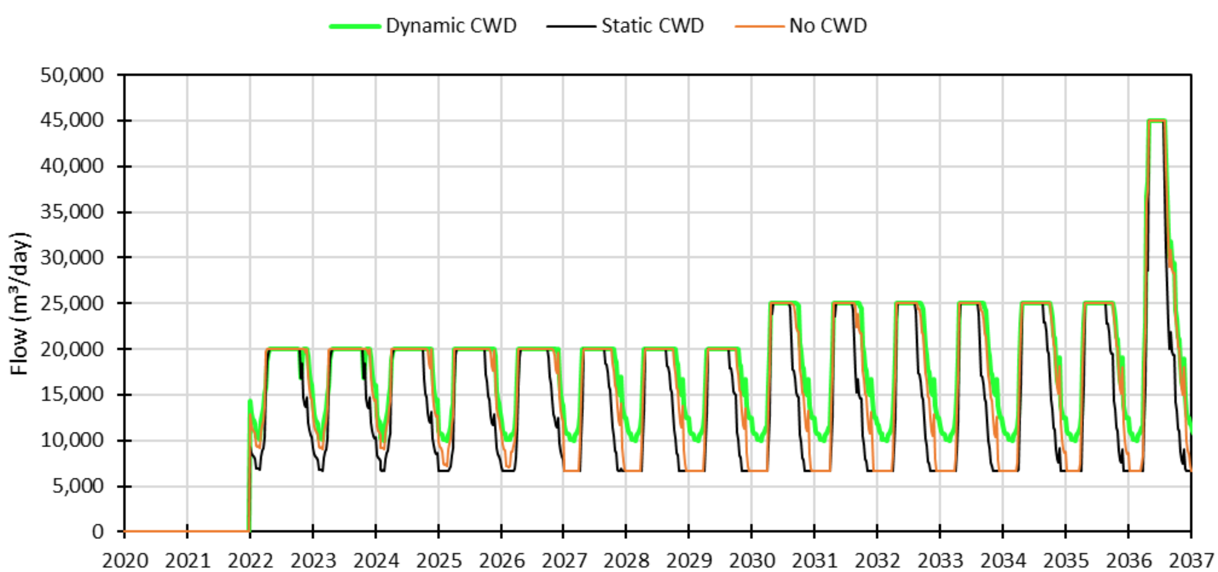
Although the dynamic approach did not result in improved downstream water quality, relative to the static approach, it likely reflects more accurately the manner in which CWDs will operate in the Elk Valley when and where they are placed in the vicinity of AWTFs.

Figure 2-2 Projected Effluent Flows from the FRO-S AWTF with a 10,000 m3/day Clean Water Diversion in Operation in Kilmarnock Creek

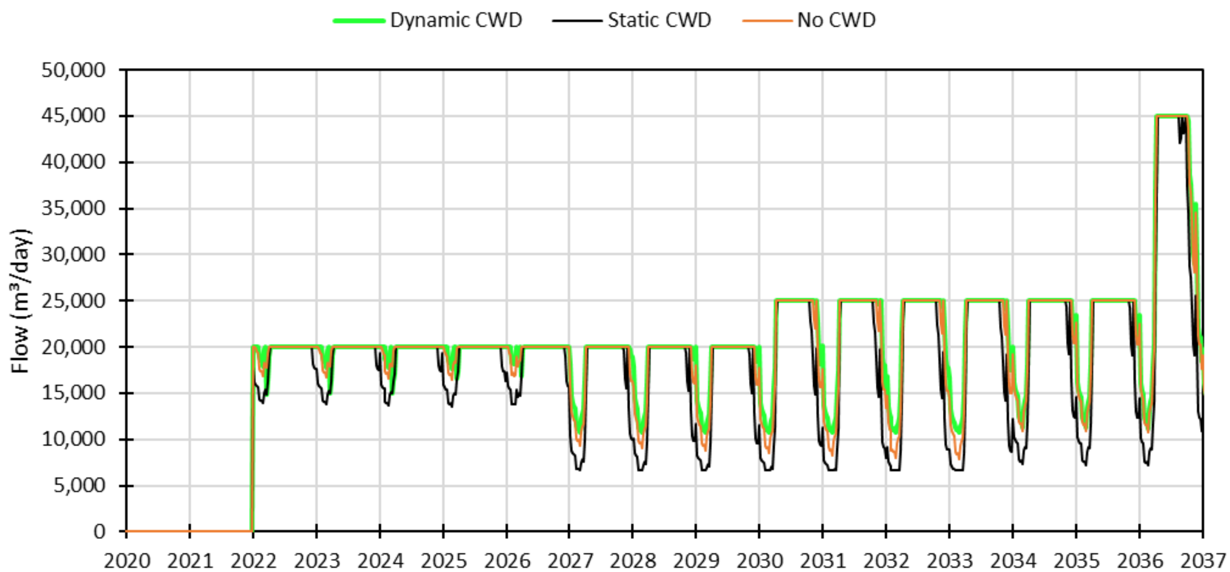
(a) Low Flow Conditions



(b) Average Flow Conditions



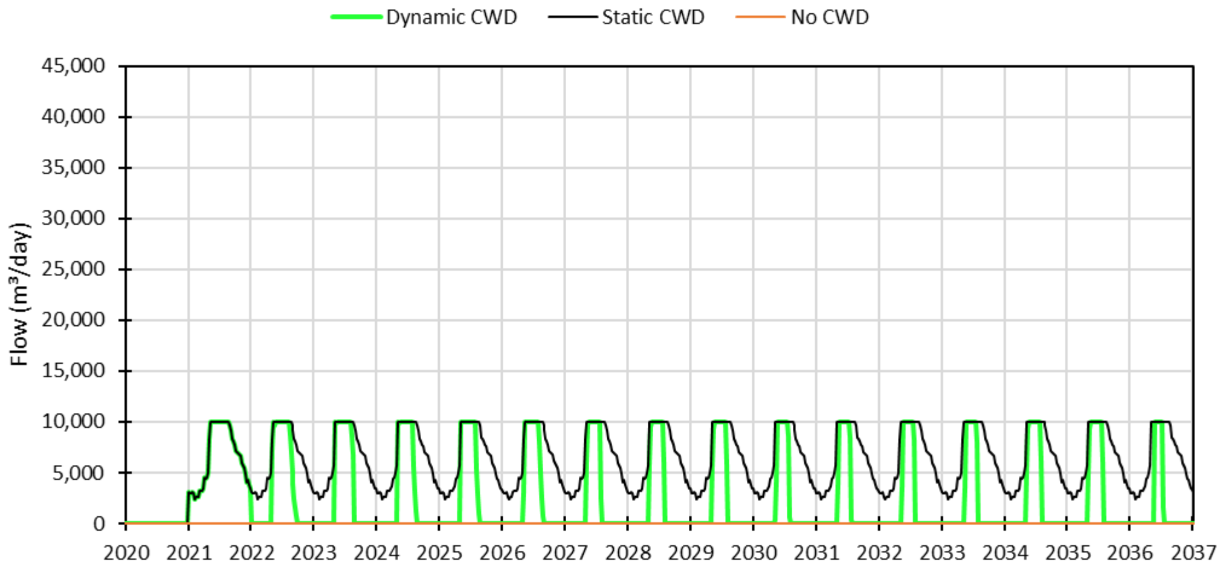
(c) High Flow Conditions



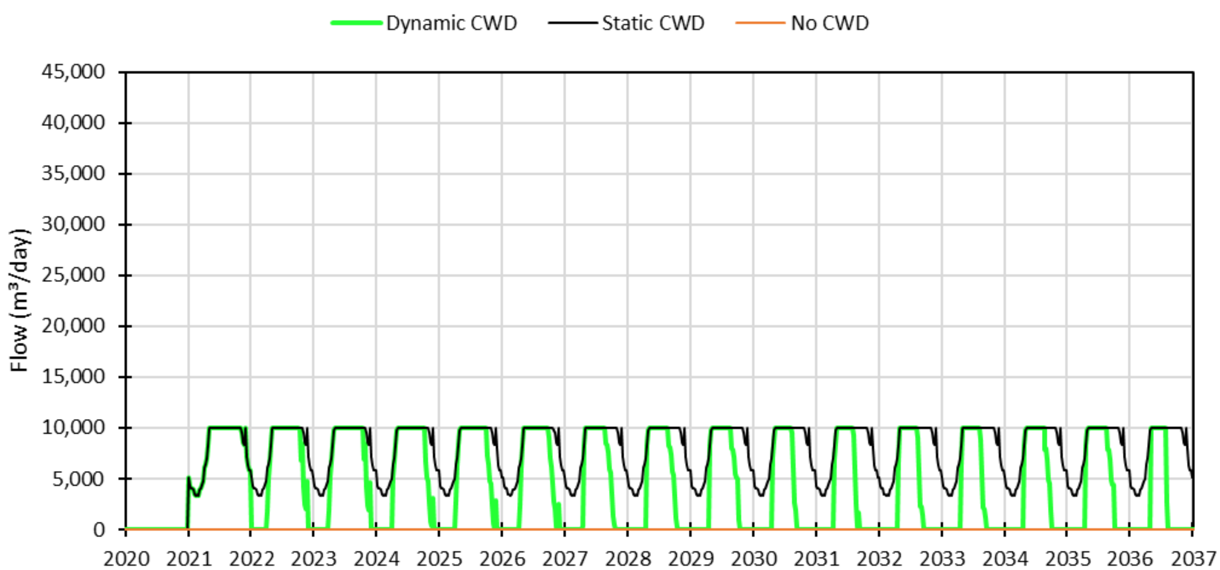
Note: Under the Dynamic CWD approach, comparisons of the incoming nitrate load to the nitrate design load removal of the AWTF were done both before and after addition of water from the clean water diversion to the AWTF influent stream.

