Elk Valley Water Quality Plan

2019 Implementation Plan Adjustment

Annex C: Mitigation Inputs to 2017 Regional Water Quality Model

July 2019

Teck

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
AWTF	Active Water Treatment Facility
BSC	Ballasted Sand Clarifier
EVO	Elkview Operations
FBR	Fluidized Bed Reactor
FRO	Fording River Operations
IPA	Implementation Plan Adjustment
MBBR	Moving Bed Bioreactor
RWQM	Regional Water Quality Model
Teck	Teck Coal Limited
WLC	West Line Creek

UNITS OF MEASURE

Unit of Measure	Description
%	percent
m^3/d	cubic metre per day
mg/L	milligram per litre
µg/L	microgram per litre

1 Introduction

The water mitigation and treatment related inputs to the 2017 Regional Water Quality Model (RWQM) used to develop the 2019 Implementation Plan Adjustment (IPA) are described in this document. These inputs are based on Teck's updated understanding, information, and learnings since 2014, when the Elk Valley Water Quality Plan (EVWQP) Initial Implementation Plan (IIP) was developed.

2 Summary of Inputs

A summary of water mitigation / treatment inputs are shown in Table 2-1. More details are provided in the supporting sections below.

Table 2-1 Summary of Water Mitigation and Treatment Inputs to the 2017 Regional Water Quality Model

Parameter	Input	Notes
West Line Creek Active Water Treatment		
Treatment Capacity / Throughput	6,000 m^3/d (from December 31, 2018 to December 31, 2019) 7,100 m^3/d (from January 1, 2020 onwards)	Based on 2016 and 2017 performance at 5,500 m^3/d and initial operational improvements which have achieved close to ~6,000 m^3/d by December 31, 2018. Currently forecasted to meet 6,000 m^3/d in February 2019. Target capacity of 7,100 m^3/d (by end of 2019) with additional operational improvements through 2019.
Effluent Quality – To end of 2024	• Selenium (total): 20 µg/L or 95% removal if influent greater than 400 µg/L • Nitrate: 1 mg/L	Based on actual data (Table 3-1 below) / performance to date plus the addition of the Advanced Oxidation Process (AOP). Consistent with AOP Operational Permit application and end of pipe permit limits for the WLC AWTF.
Effluent Quality – 2025 onwards	• Selenium (total): 20 µg/L. • Nitrate: 1 mg/L	Represents continuous improvement goal over time based on WLC AWTF operational data and pilot test work.
Availability	95%	Based on actual availability of 92% in 2016 and 95% in 2017. Incorporated in the model by multiplying availability by treatment capacity (e.g., 0.95 x 5,500m^3/d or 0.95 x 7,100m^3/d depending on time period) to estimate overall influence.

Table 2-1 Summary of Water Mitigation and Treatment Inputs to the 2017 Regional Water Quality Model

Parameter	Input	Notes
Active Water Treatment		
Treatment Type	Biological Treatment with AOP	Based on the addition of the AOP process to WLC AWTF, inclusion of AOP in the FRO AWTF-South and EVO AWTF 1 designs, and for future AWTFs.
Biological Seeding Date	• FRO AWTF-South: December 31, 2020 • EVO AWTF 1: September 30, 2021 • FRO AWTF-North 1: December 31, 2022	Based on latest overall treatment program schedule (January 1, 2019).
Ramp-Up Period / Operational at 100% Capacity	One year after biological seeding date.	Conservatively, no benefit of treatment is incorporated into the model until one year after the biological seeding date an AWTF. Based on one year between biological seeding date and AWTF being fully effective at design capacity. and in-stream compliance date. This is consistent with the current permit timeline, which has one year between AWTF being operational and the date when the instream compliance limits drop.
Availability (for AWTF's other than WLC AWTF)	95% once AWTF reaches 100% capacity.	AWTF design capacity will account for ability to make up this unavailability; no modelling impacts (e.g., model at 100% capacity). Reduced AWTF throughput experienced from time to time as a result of recirculation to manage effluent quality and/or for maintenance/repairs. This is not incorporated into the RWQM due to uncertainty of frequency, duration, season timing, etc. Maintenance/repairs will be planned, from an annual timing perspective, in consultation with water modelling/monitoring to manage potential increases to water quality concentrations. In addition, as operational experience is gained and operational improvements made, the frequency of AWTF reduced capacity is expected to decrease and the ability to make up for reduced capacity during normal operations will increase.

Table 2-1 Summary of Water Mitigation and Treatment Inputs to the 2017 Regional Water Quality Model

Parameter	Input	Notes
Capacity	N/A	Determined using RWQM based on nitrate and selenium load removal required to meet in-stream Compliance Limits and Site Performance Objective (SPOs).
Timing of AWTFs	Post FRO AWTF-N Phase I (fully effective end of 2023) all future AWTFs spaced two years apart consistent with the Elk Valley Water Quality Plan (EVWQP).	AWTFs have a project duration of ~5 years. Two-year spacing allows for an efficient use of resources and sufficient time to advance multiple AWTFs with overlapping delivery schedules. It also provides more of an opportunity to learn from previous AWTFs as opposed to delivering one AWTF per year.
Phasing of AWTFs	Minimum phase size of 5,000 m^3/d, except when total hydraulic capacity was less than 10,000 m^3/d.	Allows for opportunity to learn from previous AWTFs and helps to manage uncertainty with water quality projections and changes to mitigation measures / technologies over time and their impact on future AWTFs. Through monitoring of receiving water quality, effects, and what is achieved by initial AWTFs, the timing of future AWTFs will be updated. As source control and treatment R&D are advanced and proven these will be incorporated to reduce the reliance on active water treatment (AWT).
Effluent Quality – FRO AWTF-South to end of 2024	• Selenium (total): 30 µg/L or 95% removal if influent greater than 600 µg/L • Nitrate: 2 mg/L	Based on actual performance of WLC AWTF, same (biological treatment plus AOP) treatment flowsheet, and FRO AWTF-South model projected influent concentrations.
Effluent Quality – FRO AWTF-South 2025 onwards	• Selenium (total): 20 µg/L. • Nitrate: 2 mg/L	Represents estimated improvements over time based on to-date WLC AWTF operational data, to-date pilot test work, and focused R&D effort to improve AWTF selenium effluent concentrations.
Effluent Quality – EVO AWTF 1 to end of 2024	• Selenium (total): 30 µg/L or 95% removal if influent greater than 600 µg/L • Nitrate: 2 mg/L	Based on actual performance of WLC AWTF, same (biological treatment plus AOP) treatment flowsheet, and EVO AWTF 1 model projected influent concentrations.

