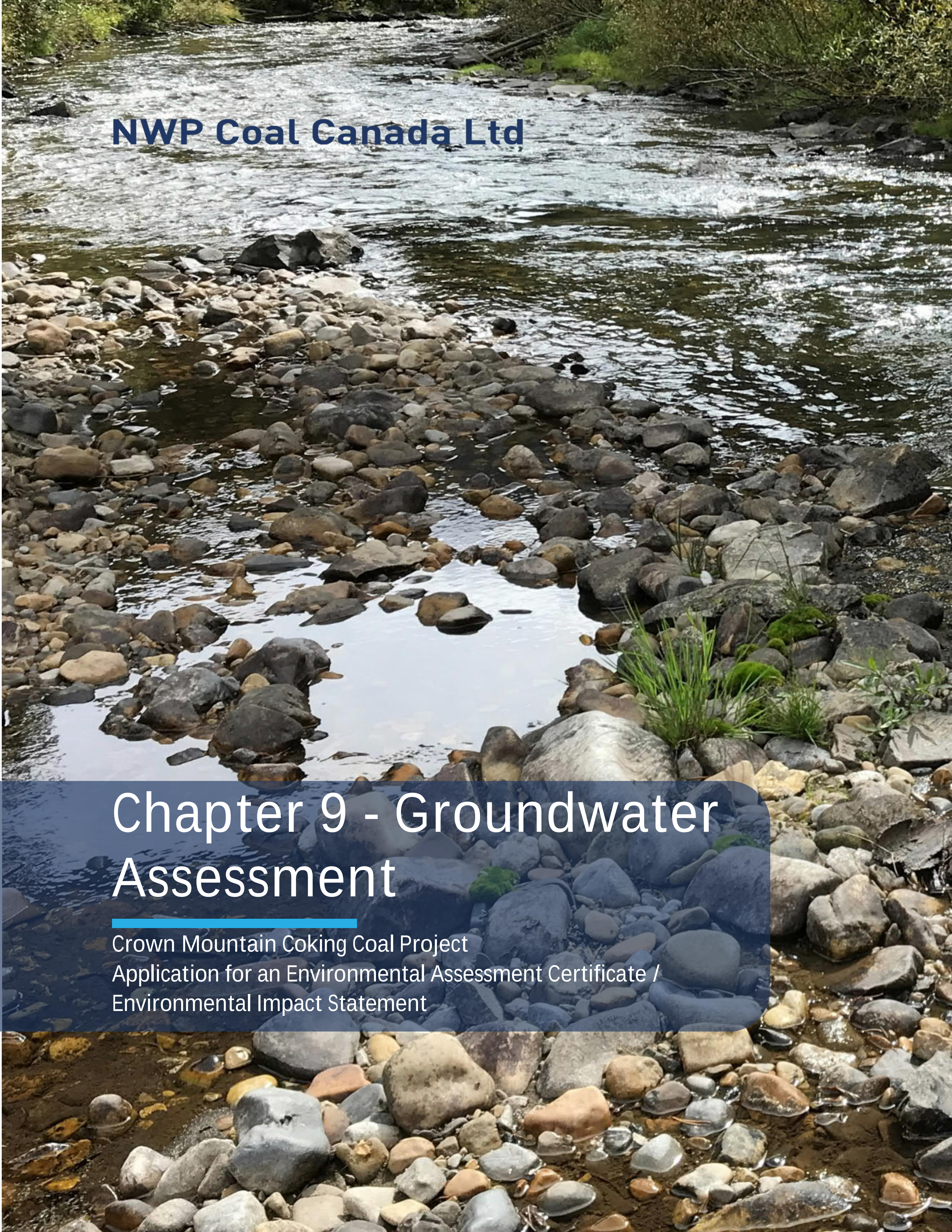

NWP Coal Canada Ltd

Chapter 9 - Groundwater Assessment

Crown Mountain Coking Coal Project
Application for an Environmental Assessment Certificate /
Environmental Impact Statement

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9. Groundwater Assessment

9.1 Introduction

Groundwater quantity and quality are key components of the biophysical environment, as they interact with the creeks and drainages in the vicinity of the Project. Groundwater quantity (as a component of baseflow) contributes to the creeks and drainages in the area, which are both gaining and losing to groundwater along their lengths. Since groundwater quality and quantity are intrinsically tied to surface waters in the vicinity of the Project, groundwater flows are considered essential to the maintenance of aquatic ecosystems, vegetation, wildlife, and human health. Groundwater quality constitutes the physical, chemical, biological, and aesthetic characteristics of groundwater as determined by regional and local factors, including the lithology, architecture, and structure of the host geologic formations, surficial deposits, rock weathering, surface water contribution, biological processes, and anthropogenic influences (Khatri and Tyagi, 2015). Within the Elk Valley, groundwater is a primary source of drinking water for residents (Teck Coal Limited, 2014), and is a potential future water usage within the vicinity of the Project.