Figure 2-3 Projected Flow Through a 10,000 m3/day Clean Water Diversion in Operation in Kilmarnock Creek

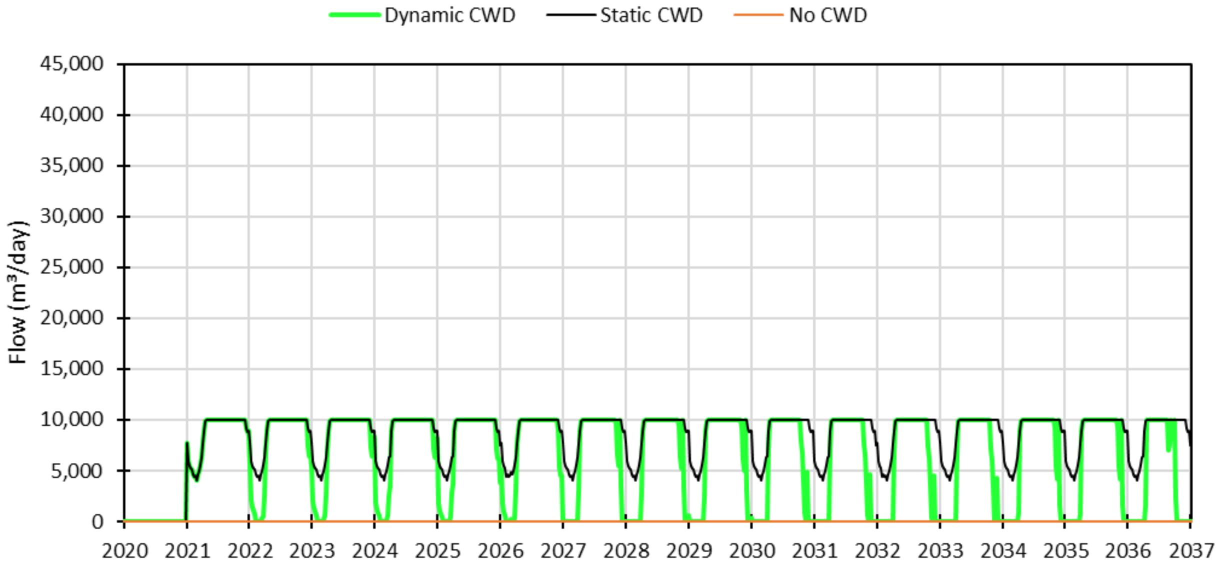
(a) Low Flow Conditions



(b) Average Flow Conditions



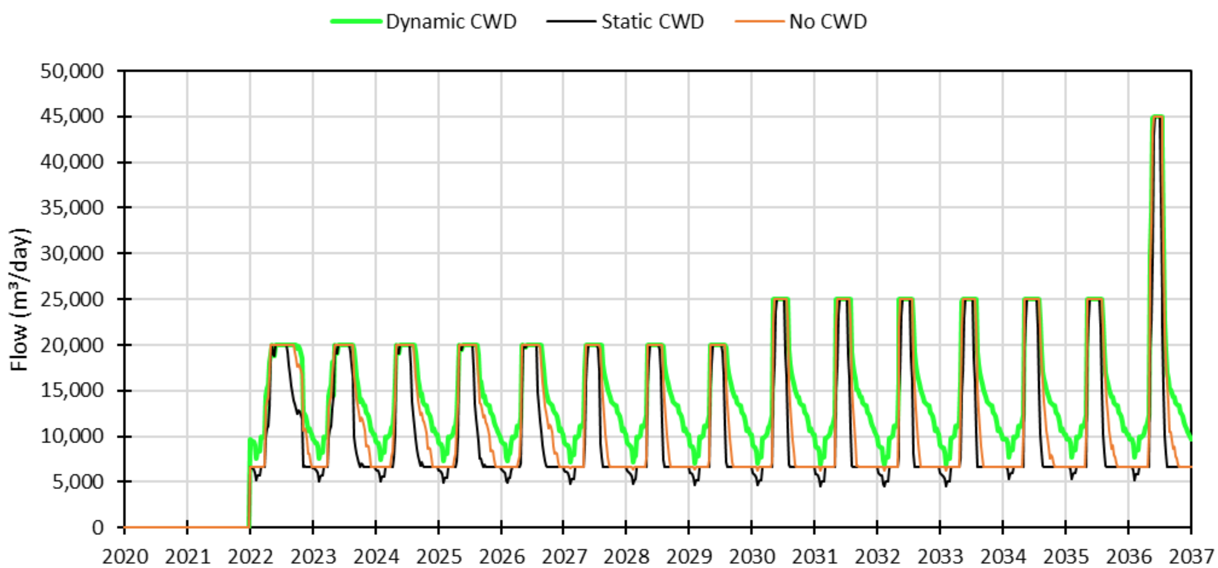
(c) High Flow Conditions



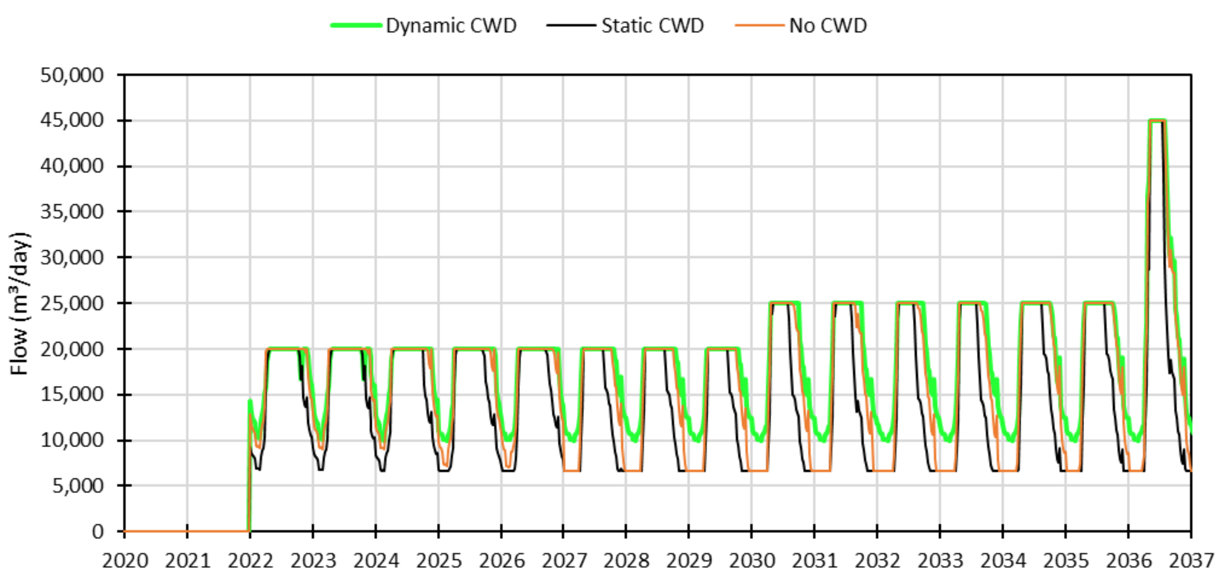
Note: Y-axis set to 45,000 m^3/d to facilitate comparison to the information shown in Figure 2-5.

Figure 2-4 Projected Effluent Flows from the FRO-S AWTF with a 40,000 m3/day Clean Water Diversion in Operation in Kilmarnock Creek