Table 2-1 Summary of Water Mitigation and Treatment Inputs to the 2017 Regional Water Quality Model

Parameter	Input	Notes
Effluent Quality – EVO AWTF 1 2025 onwards	• Selenium (total): 20 µg/L. • Nitrate: 2 mg/L	Represents estimated improvements over time based on to-date WLC AWTF operational data, to-date pilot test work, and focused R&D effort to improve AWTF selenium effluent concentrations.
Effluent Quality – FRO AWTF-North to end of 2025	• Selenium (total): 30 µg/L or 95% removal if influent greater than 600 µg/L • Nitrate: 2 mg/L	Based on actual performance of WLC AWTF, same (biological treatment plus AOP) treatment flowsheet, and model projected influent concentrations for both FRO AWTF-South and EVO AWTF 1.
Effluent Quality – FRO AWTF-North 2026 onwards	• Selenium (total): 20 µg/L. • Nitrate: 2 mg/L	Represents estimated improvements over time based on to-date WLC AWTF operational data, to-date pilot test work, and focused R&D effort to improve AWTF selenium effluent concentrations.
Effluent Quality - All new AWTFs from 2025 onwards	• Selenium (total): 20 µg/L. • Nitrate: 2 mg/L	Represents estimated improvements over time based on to-date WLC AWTF operational data, to-date pilot test work, and focused R&D effort to improve AWTF selenium effluent concentrations.
Effluent Quality - Sulphate	Addition of 20 mg/L to influent concentration.	Current biological AWT flowsheet adds an estimated ~20 mg/L through the AOP process as outlined in the WLC AWTF AOP Operational Permit application. Approximately 20 mg/L of sodium sulphite is added to the AOP effluent to quench/remove the ozone to ensure ozone is consumed prior to environmental discharge. The sulphite converts to sulphate once dosed.
Intake Locations	See maps in Attachment 1.	
Outfall Locations	See maps in Attachment 1.	Assumption is to discharge into fish bearing waters.

Table 2-1 Summary of Water Mitigation and Treatment Inputs to the 2017 Regional Water Quality Model

Parameter	Input	Notes
Clean Water Diversions		
Location, Timing and Size	An evaluation of clean water diversions was completed as part of the 2019 IPA. As a starting point for the evaluation the details associated with clean water diversions from the EVWQP were used with the exception of the operational dates that were changed to align with the updated AWTF dates as follows: • Kilmarnock Creek Diversion: December 31, 2020. • Erickson Creek Diversion: September 30, 2021. • South Gate Creek Diversion: In place and operating • Upper Line Creek/Horseshoe Creek/ No Name Creek Diversions: December 31, 2025 Additional details provided in Annex D: Clean Water Diversion Evaluation.	
Intake Water Collection		
Water Availability	Drainage / source specific values summarized below: • FRO Kilmarnock Creek – 75%, 95% (2034 onwards) • FRO Swift and Cataract Creeks – 95% (Lined Pond) FRO AWTF-North Intakes Clode Creek, Swift North Spoil Drainage and Swift Pit – 80%, 95% (2033 onwards) • EVO Erickson Creek – 90% • EVO Gate and Bodie Creeks – 95% • LCO Dry Creek – 99% • LCO Line Creek and West Line Creek – 95% • LCO No Name Creek Entering into Mine Services Area West (MSAW) – 90% • GHO Upper Greenhills Creek – 75% • GHO Leask and Wolfram Creek – 95%	See Annex H: Assessment of Water Availability
Intake Collection Efficiency	95%	The percentage of available flow that is captured by the intake. Reflects best engineering judgement of water capture.

% = percent, m^3/d = cubic metres per day; µg/L = micrograms per litre; mg/L = milligrams per litre

AOP = Advanced Oxidation Process; AWT = active water treatment; AWTF = active water treatment facility; EVO = Elkview Operations; EVWQP = Elk Valley Water Quality Plan; FRO = Fording River Operations; GHO = Greenhills Operations; IPA – Implementation Plan Adjustment; LCO = Line Creek Operations; MSAW = Mine Services Area West; N/A = not applicable; R&D = Research and Development; WLC AWTF = West Line Creek Active Water Treatment Facility.

3 Input Details

3.1 Active Water Treatment

Common inputs for AWTFs, subsequent to the WLC AWTF, are:

- Biological treatment technology (for selenium and nitrate removal) coupled with an Advance Oxidation Process (AOP) for selenium speciation treatment. This is based on the planned design change to the WLC AWTF (to add an AOP process) and the technology evaluation for Fording River Operations Active Water Treatment Facility South (FRO AWTF-South). The specific form of biological treatment (i.e. Fluidized Bed Reactor [FBR] only [WLC AWTF flowsheet] or FBR followed by Advance Biological Metals Removal [ABMet®]) is not identified and is not required for input to the water model.
- Biological seeding dates are based on the latest overall water treatment program schedule (January 1, 2019). These dates are currently referred to (and labeled as) operational dates in permit 107517. A clearer definition of operational date was determined, and applied, through discussions with regulators for the West Line Creek AWTF Restart as being the biological seeding date. These dates are:
    - FRO AWTF-South: December 31, 2020.
    - EVO AWTF 1: September 30, 2021.
    - FRO AWTF-North 1: December 31, 2022.
- The definition of commissioning in EMA Permit 107517 is: “bringing the AWTF works into operation and that subsequent to initiating operation of AWTF works, the commissioning phase includes provision of reasonable timing for undertaking operational refinement or adjustment of works to optimize efficiency and/or effluent quality. In this regard, a maximum of 120 days is considered a reasonable time to commissioning the AWTF.” For the 2019 IPA, biological seeding of an AWTF defines the start of the commissioning and ramp-up period. The commissioning and ramp-up period, or the duration from biological seeding of the bioreactors to operation at full capacity (nitrate and selenium load removal), was set at one year in the 2019 IPA. It includes the 120 days (four months) identified in permit 1057517, after which end of pipe effluent concentrations are expected to be met, plus eight months to ramp-up to 100% capacity (designed water treatment volume and load removal]; a total duration of one year, to bring an AWTF from biological seeding to fully operational. Based on the re-start of the WLC AWTF it was estimated that at the mid-point of the ramp-up period of each AWTF (i.e., six months after biological seeding) that the AWTF would be operational at 50% capacity. For modelling purposes, however, this mid-point was not captured in the RWQM and represents an opportunity for some treatment capacity to be available prior to the end of the one-year ramp-up period.
- For each AWTF availability should be set at 95% once the AWTF reaches 100% capacity, however this will be accounted for in the design of the AWTFs (i.e. an availability factor of 1.05 will need to be applied to an AWTF design) and not in the RWQM.
- Intake and outfall locations are shown in Attachment 1. Assumption is that outfalls will discharge into fish bearing waters.

3.2 Clean Water Diversions

An evaluation of clean water diversions was completed as part of the 2019 IPA. The details associated with clean water diversions from the Elk Valley Water Quality Plan were used as a starting point for this evaluation, with the exception of the operational dates that were changed to the following (to align with the updated AWTF dates):

- Kilmarnock Creek Diversion: December 31, 2020
- Erickson Creek Diversion: September 30, 2021
- South Gate Creek Diversion: In place and operating
- Upper Line Creek/Horseshoe Creek/ No Name Creek Diversions: December 31, 2025

Additional details are provided in Annex D (Clean Water Diversion Evaluation) of the 2019 IPA Report.

3.3 Intake Water Collection

A summary of RWQM input for intake water collection is included in Table 2-1. This information is from Annex H (Assessment of Water Availability) of the 2019 IPA Report.

3.4 Ongoing Improvements to Selenium Effluent Concentrations

Improvements in modelled selenium effluent concentrations over-time are outlined in Table 2-1. Improvements start in 2025, to capture forecasted improvements over the next six years, as a result of ongoing effort and learning through treatment operation. This represents estimated improvements over time based on to-date WLC AWTF operational data, to-date pilot test work, and focused R&D effort to improve AWTF selenium effluent concentrations. This section provides more information to support this.

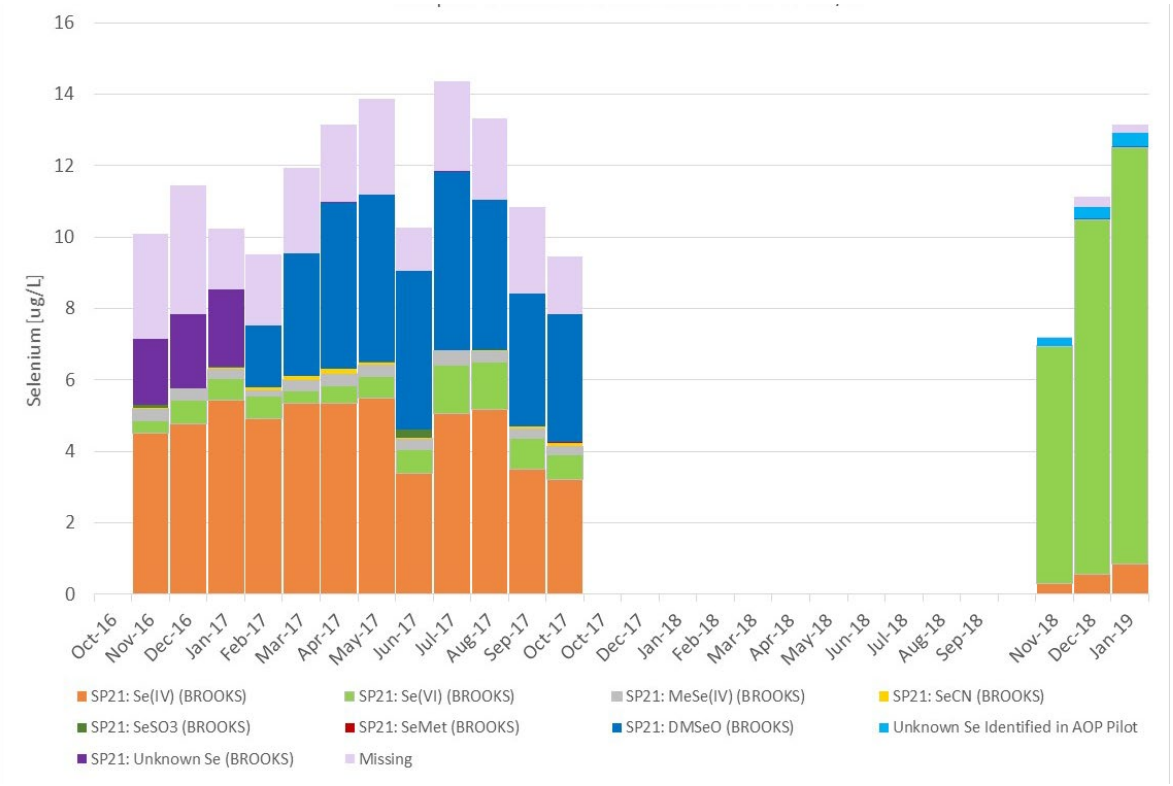
Continuous improvement and the EVWQP adaptive management plan (AMP) follow similar cycles to achieve incremental improvements that culminate towards achieving a defined goal, which is in this case is lowering effluent total selenium concentration for existing and future facilities. These cycles rely on assessing information, designing experiments/improvements, implementation of learnings, monitoring and evaluating results and adjusting operating procedures to integrate learnings. To facilitate and drive this improvement, in 2018 Teck created the Senior Processing role to lead this effort and. This role is supported by both the Water Operations and the Water R&D groups.