Given the complex relationship between groundwater and the natural environment, groundwater quantity and quality were identified as intermediate valued components (VC) for the Project in the Application Information Requirements (AIR; Environmental Assessment Office [EAO], 2018) and as components of the physical environment in the Guidelines for the Preparation of an Environmental Impact Statement for the Crown Mountain Coking Coal Project (EIS Guidelines; Canadian Environmental Assessment Agency, 2015), since groundwater baseflow contributions to surface water constitute a pathway to receptor VCs such as fish, wildlife, vegetation, and humans. An understanding of groundwater quality and quantity within and downstream of the Project is critical to the Project design, engineering, operations, and assessment and mitigation of potential environmental effects. Changes to groundwater quality and quantity have potential linkages to other intermediate and receptor VCs when groundwater interacts with surface water as baseflow contribution to watercourses within the Project area. These potential linkages with intermediate and receptor VCs are primarily assessed in the following chapters:

- Chapter 10: Surface Water Quantity Assessment;
- Chapter 11: Surface Water Quality Assessment;
- Chapter 12: Fish and Fish Habitat Assessment;
- Chapter 13: Landscapes and Ecosystems Assessment;
- Chapter 14: Vegetation Assessment;

- Chapter 15: Wildlife and Wildlife Habitat Assessment; and
- Chapter 22: Human and Ecological Health Assessment.

9.1.1 Regulatory and Policy Setting

Applicable federal and provincial legislation and guidance documents related to groundwater quality and quantity are summarized in Table 9.1-1 and Table 9.1-2. A groundwater baseline assessment was conducted by SRK Consulting, Inc. (SRK; SRK, 2021a; Appendix 9-A) which considers the provincial surface water and groundwater quality guidelines for comparison, namely:

- British Columbia (B.C.) Approved Water Quality Guidelines [WQG]: Aquatic Life (B.C. Ministry of Environment and Climate Change Strategy [ENV], 2019a); and
- Provincial groundwater quality standards (i.e., B.C. Contaminated Sites Regulation (CSR) Schedule 3.2 Generic Numerical Water Standards for the protection of Aquatic Life, Drinking Water, Livestock and Irrigation [CSR, 1996]).

These guidelines and standards provide a comparative basis for identifying groundwater quality parameters that may have elevated baseline conditions. Other relevant guidance includes the Elk Valley Water Quality Plan (EVWQP; Teck Resources Limited, 2014), also known as the Elk Valley Area Based Management Plan, which was developed in response to a Ministerial Order issued to Teck Resources Limited (Teck) in April 2013 under the B.C. Environmental Management Act (2003) to manage the cumulative effects of coal mining on water quality in the Elk Valley. The EVWQP includes short-, medium-, and long-term water quality targets for four Order constituents as specified in the directive (i.e., nitrate, sulphate, cadmium, and selenium) for the protection of ecosystem health, human health, and surface water and groundwater quality.

Groundwater is the primary source of drinking water for residents in the Elk Valley (Teck Resources Limited, 2014). As described in the EVWQP, most Elk Valley residents obtain drinking water from municipal water wells operated by the City of Fernie, District of Sparwood, and District of Elkford. Groundwater quality from these sources is tested regularly. There are approximately 250 private properties between Elkford and Fernie, which obtain water for drinking and other purposes from private wells or surface water sources outside of the municipal water supplies. The potential exists for groundwater sources within the Elk Valley to be influenced by surface water, so while not the primary source of drinking water, surface water-to-groundwater interactions are important for assessing pre-mining baseline conditions and for predicting potential effects and ongoing monitoring of drinking water quality in the region.

Table 9.1-1: Federal Regulatory Considerations and Guidance Documents for Groundwater Quality and Quantity

Legislation/Guideline Name	Year	Description
Legislation		
Canadian Environmental Protection Act	1999	Provides pollution prevention measures for the protection of human and environmental health, while promoting sustainable development and use of resources in Canada.