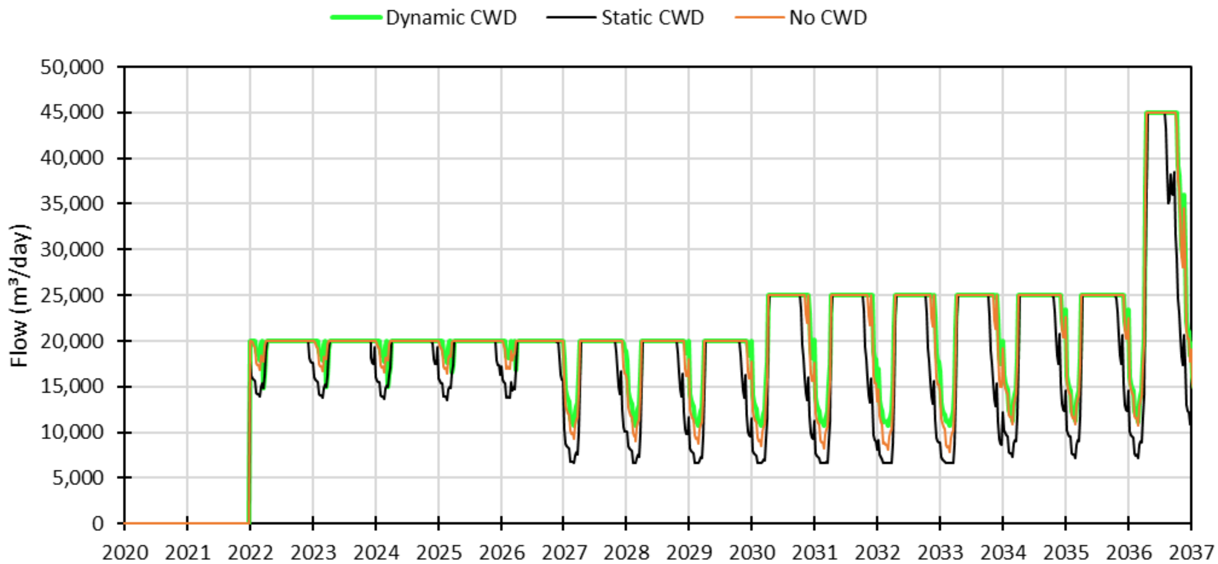
(a) Low Flow Conditions



(b) Average Flow Conditions



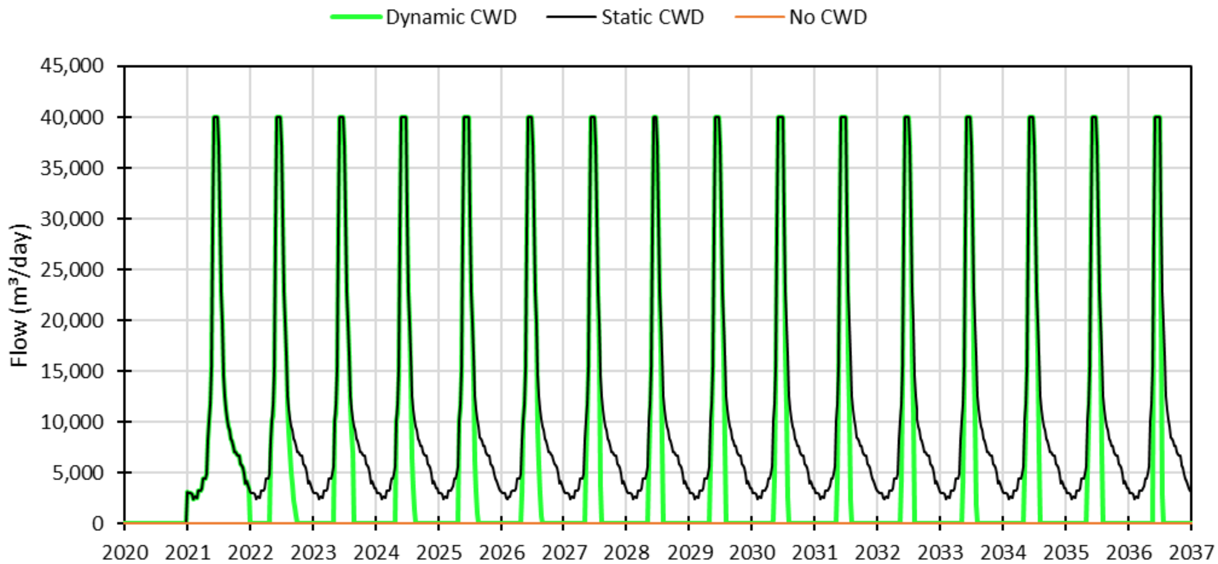
(c) High Flow Conditions



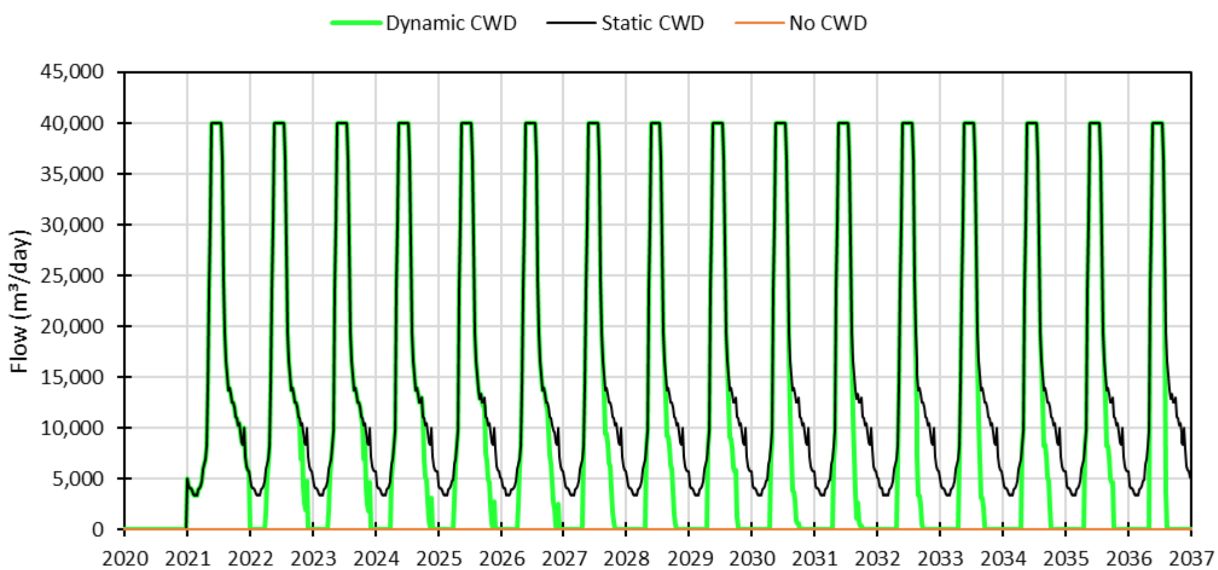
Note: Under the Dynamic CWD approach, comparisons of the incoming nitrate load to the nitrate design load removal of the AWTF were done both before and after addition of water from the clean water diversion to the AWTF influent stream.

Figure 2-5 Projected Flow Through a 40,000 m3/day Clean Water Diversion in Operation in Kilmarnock Creek

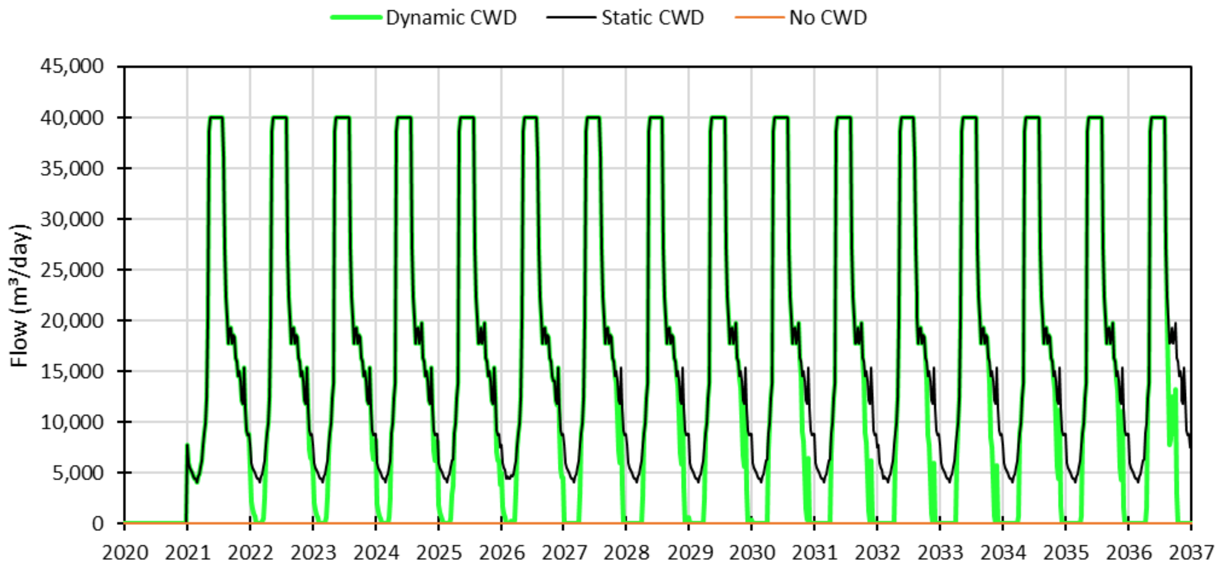
(a) Low Flow Conditions



(b) Average Flow Conditions



(c) High Flow Conditions



2.2.1.3 Scoring

Scoring of the evaluation criteria for the Kilmarnock Creek CWDs is shown in Table 2-5. Results of the evaluation support the inclusion of a CWD in Kilmarnock Creek of at least 10,000 m^3/d. A 10,000 m^3/d CWD is technically feasible to build and operate, and is projected to result in a benefit to downstream water quality. A smaller sized CWD does not produce the same water quality benefit. Larger sized CWDs may be more technically challenging to build and operate, but are likely feasible to implement. The incremental benefit of larger sized CWDs to downstream water quality is small, becoming more meaningful as nitrate concentrations in mine contact waters decline.

As previously noted, at the time the evaluation was conducted, the size of the Kilmarnock Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. The size was subsequently increased, initially to 45,000 m^3/d to be consistent with the EVWQP and then to 86,000 m^3/d. The larger sizing reflects additional water modelling and analysis done as part of the scoping stage of the Kilmarnock Creek CWD project. This information will be explained through the Kilmarnock Creek CWD project (and permit application) later in 2019 and into 2020.

Teck is likely to pursue a dynamic approach to the operation of a CWD placed in Kilmarnock Creek, regardless of its size. Such an approach will likely result in greater flows through the facility, which would benefit its effective operation.

As explained in Section 2.2.1.1, a CWD in Brownie Creek is not being pursued because of challenges related to technical feasibility and operability, as well as size of the area under consideration.