The following examples illustrate how the continuous improvement cycle has worked to improve WLC AWTF performance since the 2015 restart and the plans going forward.

1) **Selenium Speciation**
    - **Assessing information:** In the summer of 2016, a discrepancy between dissolved and total selenium assay results triggered a closer review of selenium speciation. This review raised questions regarding effluent selenium bioavailability. A review of initial receiving environment tissue assays indicated increased local selenium uptake. The next step in the cycle (designing experiment/improvements) was than initiated and the receiving environment monitoring program was increased.

- **Designing experiments/improvements:** Over the fall and winter 2016 and 2017, technologies to either reduce effluent selenium concentrations or convert selenium species were identified and the most promising tested at a bench scale. By spring of 2017, the AOP was identified and a pilot program was completed in 2017. Pilot results showed significant conversion of bioavailable selenium species back to less bioavailable selenate.
- **Implementation of learnings:** In fall 2018, a full-scale AOP installation was completed to convert selenium species in WLC AWTF effluent to selenate.
- **Monitoring and evaluating results:** AOP has operated as designed converting a substantial portion of effluent selenium species to selenate (Figure 3-1). Receiving environment selenium uptake monitoring is in place and ongoing to confirm success.
- **Adjusting operating procedures to integrate learnings:** Selenium conversion efficiency versus AOP operating conditions is being monitored and learnings are being continually integrated into operating procedures and into the designs of future AWTFs.

Figure 3-1 Monthly Average Selenium Speciation in West Line Creek Active Water Treatment Facility Effluent Showing Change in Final Selenium Speciation Due to Installation of the Advance Oxidation Process.



Notes:

SP21 = West Line Creek Active Water Treatment Facility Effluent Compliance Point (end-of-pipe)
Orange = Selenite (target selenium species to be converted to selenate through advanced oxidation process)
Green = Selenate (target, less bioavailable, form of selenium)
Blue = Dimethylselenoxide (selenium species to be converted to selenate through advanced oxidation process)
Light Purple = Missing selenium species
Purple = Unknown selenium species

2) **Selenite Removal to Reduce Total Selenium (in Effluent)**

- **Assessing information:** Triggered by selenium speciation, regular selenium speciation surveys were completed on WLC AWTF effluent (since November 2016). Results showed that selenite was one of the primary selenium species present in WLC AWTF effluent.
- **Designing experiments/improvements:** Processes improvement work to lower the selenite present in the effluent focused on optimizing ferric chloride addition in the Ballasted Sand Clarifier (BSC) because of ferric chlorides' ability to adsorb selenite. AWTF data showed the BSC was effectively removing selenite down to ~2 µg/L, but the subsequent Moving Bed Bioreactor (MBBR) was producing selenite. Bench scale tests were completed through the winter of 2017 and showed that if ferric chloride was added after the MBBR, and before the sand-filters (in the treatment train) some selenite could be removed.
- **Implementation of learnings:** Based on this, a process change notification was issued and full-scale ferric chloride addition to the sand-filters started in May 2017.
- **Monitoring and evaluating results:** An initial drop in selenite concentrations was observed; however, in July and August of 2017 the selenite leaving the MBBR increased. Ferric addition to the sand-filters helped to mitigate this increase. Further ferric chloride additions could reduce selenite further, however, the solids loading on the sand-filters limited ferric chloride dosing rates at this location.
- **Designing experiments/improvements (round 2):** The increased selenite from the MBBR triggered further bench scale work to either (a) move the BSC to after the MBBR in the treatment process or (b) eliminate the MBBR. Bench scale test results suggested that switching the MBBR and BSC in the treatment process can further reduce selenite. The downside is that selenium in solids carried over to the AOP would oxidise to selenate and increase effluent selenium concentrations. However, an additional benefit of switching the MBBR and BSC would improve BSC solid/liquid separation performance.
- **Implementation of learnings (round 2):** Piping was installed during WLC AWTF downtime, while the AOP was installed, to allow the MBBR to be operated before the BSC.
- **Monitoring and evaluating results (round 2):** Since restart, in fall 2018, WLC AWTF effluent selenite concentrations have remained low to date, although further monitoring is required as the selenite production across the MBBR has not yet achieved steady-state.
- **Adjusting operating procedures to integrate learnings (round 2):** To be determined based on monitoring and evaluating results (round 2) above.

3) **Removal of Other Selenium Species to Reduce Total Selenium (in Effluent):**

- **Assessing Information:** As shown in Figure 3-1, the three most common non-selenate species in the AWTF effluent prior to AOP were selenite, dimethylselenoxide (initially reported as "unknown"), and a "missing" selenium species. To better identify these species, Teck worked closely with the commercial lab to improve detection limits, speed up turn-around times and identify the unknown selenium species. Finding ways to minimize the formation of these selenium species could result in a lower total selenium in the AWTF effluent.