Legislation/Guideline Name	Year	Description
Canada Water Act	1985	Provides for the management of water resources for the benefit and health of Canadians, including the prevention and remedy of pollution of waters.
Fisheries Act	1985, amended 2019	Establishes a framework for the management of fisheries resources and conservation of fish, including the prevention of pollution of fish habitat. The Fisheries Act applies to water, including groundwater that discharges to fish-bearing watercourses.
International Boundary Waters Treaty Act	1985	Pertains to the legal rights of parties pertaining to the impacts to and diversion of surface water in Canada, which flow to the United States.
Guidelines		
Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG)	2014	Comparison values for surface water quality for the protection of human health, aquatic life, and for agricultural use. Where groundwater discharges to surface water, the CWQG are applicable (CCME, 2014).
Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ)	2020	Published by Health Canada, these guidelines are established based on current, published scientific research related to health effects, exposure levels, aesthetic qualities (i.e., odour and taste), and operational considerations (i.e., treatment and analytical technologies and adverse effect on drinking water infrastructure) (Health Canada, 2018).
Federal Interim Groundwater Quality Guidelines for Federal Contaminated Sites	2010, updated 2012	These guidelines were developed for the assessment, remediation, and risk management of contaminated groundwater at federal sites. The guidance document provides interim guideline values for groundwater quality assessment until Canadian groundwater quality guidelines become available (Government of Canada, 2012).

Table 9.1-2: Provincial Regulatory Considerations and Guidance Documents for Groundwater Quality

Legislation/Guideline Name	Year	Description
Legislation		
Environmental Management Act	2004	Regulates the development of policies for the management, protection and use of the environment, including the development of land which is subject to flooding, and the management of water resources, fisheries, aquatic life, and waste disposal.
Water Protection Act	1996	The Water Protection Act confirms the Province’s ownership of surface and groundwater, defines limits for bulk water removal and prohibits large-scale diversions of water between major provincial watersheds and/or to locations outside the province.

Legislation/Guideline Name	Year	Description
Mines Act	1996	Applies to permitting and operating procedures of mining operations in B.C., including environmental compliance (i.e., monitoring, metal leaching, acid rock drainage [ARD] generation and erosion control), health and safety and accident reporting, and abandonment and reclamation requirements.
Riparian Areas Protection Act	1997	Establishes directives to protect and enhance riparian zones in the vicinity of development, including industrial activity.
Water Sustainability Act	2014	Enforces the protection of stream and aquatic environment health, and considers the potential effects on surface water and groundwater in land use decisions.
Drinking Water Protection Act	2001	Provides guidelines and directives for the use and development of water supply systems used for domestic purposes, for the protection of public health.
Guidelines		
Ambient Water Quality Guidelines for Selenium Update	2014	Provides updated Water Quality Guidelines (WQGs) for selenium in water for the protection of aquatic life. Analytical results can be compared to the guideline value and alert value for selenium in water for comparison purposes (B.C. MOE, 2014a).
Derivation of Water Quality Guidelines for the Protection of Aquatic Life in British Columbia	2019	Provide reference for the derivation of water quality guidelines for use in B.C. (ENV, 2019b).
Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators	2016	Guidance which defines the requirements of baseline studies and monitoring programs for surface water and air effluents for proposed and operating mineral developments in B.C. (Carmichael et al, 2016).
B.C. Water Quality Guidelines (WQG; Approved and Working)	2019; 2020	Provide short term maximum “acute” and long term “chronic” comparison values for surface water quality, for the protection of aquatic organisms against severe effects such as lethality due to short-term intermittent or transient exposures to contaminants, and from lethal and sub-lethal effects over long-term indefinite exposures (ENV 2019a, 2020).
B.C. Contaminated Sites Regulation (CSR), Schedule 3.2 Generic Numerical Water Standards	2019	Provide numerical standards for comparison to groundwater parameters, representing acceptable concentrations of substances in groundwater. Monitoring results may be compared directly to the substance concentrations in Schedule 3.2 to determine whether a groundwater source is in compliance with applicable water use standards. Under the CSR, four groundwater classes are provided: DW – drinking water, AW – aquatic life protection, IW – irrigation water, and LW – livestock watering. Applicability of these classes are determined by the current, and future land uses in proximity to the property boundary (CSR, 1996).

Legislation/Guideline Name	Year	**Description**
Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities of the British Columbia Ministry of Environment	2012	These guidelines address the broader concepts of groundwater modelling related to the environmental assessment (EA) process in B.C. Guidelines for using models as a tool to identify and assess the impacts of natural resource projects in B.C., including generally accepted best practices in groundwater modelling for development and use of groundwater models by resource industry groundwater professionals, and review of groundwater models by regulators (Wels et al., 2012).