Table 2-5 Summary Evaluation of Clean Water Diversions at Fording River Operations

<table>
<tr><th rowspan="3">Criteria</th><th colspan="4">Size of Clean Water Diversion (m^3/d)</th><th rowspan="3">Scoring System</th></tr>
<tr><th>Winter Average</th><th>2019 IPA</th><th>Annual Average</th><th>May Average</th></tr>
<tr><th>5,500</th><th>10,000[(a)]</th><th>22,500</th><th>40,000</th></tr>
<tr><td>Feasibility and Operability</td><td colspan="4">Challenging to construct due to terrain and geotechnical risk</td><td>Red = complex to build and operate / not likely to be feasible
Yellow = challenging to construct and operate effectively
Green = straightforward to construct and operate, or have sufficient in-house knowledge to overcome expected challenges</td></tr>
<tr><td>Potential to Improve Water Quality</td><td>1.5 µg/L</td><td>2.3 µg/L</td><td>2.9 µg/L</td><td>3.2 µg/L</td><td>Based on average change in projected maximum monthly average selenium concentrations from modelling scenario without CWD in place
Red = ≤1 µg/L difference at nearest compliance point
Yellow = >1 and ≤ 5 µg/L difference at nearest compliance point
Green = >5 µg/L difference at nearest compliance point</td></tr>
</table>

(a) At the time the evaluation was conducted, the size of the Kilmarnock Clean Water Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. It was subsequently increased to 45,000 m^3/d to be consistent with the EVWQP and then to 86,000 m^3/d to be consistent with additional modelling and analysis completed to-date for the Kilmarnock Creek Clean Water Diversion Project.

AWTF = active water treatment facility; CWD = clean water diversion; FRO = Fording River Operations; Se = selenium

2.2.2 Line Creek Operations – Upper Line Creek / Horseshoe and No Name Creek Diversions

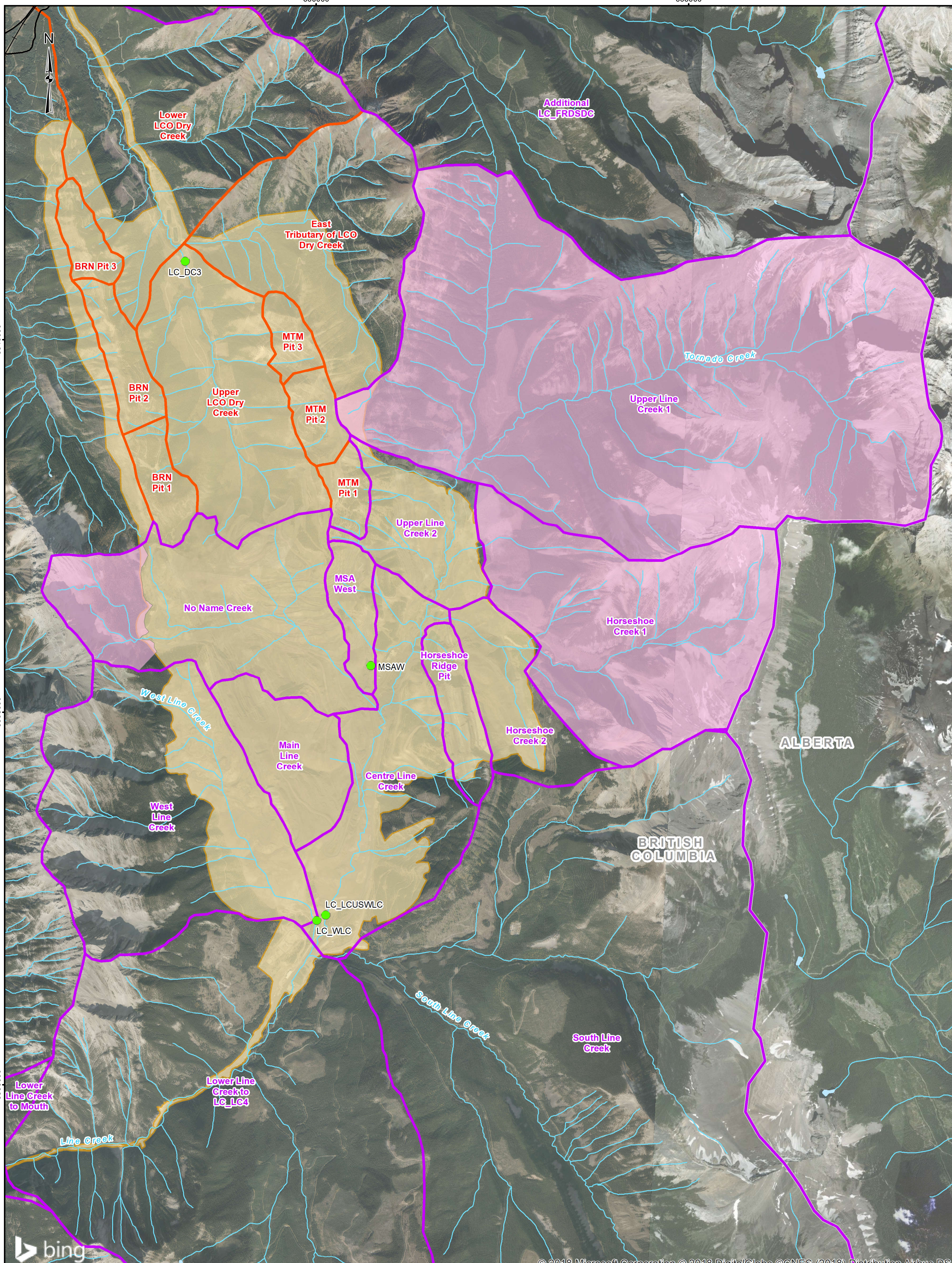
2.2.2.1 Technical Feasibility and Operability

Site Conditions

The Line Creek upstream of West Line Creek (WLC) drainage area, which includes, but is not limited to, the Upper Line Creek, Horseshoe Creek and No Name Creek drainages, has an estimated drainage area of ~61 km^2. Approximately 14 km^2 of this area is disturbed (by mining). Preliminary quantification of drainage areas available for diversion, for the Upper Line Creek, Horseshoe Creek and No Name Creek drainages, was not completed, but the conceptual areas are shown in Figure 2-6.

Conceptually, the Horseshoe Creek drainage area would be diverted into the Upper Line Creek drainage, with the combined flow entering into Line Creek. No Name Creek flows subsurface, through waste rock, into Line Creek down gradient of Upper Line Creek. The headwaters of Horseshoe Creek is ~1,700 masl. The headwaters of the No Name Creek drainage is ~2,100 masl. The combined diversion of Horseshoe and Upper Line Creek, and the diversion of No Name Creek, would reach Line Creek at ~1,400 masl; an elevation difference of ~300 m and ~700 m from the headwaters of the Horseshoe Creek drainage and from the headwaters of the No Name Creek drainage, respectively.

Document Path: S:\Clients\Teck_Resources\ElkValley\99_PROJ\1792554_Teck\40_PROD\0006_Clean_Water_Diversion_Annex\1792554-0006-CS-0002.mxd



LEGEND

- MONITORING / MODELLING NODE
- CITY/TOWN/COMMUNITY
- ROAD
- CANADIAN PACIFIC RAILWAY
- WATERCOURSE
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL BOUNDARY
- LINE CREEK OPERATIONS C-129 PERMIT BOUNDARY
- PHASE I SUB-WATERSHED
- PHASE II SUB-WATERSHED
- LCO CLEAN WATER DIVERSION SUB-WATERSHED
- LINE 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

POTENTIAL CLEAN WATER DIVERSIONS AT LINE CREEK OPERATIONS UNDER THE PERMITTED DEVELOPMENT SCENARIO (2037 SNAPSHOT)

Teck

PROJECT		1792554	FILE No.	5000
DESIGN	PR	27 Aug. 2018	SCALE AS SHOWN	REV. A
GIS	PR	28 Aug. 2018		
CHECK	ES	28 Aug. 2018	**FIGURE: 2-6**	
REVIEW	JPB	28 Aug. 2018		

All three of these drainages are mine-impacted, with existing waste rock piles on one side and gradual, rugged, slopes on the other side(s). Small streams, with peaky freshet run-off flows are scattered along the non-mine-impacted mountainside slopes of the Horseshoe Creek and No Name Creek drainages. The Upper Line Creek drainage, on the other hand, comes to an existing catchment area where water could be collected for diversion.

Additional site conditions of each drainage are listed below:

1) Upper Line Creek Drainage

   - Conceptually the largest of the three LCO drainage areas considered for diversion
   - Mountainous and arborous terrain.
   - Small streams, with peaky freshet flows are scattered along the non-mine-impacted mountain side slopes.
   - Relatively accessible by existing roads.
   - Utilities (mainly power) available within ~2 km.

2) Horseshoe Creek Drainage

   - Mountainous and arborous terrain.
   - Consists of small streams, with peaky freshet flows which are scattered along the non-mine-impacted mountain side slopes.
   - Road access limited to existing exploration road.
   - Utilities (mainly power) available within ~1.5 km.

3) No Name Creek Drainage

   - Mountainous and arborous terrain.
   - Consists of small streams, with peaky freshet flows which are scattered along the non-mine-impacted mountain side slopes.
   - Highly seasonal surface flows, but surface flows limited to mid-March to late October.
   - Existing diversion in place which diverts flow into LCO South Pit (a back-filled pit).
   - Utilities (mainly power) available in close proximity.

Technical Feasibility and Operability

Figure 2-7 shows the conceptual routings of the Upper Line Creek, Horseshoe Creek, and No Name Creek CWDs. Based on learnings from the 2011 Kilmarnock Creek CWD, the conceptual design of the Upper Line Creek / Horseshoe Creek and No Name Creek CWDs is based on pump-and-pipe and gravity-pipe systems. The terrain of the Upper Line Creek / Horseshoe Creek and No Name Creek CWDs is also comparable to the Kilmarnock Creek drainage at FRO.