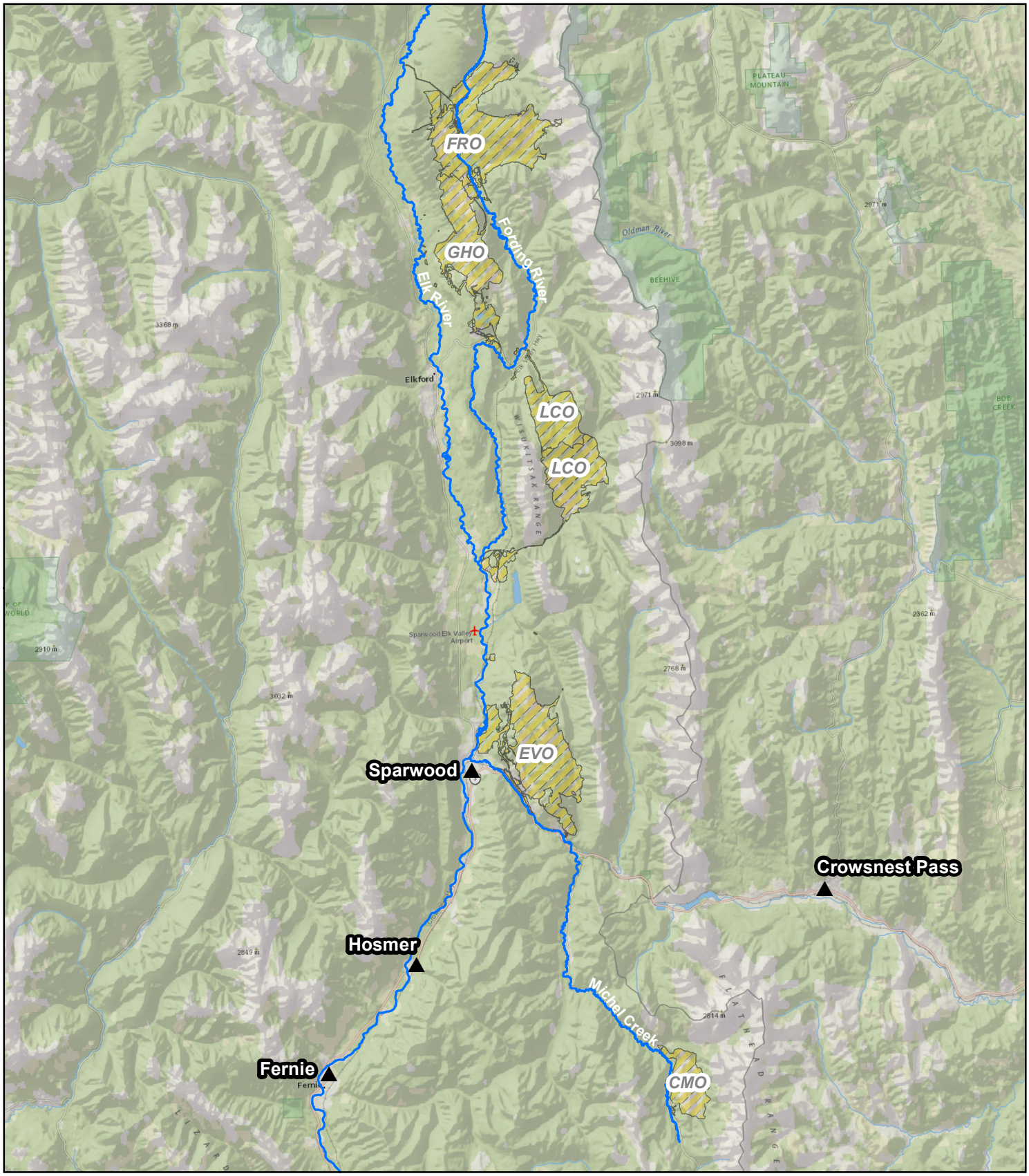
- **Designing experiments/improvements:** A research program is planned for 2019 to better understand the conditions that lead to the formation of the various selenium species. The first component will consist of a lab program with creek water to understand the impact of carbon source and extent of reduction on selenium speciation. The second component will consist of small-scale parallel FBR trials operated continuously at WLC AWTF to further evaluate the impact of carbon dosing on selenium speciation and will include plant recycle streams in the test feeds, in addition to creek water.
- **Implementation of learnings:** Learnings from the FBR trials will be used to develop operating strategies for both WLC AWTF and Fording River South AWTF (FRO AWTF-S).

The examples above all contribute to improvement in the quality of effluent from the WLC AWTF that will inform future operations and design, towards the effluent goals described in Table 2-1. In addition to the examples explained above, mean monthly total selenium effluent (and influent) concentrations for the WLC AWTF and average treatment facility throughput are shown in Table 3-1. Mean monthly total selenium effluent concentrations at the WLC AWTF have consistently been below 20µg/L.

Table 3-1 West Line Creek Active Water Treatment Facility Mean Monthly Treatment Throughput and Influent and Effluent Total Selenium Concentrations

Month-Year	Mean AWTF Throughput (m^3/d)	Influent Mean Total Selenium Concentration (µg/L)	Effluent Mean Total Selenium Concentration (µg/L)
Feb-16	6,500	226	9.1
Mar-16	5,300	291	10.9
Apr-16	5,800	305	10.6
May-16	6,100	230	10.5
Jun-16	4,700	252	10.1
Jul-16	5,900	297	13.5
Aug-16	5,400	318	15.0
Sep-16	5,800	298	18.2
Oct-16	5,600	282	10.0
Nov-16	5,300	305	11.9
Dec-16	5,400	298	12.9
Jan-17	5,100	299	12.5
Feb-17	5,400	297	12.6
Mar-17	4,900	339	15.9
Apr-17	5,400	317	17.2
May-17	5,400	360	17.4
Jun-17	5,300	224	13.7
Jul-17	5,400	336	16.1
Aug-17	5,200	389	16.9
Sep-17	5,300	370	11.8
Oct-17	4,000	241	9.5
Oct-18	3,300	297	8.9
Dec-18	4,500	273	11.9
Jan-19	4,800	260	15.5
Feb-19 (forecast)	6,000	260	15.5

Attachment 1 Active Water Treatment Facility Approximate Intake and Outfall Locations



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Elk Valley Overview

- Communities
- Railway
- Water Network
- State - Province Boundaries
- Mine Permit Boundaries