Though not yet in force, the proposed Coal Mining Effluent Regulations (CMER) under the Fisheries Act will provide national baseline effluent quality standards for all coal mines upon promulgation and will include environmental effects monitoring provisions. The proposed CMER include chronic and acute standards for total suspended solids, total selenium, and total nitrate in effluent from new and existing coal mines. These standards would apply to the Project at the time that they come into effect.

9.2 Scope of the Assessment

9.2.1 Valued Components and Measurement Indicators

Groundwater quality and quantity are linked to the surface water environment, and as such, impacts to groundwater may result in changes in surface water resources and vice versa. Groundwater may be impacted as a result of mine development and dewatering activities, mine rock management and other mine-related activities. Changes in groundwater quantity may result in stream flow reductions or changes in peak flow, which may affect downstream surface water quantity. Potential changes in groundwater quality and quantity can also affect sources of drinking water. Groundwater levels and concentrations of metals and non-metal constituents were selected as the measurement indicators for groundwater quantity and quality (Table 9.2-1).

Table 9.2-1: Measurement Indicators and Effects Pathways for Groundwater Quantity and Quality

Valued Component	Measurement Indicators	Effects Pathways
Groundwater Quality	Groundwater quality measured as concentrations of metals and non-metal constituents in groundwater	VCs or VC groups for which groundwater quality is an effects pathway include: • Surface Water Quality; • Fish and Fish Habitat; • Benthic Invertebrates; • Landscapes and Ecosystems; • Vegetation; • Wildlife and Wildlife Habitat; • Human Health; and • Wildlife Health.

Valued Component	Measurement Indicators	Effects Pathways
Groundwater Quantity	Groundwater quantity measured through groundwater levels	VCs or VC groups for which groundwater quantity is an effects pathway include: • Surface Water Quantity; • Surface Water Quality; • Fish and Fish Habitat; • Benthic Invertebrates; • Landscapes and Ecosystems; • Vegetation; and • Wildlife and Wildlife Habitat.

9.2.2 Indigenous and Stakeholder Consultation

NWP engaged with Indigenous groups and conducted consultation with public stakeholders and regulators. A summary of all consultation and engagement activities undertaken to date is presented in Chapter 4. A summary of consultation feedback specific to groundwater is presented in Table 9.2-2 below. Indigenous and stakeholder consultation feedback received was used to inform the groundwater modelling and reporting.

9.2.3 Assessment Boundaries

9.2.3.1 Spatial Boundaries

The study areas considered in the groundwater quantity and quality assessments include the Project footprint, the Groundwater Local Study Area (LSA), and the Groundwater Regional Study Area (RSA; Figure 9.2-1). As detailed in Chapter 5, Table 5.3-2, the spatial boundaries for the groundwater quantity and quality VCs have changed from the study areas presented in the AIR. A discussion on the spatial boundaries used in the assessment is provided below.

The Project footprint encompasses the location of temporary and permanent works associated with the Project and covers approximately 13 square kilometres (km^2) or 1,283 hectares (ha) (Figure 9.2-2). The centre of the Project is positioned approximately 12 km northeast of the District of Sparwood and approximately 5 km west of the provincial boundary between B.C. and Alberta. The Project footprint is the area of physical disturbance associated with the Project, and consists of: the proposed surface extraction areas (i.e., three open pits - North Pit, East Pit, and South Pit); mine rock management areas; mine infrastructure and support facilities, including the plant area (i.e., raw coal stockpile area and processing plant); clean coal transportation route; rail loadout facility and rail siding; and ancillary facilities (i.e., water supply, power supply, natural gas supply, water, sewage treatment, fuel storage and explosives storage). The Project footprint and associated infrastructure are located within portions of two main watersheds: Grave Creek and Alexander Creek. The majority of the Project footprint is located within the Alexander Creek watershed, while the access roads leading to the mine are generally located within the Grave Creek watershed.