There is adequate accessibility to all three of these drainages, with utilities within reasonable proximity (~2 km). The size and relatively accessible terrain of the Upper Line Creek drainage suggest that it is constructible. However, the long diversion distance (~7 km), coupled with a diversion alignment (route) through a narrow and congested corridor (including the area of the LCO general office, mine maintenance shop and the main mine-site access road) does present some challenges. The steep gradient required at the discharge of the diversion, where the CWD conceptually re-connects to main Line Creek (downstream of the existing 4 km Line Creek rock drain), also poses a construction challenge.

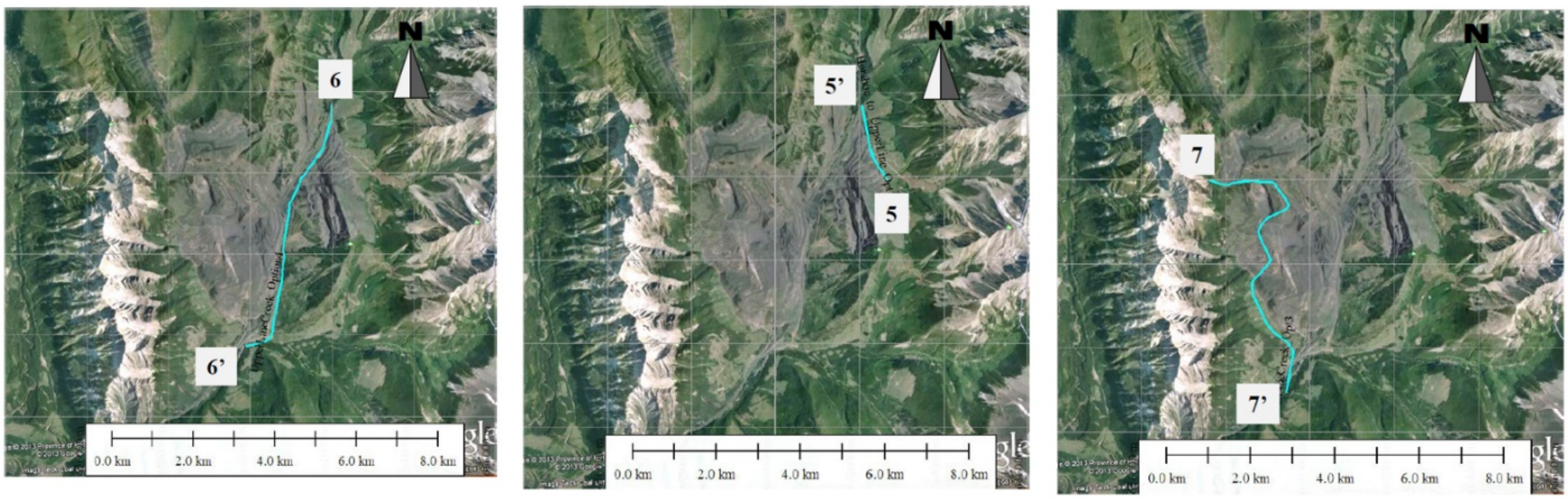
Horseshoe Creek, being the steepest, has the largest challenge from a constructing along a side slope perspective.

The existing diversion at No Name Creek provides an opportunity for expansion. It is, however, a relatively long diversion (estimated at ~7.5 km) through active mining areas which could pose some construction (and operability) challenges.

While there are constructability and operability challenges associated with all three potential CDWs at LCO, all three appear technically feasible based on this conceptual assessment. As a result, this assessment of technical feasibility and operability, supports further, more detailed evaluation of all three diversions. This work will occur as part of the next phase of the WLC AWTF project to which these diversions are linked. Consequently, the evaluation and/or configuration of these CWDs may change as a result of future assessments.

Figure 2-7 Conceptual Alignments of the Upper Line Creek, Horseshoe Creek and No Name Creek Clean Water Diversions at Line Creek Operations

LCO – Upper Line Collection Pond to Lower Line Creek | **LCO – Horseshoe Creek to Upper Line Collection Pond** | **LCO – No-Name Collection Pond to Lower Line Creek**



2.2.2.2 Potential Water Quality Improvements

Results of the modelling exercise indicate that inclusion of CWDs in Line Creek should result in improved water quality at the LCO compliance point. The combined use of CWDs in Upper Line Creek and in No Name Creek was projected to result in reductions in projected maximum monthly selenium concentrations in the order of 6 to 14 µg/L between 2026 (the assumed date when the diversions would be commissioned) and 2033 (Table 2-6). After 2033, the projected benefit of CWDs was lower, in the order of 2 to 6 µg/L. The projected benefit was lower after 2033 because the size of the WLC AWTF has increased; as a result, it can treat a larger volume of water, so the ability of the CWDs to reduce the volume of mine contact water requiring treatment becomes less influential.

Between 2026 and 2033, projected reductions achieved with a combined 42,000 m^3/d CWD were, on average, 4 µg/L more than with smaller diversions sized to average winter flows (Table 2-6). Incremental benefits of moving beyond a combined 42,000 m^3/d CWD (i.e., one sized to average annual or average May flows) were negligible in terms of further reductions to projected maximum monthly selenium concentrations. After 2033, the incremental benefits of larger CWDs become more apparent, although they remain small (Table 2-6), for the same reasons as outlined above with reference to CWDs in Kilmarnock Creek.

Although the No Name Creek CWD is relatively small (see Table 2-1), model results indicate that it can be effective when combined with a CWD in upper Line Creek, particularly prior to 2033 (see Figure 2-8). Hence, the modelling evaluation focused on the potential benefits of using the two CWDs in combination.

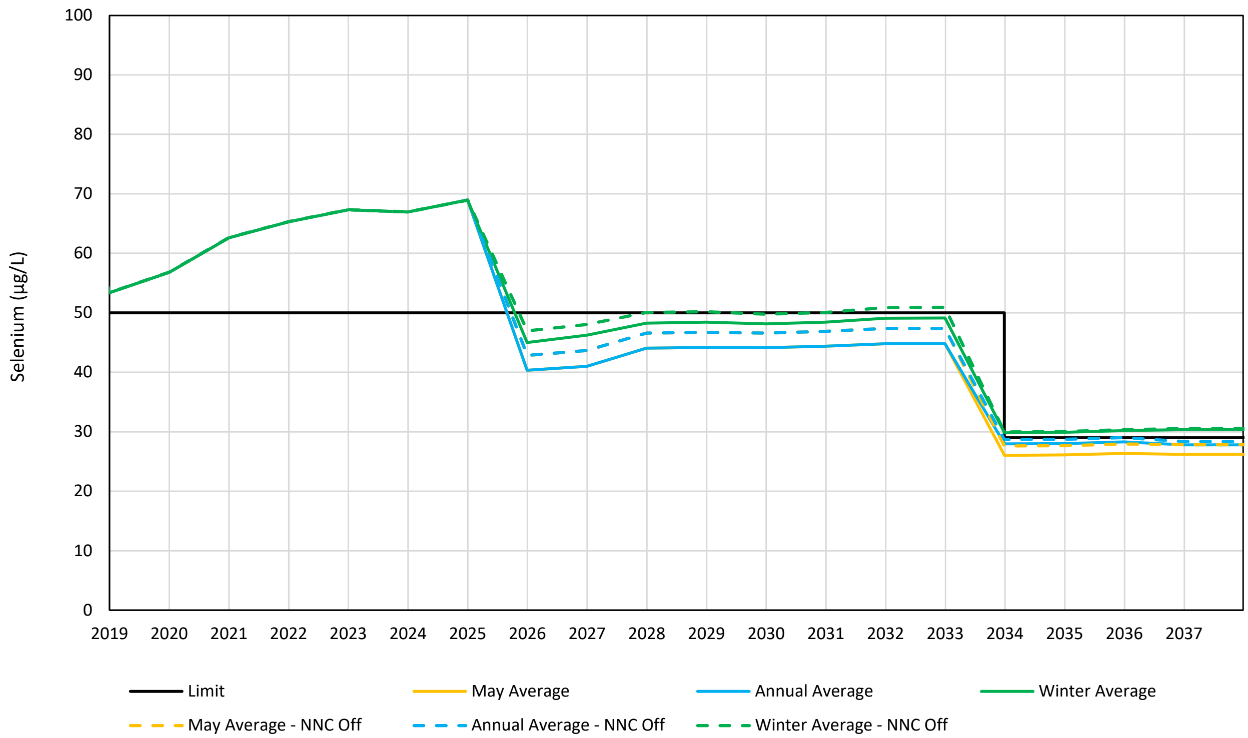
Table 2-6 Summary of Differences in Projected Maximum Monthly Average Selenium Concentrations between the Four Clean Water Diversion Modelling Scenarios and the No Clean Water Diversion Modelling Scenario

Year	Projected Maximum Monthly Average Selenium Concentrations (µg/L)					Differences in Projected Maximum Monthly Average Selenium Concentrations from No CWD Scenario (µg/L)			
	No CWD Scenario	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May	Average Monthly Winter Flow	2019 IPA	Average Annual Monthly Flow	Average Monthly Flow in May
	(0 m^3/d)	(19,500 m^3/d)	(42,000 m^3/d)	(64,000 m^3/d)	(171,000 m^3/d)	(19,500 m^3/d)	(42,000 m^3/d)	(64,000 m^3/d)	(171,000 m^3/d)
2021	63	63	63	63	63	0	0	0	0
2022	65	65	65	65	65	0	0	0	0
2023	67	67	67	67	67	0	0	0	0
2024	67	67	67	67	67	0	0	0	0
2025	69	69	69	69	69	0	0	0	0
2026	54	45	40	40	40	9	14	14	14
2027	54	46	41	41	41	8	13	13	13
2028	55	48	44	44	44	7	11	11	11
2029	55	48	44	44	44	7	11	11	11
2030	54	48	44	44	44	6	10	10	10
2031	54	48	44	44	44	6	10	10	10
2032	56	49	45	45	45	7	11	11	11
2033	56	49	45	45	45	7	11	11	11
2034	32	30	29	28	26	2	3	4	6
2035	32	30	29	28	26	2	3	4	6
2036	32	30	29	28	26	2	3	4	6
2037	32	30	29	28	26	2	4	5	6

Note: Differences in projected maximum monthly average selenium concentrations were calculated by subtracting the projected maximum monthly average selenium concentrations of each clean water diversion modelling scenario from those of the No Clean Water Diversion Scenario. Calculated values were rounded to the nearest whole number. The CWDs were assumed to be on-line by 2026.