N

0 2.5 5 10 Kilometers

DATE:	MINE OPERATION:
8/6/2015	Coal Mountain
SCALE:	COORDINATE SYSTEM:
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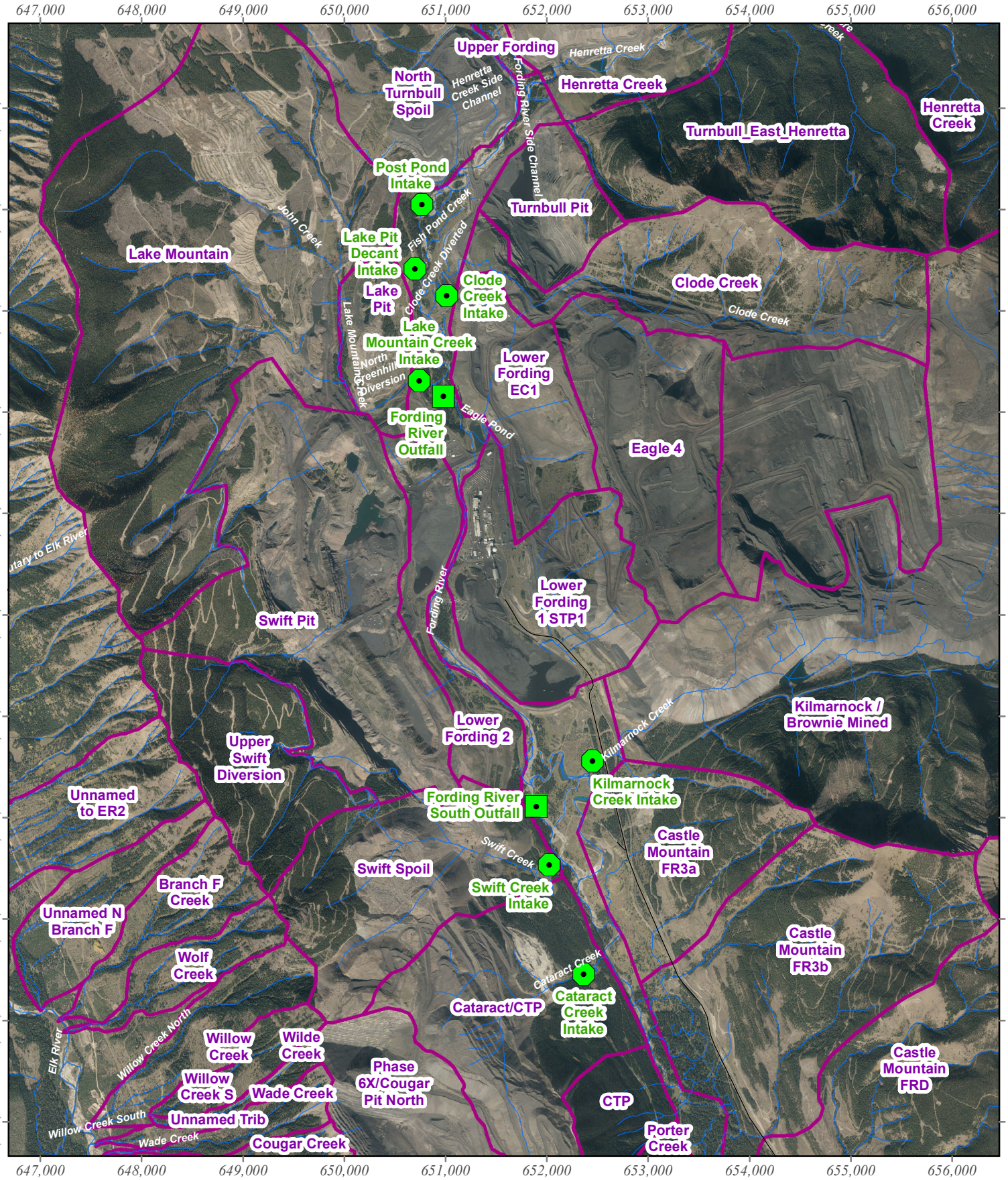

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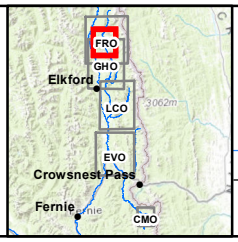