The Groundwater LSA encompasses the Project footprint and surrounding area within which all or most of the potential Project effects are anticipated to occur. It extends north to the headwaters of Alexander Creek, and along the topographic drainage divides represented by the mountain ridges to the east and

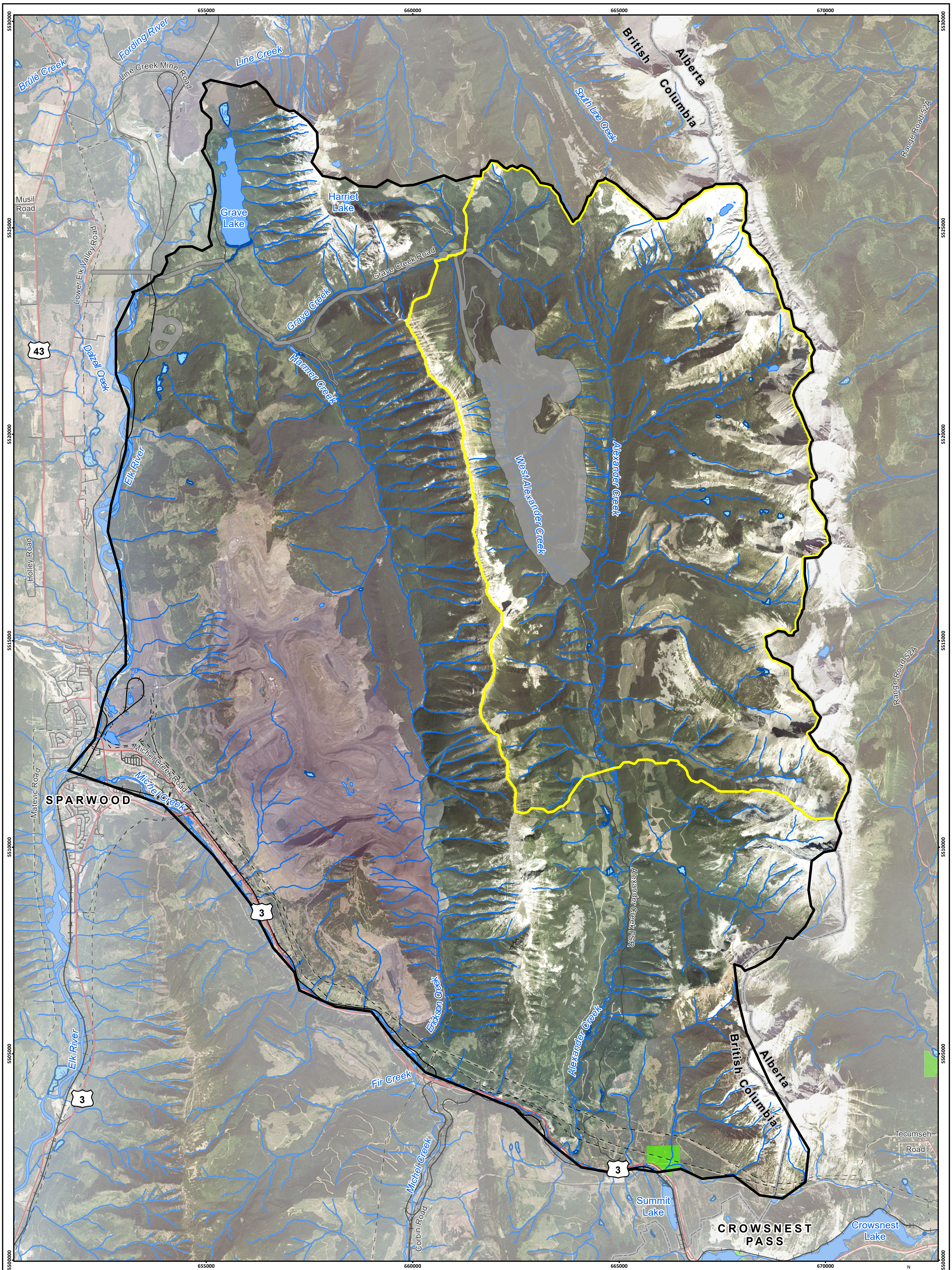
Table 9.2-2: Summary of Consultation Feedback on Groundwater Quantity and Quality