CWD = clean water diversion; IPA = Implementation Plan Adjustment; µg/L = micrograms per litre; m^3/d = cubic metres per day.

Figure 2-8 Projected Maximum Monthly Average Selenium Concentration at the Line Creek Operations Compliance Point (LC_LCDSSLCC) Across Three Clean Water Diversion Scenarios, with and without Consideration of a Clean Water Diversion in No Name Creek



NNC = No Name Creek.

2.2.2.3 Scoring

Scoring of the evaluation criteria for the Line Creek CWDs is shown in Table 2-7. Results of the evaluation support the inclusion of a combined CWD in the order of 20,000 to 42,000 m^3/d that considers No Name Creek and Upper Line Creek. A combined CWD of this size appears to be technically feasible to build and operate and is projected to result in a benefit to downstream water quality.

A smaller sized CWD does not produce the same water quality benefit. Larger sized CWDs may be more technically challenging to build and operate, and their projected incremental benefit to downstream water quality is marginal.

The WLC AWTF treats flows sourced from both WLC, which is not impacted by the CWDs considered, and Line Creek, which is impacted by the CWDs considered. Based on operational data from the WLC AWTF, in the late winter months, just over two-thirds (5,000 to 5,500 m^3/d) of the total design influent flow (7,500 m^3/d) to the WLC AWTF is from Line Creek as there is not sufficient flow from WLC to maintain capacity of the WLC AWTF. During these same months, the total flow in Line Creek (at the Line Creek intake structure to the WLC AWTF) ranges from 15,000 to 20,000 m^3/d.

With treatment capacity of the WLC AWTF planned to be increased by 12,500 m^3/d in 2025 (for a total capacity of 19,600 m^3/d), as much flow from Line Creek as possible will be required to maintain effective operations of the WLC AWTF, since WLC only has ~2,000 m^3/d available during the late winter months. As a result, a dynamic approach to the operation of the CWD will be used, so that waters travelling through the CWD can be directed to the WLC AWTF when necessary to maintain effective operations of the facility.

Table 2-7 Summary Evaluation of Clean Water Diversions at Line Creek Operations

Criteria	Size of Clean Water Diversion (m^3/d)				Scoring System
	Winter Average	2019 IPA	Annual Average	May Average	
	19,500	42,000	64,000	171,000	
Feasibility and Operability	Challenging, but feasible, to construct and operate.		Due to size, complex to build. Due to size and large seasonal flow variation, may not be feasible to operate effectively.		Red = complex to build and operate / not likely to be feasible Yellow = challenging to construct and operate effectively Green = straightforward to construct and operate, or have sufficient in-house knowledge to overcome expected challenges
Potential to Improve Water Quality	5 µg/L	8 µg/L	9 µg/L	9 µg/L	Based on change in average projected maximum monthly average selenium concentrations from modelling scenario without CWD in place Red = ≤1 µg/L difference at nearest compliance point Yellow = >1 and ≤5 µg/L difference at nearest compliance point Green = >5 µg/L difference at nearest compliance point

CWD = clean water diversion; IPA = Implementation Plan Adjustment.

2.2.3 Elkview Operations – Erickson Creek

2.2.3.1 Technical Feasibility and Operability

Site Conditions

The South Gate Creek CWD is currently in place, and is part of EVO site water management. Therefore, this evaluation focuses on the upper Erickson Creek diversion.

The upper Erickson Creek drainage area available for diversion has an estimated area of 4 km^2. A map of the Erickson catchment showing the portion of the watershed to be collected by a CWD is provided in Figure 2-8. The catchment area is located outside and adjacent to the southeast C-Permit mine boundary, south of Harmer Creek and above EVO Dry Creek. The upper Erickson drainage area of ~4 km^2 (available for diversion) is small compared to the non-contact drainage areas of Brownie Creek at FRO (~7 km^2) and the non-contact drainage that could be collected by the Kilmarnock Creek CWD at FRO (~16 km^2).

The Erickson Creek catchment drains into a narrow valley with existing waste rock piles on one side and steep, rugged mountain terrain on the other side. Small streams, with peaky freshet run-off flows are scattered along the non-mine-impacted mountain side slope of the drainage. The steep mountain slope has avalanche shoots with high avalanche risk during the winter months (Figure 2-9).

There is limited access to the headwaters of the Erickson Creek drainage and no access along the length of the conceptual CWD alignment. There are no utilities (mainly power which may be required for pumping water) in proximity to the headwaters of the drainage nor along the conceptual alignment.

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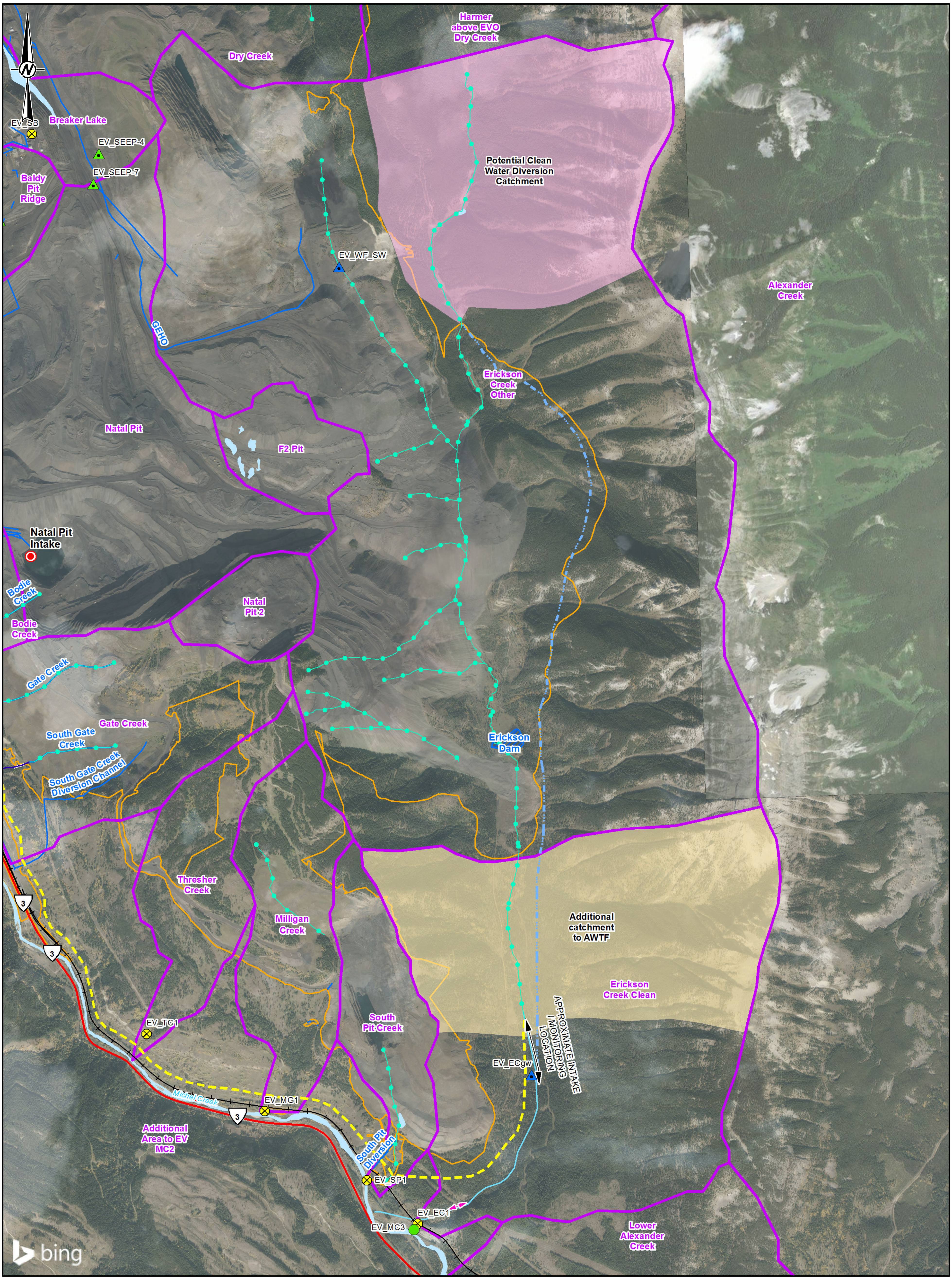


LEGEND

- PRIMARY HIGHWAY
- CANADIAN PACIFIC RAILWAY
- WATER MANAGEMENT LINE
- WATER MANAGEMENT AREA
- WATERBODY
- BRITISH COLUMBIA - ALBERTA PROVINCIAL BOUNDARY
- SUB-WATERSHED
- ELKVIEW OPERATIONS C-2 PERMIT BOUNDARY
- ADDITIONAL CATCHMENT TO AWTF
- POTENTIAL CLEAN WATER DIVERSION CATCHMENT
- APPROXIMATE INTAKE / MONITORING LOCATION
- APPROXIMATE OUTFALL LOCATION
- CONCEPTUAL CLEANWATER DIVERSION
- CONCEPTUAL INTAKE PIPE
- SUBSURFACE DRAINAGE PATH