Water Treatment Proposed Intake and Outfall Locations Fording River Operations

Rivers
Roads
MinedOutWatershed
Intake Location
Outfall Locaton

N

0 315 630 1,260 Meters

DATE:	MINE OPERATION:
7/25/2017	Coal Mountain
SCALE:	COORDINATE SYSTEM:
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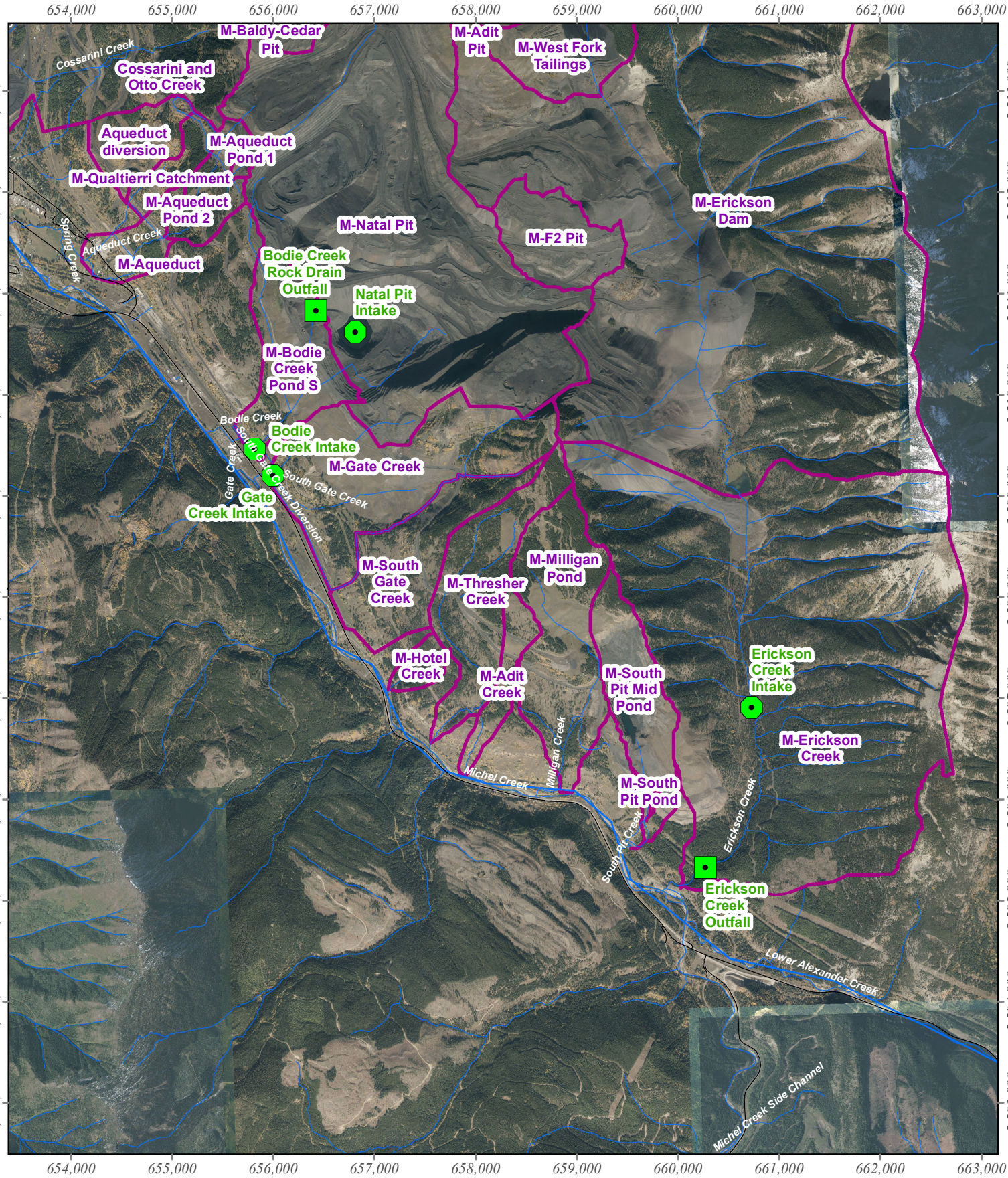

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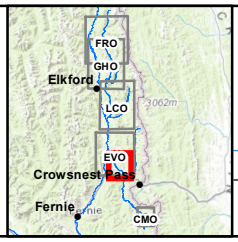

Water Treatment Proposed Intake and Outfall Locations Elkview Operations

Rivers
Roads
MinedOutWatershed
Intake Location
Outfall Locaton

N

0 315 630 1,260 Meters

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SCALE: 1:50,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

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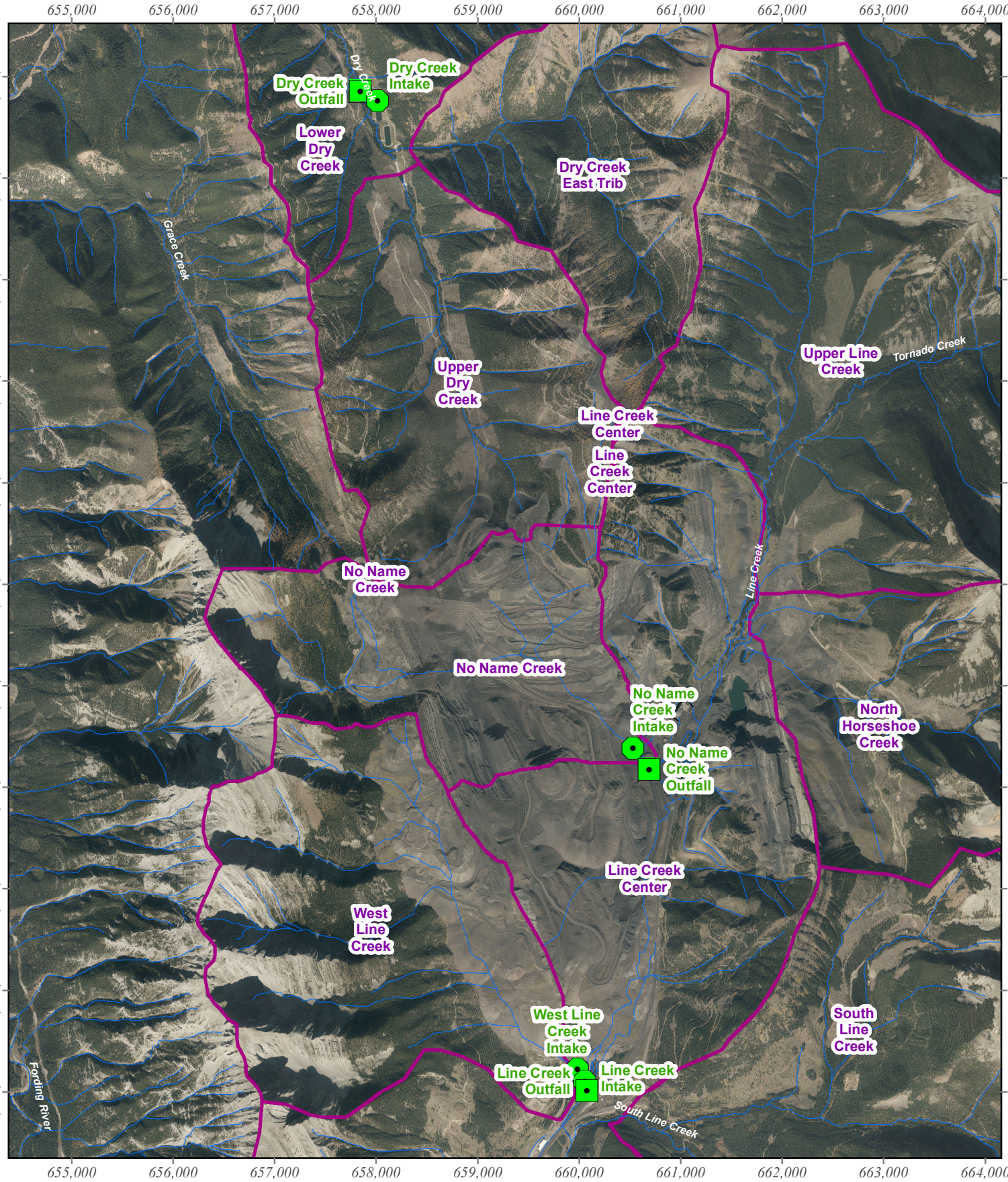