Topic	Feedback Received*:				Consultation Feedback	Feedback Source	Response or Actions Identified
	IG	G	P/S	O			
Groundwater Modelling	✓				Confirm if gaining and losing reaches on West Alexander and Alexander Creeks are mapped and being considered as part of hydrogeological modelling for the Project	Comment received from the Ktunaxa Nation Council (KNC) during the June 6, 2019 Aquatics Working Group Meeting.	Gaining and losing reaches on West Alexander and Alexander Creeks were mapped during a flow survey. This information was considered as part of the hydrogeological modelling for the Project and is discussed in Section 9.4.3.
Groundwater Modelling and Seepage Monitoring	✓				Is Active Water Treatment (AWT) part of the mine plan? How is seepage from the Mine Rock Storage Facility (MRSF) going to be collected for monitoring and treatment (if required)? How are losses of MRSF effluent to the groundwater system being dealt with in the water quality model? If required, will the treatment intake be upstream of the Fluvial/Glaciofluvial aquifer to prevent infiltration of untreated mine contact water to the aquifer? How will groundwater in the Fluvial/Glaciofluvial aquifer be monitored? The hydraulic conductivity of Colluvium is generally orders of magnitude higher than Till. In a layered system, horizontal hydraulic conductivity (Kx) often does not equal hydraulic conductivity parallel to bedding (Ky). For example, if the layers mirrored topography the down valley flow in a surficial Colluvium layer would be dominated by the higher Kx of the Colluvium while infiltration deeper into the surficial sediments might be limited by a lower Ky of the Till. What is the geometry of the Colluvium and Till layering? Why is Colluvium and Till being considered a single unit in the hydrogeological model?	Comment received from the KNC on October 17, 2019 as a follow-up item to the June 6, 2019 Aquatics Working Group Meeting.	Active water treatment is not part of the mine plan. Water quality modelling is described in Section 9.5.4.1. The model is a water and load balance, using stochastic inputs of precipitation, evaporation, snowmelt, etc. to generate a range of plausible flows. The model incorporates estimates of pit groundwater inflow (and seepage at closure) and inherently incorporates groundwater with relatively short travel times (runoff). Groundwater with longer travel times (i.e., deeper flow paths) are considered separately as part of the groundwater assessment and are not estimated to constitute a significant percentage of total catchment water flow. Points acknowledged regarding hydraulic conductivity (K) in layered systems and contrasts between colluvium and till. All available data has been incorporated into the conceptual model, definition of hydrostratigraphic units and groundwater modelling. In many places, overburden is relatively thin and differentiation of interbedded units is not considered justified or necessary for the purpose of modelling at the scale completed for the EA.
Groundwater Modelling		✓			Re-evaluate the potential for lateral flow in the waste rock piles.	Comment received from the B.C. Ministry of Environment and Climate Change Strategy (ENV) during the April 29, 2020 Water Quality Working Group Meeting	Modelling for the mine rock is described in Section 9.5.4.1. Groundwater modelling indicates that flow from the surrounding catchment is not expected to interact significantly with mine rock, except as flow along its base.
Groundwater Modelling	✓				Would the findings of the hydrogeological model influence or change the water quality model results? Do we expect the end of life concentrations to be updated once the hydrogeological model is finalized? • This was briefly discussed in the June 2020 meeting and is also a follow up to Waterline's action items from June 6th, 2019 where it was discussed that West Alexander was a "losing creek" and therefore infiltrated water from the rock dump could/would seep into the surficial sediments and be conveyed downgradient past the sediment ponds and / or potential water treatment system.	Comment received from the KNC on September 23, 2020 as a follow-up item to the April 29, 2020 Aquatics Working Group Meeting	Water quality modelling assumes that all water collecting load from the MRSF or pits ultimately reports to surface water receptors, therefore is incorporated in predictions. Groundwater modelling for deeper flows that may not report immediately to surface water receptors is assessed separately in this section.