MONITORING LOCATIONS

- GROUNDWATER
- GROUNDWATER - SEEP
- SURFACE WATER - PERMITTED (FLOW AND WQ)
- SURFACE WATER - PERMITTED (WQ ONLY)

0 500 1,000 1,500 2,000

1:30,000 METERS

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

CLIENT
TECK COAL LIMITED

PROJECT
ELKVIEW OPERATIONS AWTF DESIGN BASIS SUPPORT

TITLE
CONCEPTUAL WATER MANAGEMENT IN ERICKSON CREEK

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-12-01
DESIGNED	PR
PREPARED	PR
REVIEWED	AG
APPROVED	AG

PROJECT NO.	CONTROL	REV.	FIGURE
1789013	0001	0	2-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM:
25mm
0

Figure 2-9 Eastern Side of Erickson Valley Showing Avalanche Chutes with Erickson Creek Waste Rock Pile in the Foreground

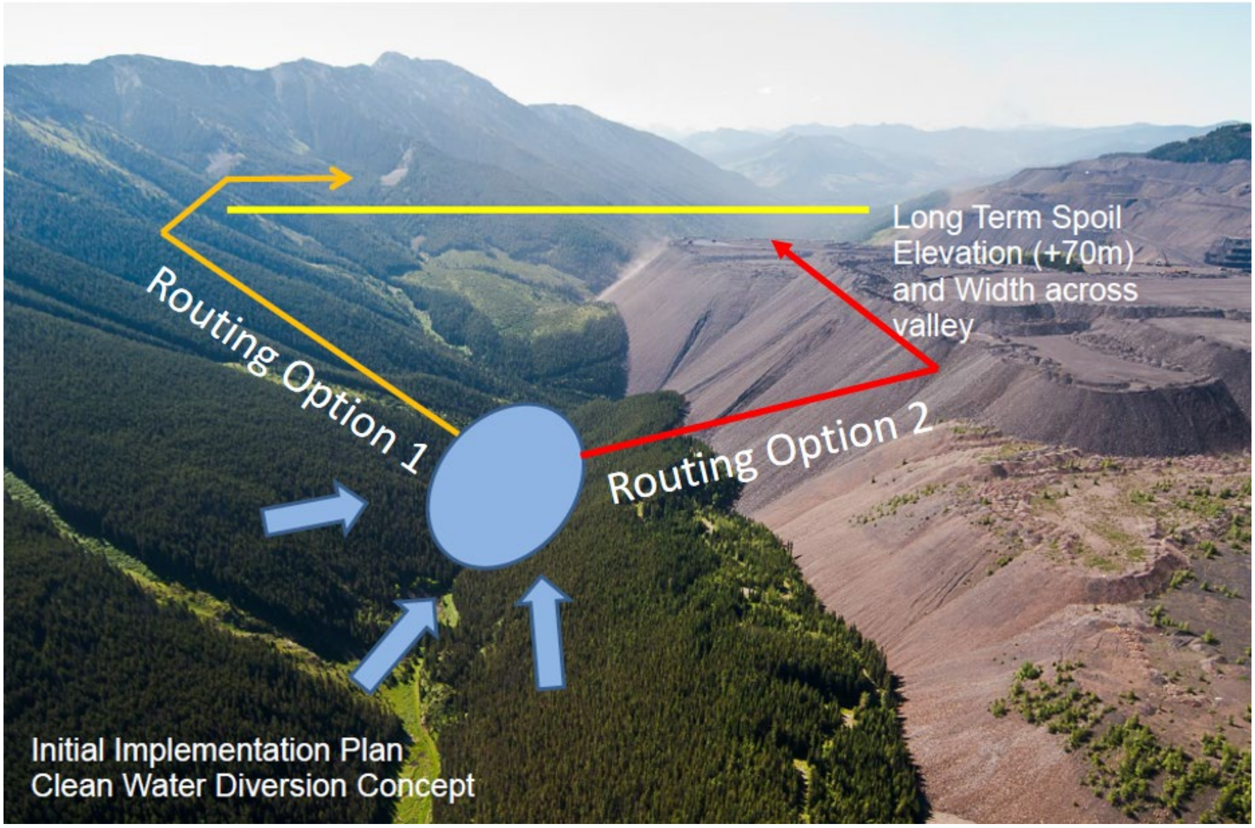
Technical Feasibility and Operability

A CWD of Erickson Creek would conceptually convey non-contact water from the headwaters of Erickson Creek south around the Erickson waste rock spoils (to the west) and discharge into lower Erickson Creek, a distance of ~4.3 km, before connecting to Michel Creek. Two conceptual alignments (routes) have been considered for the CWD and are shown in Figure 2-10:

1) **Routing Option 1**: Along the east side of the Erickson Valley above the approximate 70 m planned additional height of the Erickson waste rock piles.

2) **Routing Option 2**: Along active waste rock placement on the west side of the Erickson Valley (along the eastern edge of the Erickson waste rock piles).

Figure 2-10 Conceptual Routing Options of a Clean Water Diversion of Erickson Creek at Elkview Operations (West is Left in the Photograph)



Both pipeline and open channel designs were considered conceptually for routing options. Open channel designs are not feasible for Routing Option 1 based on operational experience and issues associated with the 2011 Kilmarnock Creek CWD, mainly:

- Water that flows via gravity down non-mine-impacted slopes likely flows sub-surface for the majority of the year, bypassing the channel and negating effective collection.
- Ice anchoring in a constructed channel in the winter months will result in water over-topping the diversion channel, limiting collection and increasing geotechnical risks.

An open channel for Routing Option 2 was considered not feasible due to active waste rock placement along this route (e.g., waste rock placement would result in burial of an open channel CWD). As a result, for both routes, a pipeline design (requiring pumping) was carried forward for further consideration.

Further review of the feasibility of a pipeline along Routing Option 1 was completed. Considering the site conditions (outlined above), a pumped and piped diversion along this route is not feasible due to:

- The steep and rugged mountain terrain associated with this route resulting in high geotechnical and avalanche risks during both construction and operations.
- Limited access (e.g., roads) to the headwaters and no access along the conceptual alignment of the CWD.

- No existing utilities (mainly power required for pumping) near the headwaters or along the conceptual alignment. Power would need to be built and connected with existing power, which is a long distance away. Power infrastructure would also susceptible to the same geotechnical and avalanche risk during construction and operations.

A similar review of a pipeline along Routing Option 2 was completed. The risk of constructing, operating and maintaining a pipeline along the edge of an active waste rock pile presents a high enough geotechnical risk, due to slope stability issues, that this is not a feasible option.

Based on this evaluation, it is not feasible to construct (and operate) a CWD of Erickson Creek due to high geotechnical and avalanche risks. This information, coupled with the small drainage area available for diversion and no access along the conceptual CWD alignment, does not support a CWD in Erickson Creek.

2.2.3.2 Potential Water Quality Improvements

Results of the modelling exercise indicate that inclusion of a CWD in the Erickson drainage will result in negligible improvements to water quality at the Michel Creek compliance point. Across all three scenarios involving the use of a CWD, projected selenium concentrations in Michel Creek were either the same as or only marginally different from those projected to occur without a CWD (Table 2-8).

CWDs are projected to yield negligible water quality benefits in Erickson Creek because the area available to divert is small. In addition, waters flowing through lower Erickson Creek, downstream of the waste rock spoil, travel through an apparent retention area, which results in less observed seasonal variability in downstream constituent concentrations compared to other watercourses targeted for treatment. Diverting non-contact water around this retention area results in longer retention times; longer retention times provide greater opportunity for higher incoming winter concentrations and loads to influence outgoing concentration and loads from Erickson Creek to Michel Creek during the summer months when maximum monthly concentrations in Michel Creek are projected to occur. In other words, longer retention times result in further reductions in seasonal variability and in higher concentrations and loads being released from Erickson Creek to Michel Creek during summer months when maximum monthly concentrations in Michel Creek are projected to occur.

Table 2-8 Projected Maximum Monthly Average Selenium Concentrations at the EVO Michel Creek Compliance Point for Each of the Five Clean Water Diversion Scenarios between 2021 and 2037

Year	Projected Maximum Monthly Average Selenium Concentrations (µg/L)					Differences in Projected Maximum Monthly Average Selenium Concentrations from No CWD Scenario (µg/L)			
	No CWD Scenario	2019 IPA	Average Monthly Winter Flow	Average Annual Monthly Flow	Average Monthly Flow in May	2019 IPA	Average Monthly Winter Flow	Average Annual Monthly Flow	Average Monthly Flow in May
	(0 m^3/d)	(0 m^3/d)	(5,500 m^3/d)	(8,000 m^3/d)	(16,500 m^3/d)	(0 m^3/d)	(5,500 m^3/d)	(8,000 m^3/d)	(16,500 m^3/d)
2021	29	29	29	29	29	0	0	0	0
2022	32	32	32	32	32	0	0	0	0
2023	17	17	17	17	17	0	<1	<1	<1
2024	18	18	18	18	18	0	<1	<1	<1
2025	18	18	19	19	19	0	<1	<1	<1
2026	20	20	20	20	20	0	<1	<1	<1
2027	21	21	22	22	22	0	<1	<1	<1
2028	12	12	12	12	12	0	<1	<1	<1
2029	13	13	12	13	13	0	<1	<1	<1
2030	14	14	13	13	13	0	<1	<1	<1
2031	14	14	13	13	13	0	<1	<1	<1
2032	14	14	14	14	14	0	<1	<1	<1
2033	15	15	15	15	15	0	<1	<1	<1
2034	16	16	15	15	16	0	<1	<1	<1
2035	17	17	16	16	17	0	<1	<1	<1
2036	17	17	16	16	16	0	<1	<1	<1
2037	17	17	17	17	17	0	<1	<1	<1

Notes: Active water treatment begins in 2023. Differences in projected maximum monthly average selenium concentrations were calculated by subtracting the projected maximum monthly average selenium concentrations of each clean water diversion modelling scenario from those of the No Clean Water Diversion Scenario. Calculated values for rounded to the nearest whole number. The CWDs were assumed to be on-line by 2023.