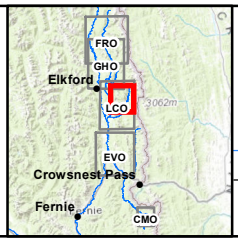

Water Treatment Proposed Intake and Outfall Locations Line Creek Operations

Rivers
Roads
MinedOutWatershed
Intake Location
Outfall Locaton

N

0 315 630 1,260 Meters

DATE: 7/25/2017	MINE OPERATION: Coal Mountain
SCALE: 1:50,000	COORDINATE SYSTEM: NAD 1983 UTM Zone 11N

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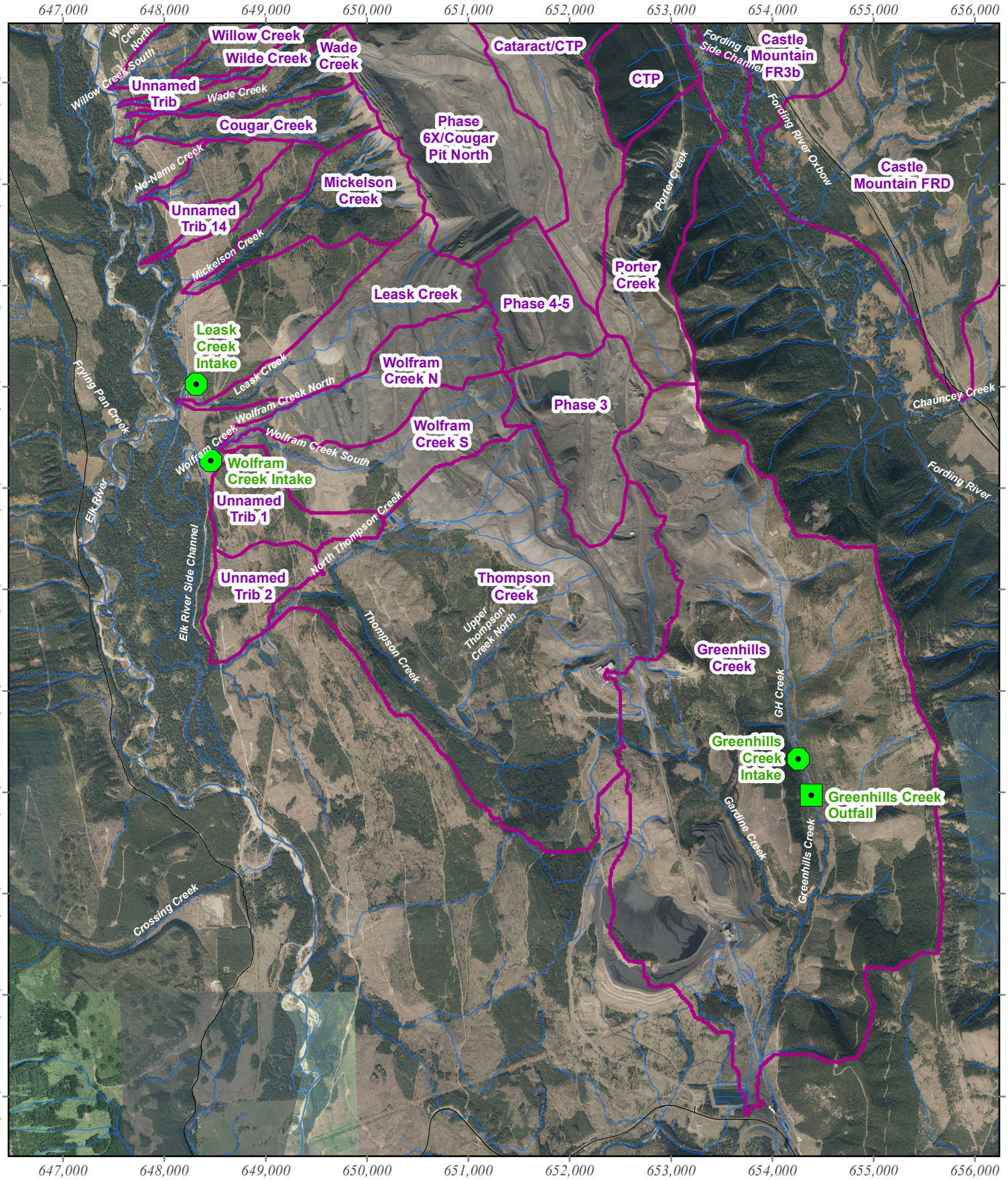

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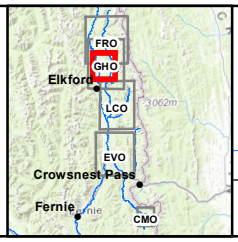

Water Treatment Proposed Intake and Outfall Locations Greenhills Operations

Rivers
Roads
MinedOutWatershed
Intake Location
Outfall Locaton

N

0 315 630 1,260 Meters

DATE:	MINE OPERATION:
7/25/2017	Coal Mountain
SCALE:	COORDINATE SYSTEM:
1:50,000	NAD 1983 UTM Zone 11N

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