Topic	Feedback Received*:				Consultation Feedback	Feedback Source	Response or Actions Identified
	IG	G	P/S	O			
Groundwater Modelling	✓				Will the modelling provide any reassurance that all potential pathways for groundwater/surface water have been considered? • Has the conceptual model changed since June 2019? Has there been more emerging details on the overburden variation? • Can SRK/NWP indicate what inputs from drilling were or will be used in the hydrogeological modelling? The Aquatics meeting from June 06, 2019 indicated a baseline program would include drilling of: o 16 single monitoring wells, 3 nested wells and 12 locations with 1 pumping well etc.	Comment received from the KNC on September 23, 2020 as a follow-up item to the April 29, 2020 Aquatics Working Group Meeting	Water quality modelling does not specifically define groundwater pathways. Any load that is generated in the water quality model reports to a surface water receptor. Hydrogeological modelling considers both shallow and deep pathways, but cannot guarantee that every possible pathway has been specifically defined. The modelling approach is conservative in that all load is assumed to be able to reach the receiving environment, thus should capture each potential pathway. All drilling results were used in generation of the hydrogeologic conceptual model.
Groundwater Modelling	✓				Does the seepage volume from the MRSF toe (MRSF pond discharge; GoldSim) agree with the groundwater model predictions for outflow from West Alexander Creek for life of mine and long-term closure?	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	The seepage volumes from the MRSF toes between the groundwater and Goldsim models cannot be directly compared but are consistent. The models use the same base hydrological data for inputs, but seepage volumes cannot be compared directly. The Goldsim water balance is estimating cumulative flow from the catchment, including through the MRSF. This is a lumped value, reflecting a combination of seepage on top of natural ground (runoff), seepage through the MRSF, as well as a baseflow contribution (inherent in runoff calcs). The groundwater model is only estimating the flow through the groundwater system (i.e., below natural ground surface). The Goldsim model flows vary seasonally, with low flow season values greater than 45 L/s. The groundwater flow through this area is on the order of 2.5 L/s. Groundwater reflects approximately 5% of surface flow rates during the winter and less than 1% during peak freshet.
Groundwater Modelling	✓				Similarly, can the same be confirmed for Alexander Creek below the confluence, to account for the loosing stream conditions?	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	Again, the results from the two models cannot be compared directly, but are consistent. Flow measurements indicated a gaining reach above the final sedimentation pond and losing only below the sedimentation pond. From the perspective of the Goldsim model, these are assumed to balance out. The groundwater component would not have any statistical significance on surface water predictions.
Groundwater Modelling	✓				As the data from the monitoring well network is important for model calibration, please confirm: That wells in bedrock are accurately representing bulk rock conductivity, including conditions near the mapped fracture zones/fault)? Is there a model scenario that includes increased groundwater flow through these higher permeability "conduits"?	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	Yes, there was a model scenario that included the primary mapped structure as a conduit. This is described in Appendix B (Groundwater Model) of the Groundwater Technical Report (Appendix 9-A).
Groundwater Modelling	✓				As the data from the monitoring well network is important for model calibration, please confirm: Is the particle tracking predictions from the sediment pond based on groundwater flow through the surficial sediments only? Is there a component of bedrock? The model calibration would likely benefit from a bedrock well located down gradient of the sediment pond to confirm groundwater flow in bedrock from the loosing creek. Is such an option considered?	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	Particle tracking is based on the full groundwater model, which includes both surficial sediments and bedrock flow paths. Particles were started at the ponds and are allowed to follow whatever pathway is necessary, overburden or bedrock. Bedrock monitoring in the losing reach has not been considered at this time to monitor for effects of losing from the creek. Overburden is on the order of 50 m thick in most of the area where the losing stream is.

Topic	Feedback Received*:				Consultation Feedback	Feedback Source	Response or Actions Identified
	IG	G	P/S	O			
Groundwater Modelling	✓				Can you confirm what element/species was used in the particle tracking model? Was the parameter less or more conservative than the species in the Goldsim model (e.g., selenium, sulphate and nitrate)?	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	The groundwater model assumes a generic perfectly conservative species. It can be considered as analogous to sulphate (as long as sulphate acts conservatively, which is a common assumption), and more conservative than nitrate or selenium (if they are considered reactive in the sense of groundwater transport). The groundwater model approach is intended to be conservative overall.
Groundwater Modelling	✓				To what extent (if any) are the predicted changes to water levels to West Alexander Creek related to dewatering, higher evaporation and redirection of groundwater flow from land use changes? Please provide more context to the results.	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	Changes to water levels estimated in the groundwater modelling are related to presence of the open pits (i.e., pit dewatering).
Groundwater Modelling	✓				SRK to look into using the recharge rate in the prediction model and connect to the water balance model.	Comment received from the KNC on February 1, 2021 as a follow-up item to the December 16, 2020 Groundwater Working Group Meeting	The groundwater model and Goldsim model are not coupled. Parameter consistency and effects of interactions were discussed and it was concluded not required to specifically input groundwater recharge into the water balance. The water quality prediction model assumes all water through the site reports to surface water and is considered conservative from its perspective.

Note:
*IG = Indigenous Group (group specified in column); G = Government (provincial or federal agencies); P/S = Public/Stakeholder (Interest group, local government, tenure and license holders, members of the public); O = Other



Crown Mountain Coking Coal Project

Figure 9.2-1
Groundwater Local and Regional Study Areas

LEGEND

- ▭ Groundwater Regional Study Area
- ▭ Groundwater Local Study Area
- ■ Project Footprint
- — Highway
- — Arterial/Collector Road
- — Local/Resource Road
- ┼ Railway
- - - Transmission Line
- — Watercourse
- ■ Waterbody
- ▨ Wetland
- ■ Provincial Park/Protected Area
- ▭ British Columbia/Alberta Border