CWD = clean water diversion; EVO = Elkview Operations; IPA = Implementation Plan Adjustment; µg/L = micrograms per litre; m^3/d = cubic metres per day.

2.2.3.3 Scoring

Scoring of the evaluation criteria for the Erickson Creek CWDs is shown in Table 2-9. Results of the evaluation indicate that CWDs should not be considered for this drainage area.

Table 2-9 Summary Evaluation of Clean Water Diversions at Elkview Operations

Criteria	Size of Clean Water Diversion (m^3/d)			Scoring System
	Winter Average	Annual Average	May Average	
	5,500	8,000	16,500	
Feasibility and Operability	Not technically or operationally feasible due to avalanche and geotechnical risk			Red = complex to build and operate / not likely to be feasible Yellow = challenging to construct and operate effectively Green = straightforward to construct and operate, or have sufficient in-house knowledge to overcome expected challenges
Potential to Improve Water Quality	<1 µg/L	<1 µg/L	<1 µg/L	Based on change in average projected maximum monthly average selenium concentrations from modelling scenario without CWD in place Red = ≤1 µg/L difference at nearest compliance point Yellow = >1 and ≤5 µg/L difference at nearest compliance point Green = >5 µg/L difference at nearest compliance point

AWTF = active water treatment facility; CWD = clean water diversion; Se = selenium.

3 Summary and Conclusions

Based on this evaluation, CWDs included in the 2019 IPA are shown in Table 3-1, in comparison to CWDs in the IIP of the EVWQP. CWDs in the 2019 IPA include a diversion of Kilmarnock Creek at FRO, of South Gate Creek at EVO, and of Upper Line Creek, Horseshoe Creek and No Name Creek at LCO.

Table 3-1 Clean Water Diversions Included in the Initial Implementation Plan of the Elk Valley Water Quality Plan compared to the 2019 Implementation Plan Adjustment

Clean-Water Diversion	Associated Active Water Treatment Facility	EVWQP		2019 IPA	
		Streams and Volume Diverted	Date Operational	Streams and Volume Diverted	Date Operational
Kilmarnock Creek	FRO AWTF-S	Upper Brownie and Kilmarnock watersheds, estimated at 45,000 m^3/d	December 31, 2018	Upper Kilmarnock watershed, estimated up to 86,000 m^3/d[(a)]	December 31, 2020[(a)]
Erickson Creek	EVO AWTF 1	Upper Erickson watershed, estimated at 14,000 m^3/d	December 31, 2020	Not included	
South Gate Creek	EVO AWTF 1	South Gate Creek, estimated at 3,500 m^3/d	December 31, 2020	South Gate Creek, estimated at 3,500 m^3/d	In place and operating
Upper Line, Horseshoe and No Name creeks	WLC AWTF 2	Upper Line Creek and Horseshoe Creek, estimated at 35,000 m^3/d, and No Name Creek, estimated at 7,000 m^3/d	2032	Upper Line Creek and Horseshoe Creek, estimated at 35,000 m^3/d, and No Name Creek, estimated at 7,000 m^3/d, for total of 42,000 m^3/d	December 31, 2025

a) The Kilmarnock Creek Clean Water Diversion Project is ongoing and includes a more detailed assessment of the sizing and timing of the diversion, and of constructability and operability considerations. This more detailed assessment may result in changes to the sizing, timing or operational approach of the diversion.

AWTF = Active Water Treatment Facility; EVO = Elkview Operations; EVWQP = Elk Valley Water Quality Plan; FRO = Fording River Operations; IPA = Implementation Plan Adjustment; WLC = West Line Creek.

A summary of findings from this evaluation that support the conclusions are as follows:

FRO Kilmarnock Creek CWD

- A CWD of at least 10,000 m^3/d in Kilmarnock Creek is technically feasible to build and operate and is projected to result in a benefit to downstream water quality.
- A smaller sized CWD does not produce the same water quality benefit.
- Larger sized CWDs may be more technically challenging to build and operate, but are likely feasible to implement. The incremental benefit of larger sized CWDs to

downstream water quality is small, becoming more meaningful as nitrate concentrations in mine contact waters decline.

- As previously noted, at the time the evaluation was conducted, the size of the Kilmarnock Diversion to be included in the 2019 IPA was set to 10,000 m^3/d. The size was subsequently increased, initially to 45,000 m^3/d to be consistent with the EVWQP and then to 86,000 m^3/d. The larger sizing reflects additional water modelling and analysis done as part of the scoping stage of the Kilmarnock Creek CWD Project. This information will be explained through the Kilmarnock Creek CWD Project (and permit application) later in 2019 and into 2020.
- A more detailed assessment of the sizing and timing of the Kilmarnock Creek diversion, and of constructability and operability considerations, remains ongoing through the Kilmarnock Creek CWD Project. This more detailed assessment may result in changes to the sizing, timing and/or operational approach of the diversion. Nevertheless, it is expected that a dynamic approach to the operation of the CWD will be used, so that waters travelling through the CWD can be directed to the FRO-S AWTF when necessary to maintain effective operations of the facility.
- A CWD in Brownie Creek is not being pursued because of challenges related to technical feasibility and operability, as well as size of the area under consideration.

LCO Upper Line Creek / Horseshoe and No Name Creek CWDs

- Evaluation supports the inclusion of a combined CWD in the order of 20,000 to 42,000 m^3/d that considers No Name Creek and Upper Line Creek.
- A combined CWD of this size appears to be technically feasible to build and operate and is projected to result in a benefit to downstream water quality.
- A smaller sized CWD does not produce the same water quality benefit. Larger sized CWDs may be more technically challenging to build and operate, and their projected incremental benefit to downstream water quality is marginal.
- A more detailed assessment of constructability and operability, and of the total cost of the combination of different volumes of CWD and planned treatment, is required (post-2019 IPA). This more detailed assessment will be done as part of the AWTF project to which this CWD is linked (e.g., the next phase of the WLC AWTF). Consequently, the configuration of this CWD may change in future IPAs once this assessment is complete.
- It is expected that a dynamic approach to the operation of the CWD will be used, so that waters travelling through the CWD can be directed to the WLC AWTF when necessary to maintain effective operations of the facility.

EVO South Gate Creek CWD

- In place as part of EVO site water management and included in the 2019 IPA.

EVO Erickson Creek CWD

- Not included in the 2019 IPA since access and operational challenges render this diversion unfavourable. Steep and rugged terrain with high avalanche risk (on the side slope of a mountain) suggests that this diversion would be extremely challenging to construct and in turn operate and maintain. Water quality modelling also indicates that the diversion would have minimal influence on water quality in Michel Creek. For these reasons, this CWD was not included in the 2019 IPA.

4 Adaptive Management and Research and Development

Key Uncertainty 3.3 of the Adaptive Management Plan is “Is clean water diversion an effective water management strategy?” Moving forward, CWDs will continue to be evaluated (post-2019 IPA) and adaptively managed as follows:

- Through the design, permitting, constructing, commissioning and operating of the Kilmarnock Creek CWD and studying its effectiveness and influence on the amount of selenium and other water quality constituents reporting to the un-diverted volume of Kilmarnock Creek.
- By applying the results from the Kilmarnock Creek CWD study (or other applicable research) in evaluating the potential of diversions associated with subsequent AWTFs.
- Through more detailed assessments as part of the AWTF project to which a CWD is linked (e.g., for the CWD at LCO with the next phase of the WLC AWTF). These assessments will be used to refine the timing and sizing, as well the construction and operating approach, for each CWD providing a clear linkage with the design basis and permit application of the associated AWTF. Consequently, this detailed assessment may change the configuration of individual CWDs and will be used to inform future IPAs.

5 References

Teck (Teck Coal Limited). 2011. *Line Creek Operations Phase II Project Environmental Assessment Certificate Application*. Submitted to the British Columbia Environmental Assessment Office Pursuant to the British Columbia *Environmental Assessment Act* and the *Canadian Environmental Assessment Act*. Prepared by Teck Coal Limited – Line Creek Operations, Sparwood, BC. Issued December 2011, updated February 2012.

Teck. 2014. *Elk Valley Water Quality Plan*. Submitted to the British Columbia Ministry of Environment, July 2014.

Teck. 2017. *2017 Elk Valley Regional Water Quality Model Update Overview Report.* Prepared by Teck Coal Limited and submitted to the British Columbia Minister of Environment. October 31, 2017.

Villeneuve SA, Barbour SL, Hendry MJ, & Carey SK. 2017. Estimates of water and solute release from a coal waste rock dump in the Elk Valley, British Columbia, Canada. *Science of the Total Environment*, 601–602, 543–555. http://doi.org/10.1016/j.scitotenv.2017.05.040

Wellen CC, Shatilla NJ, & Carey SK. 2018. *The Influence of Mining on Hydrology and Solute Transport in the Elk Valley, British Columbia, Canada*.