Scale 1:85,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

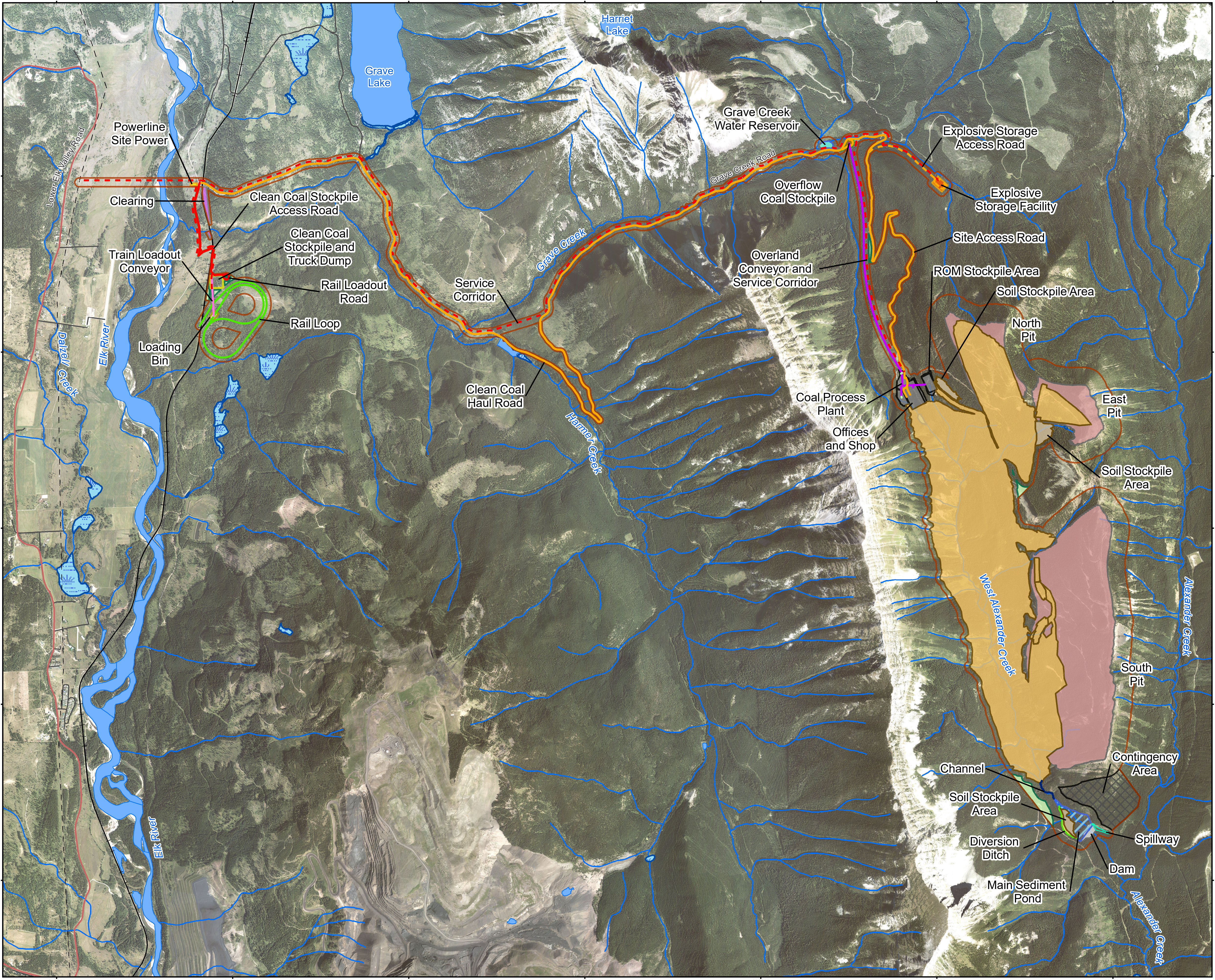
Map Created By: RB
Map Checked By: HEB
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231

Status: FINAL

Date: 2021-05-25



Crown Mountain Coking Coal Project

Figure 9.2-2
Project Footprint Infrastructure

LEGEND

- Project Footprint
- Channel to Ultimate Pond
- Clean Coal Haul Road\Site Access
- Explosive Storage Access\Facility Road
- Rail Loadout Road
- Rail Loop
- Service Corridor
- Coal Process Plant Conveyor
- Coal Process Plant Duct
- Train Loadout Conveyor
- Waste Dump
- Mined Area
- Clean Coal Stockpile and Truck Dump
- Overflow Coal Stockpile
- Soil Stockpile Area
- Explosive Storage Facility\Pad
- Loading Bin
- Plant Site\ROM Stockpile Area
- Powerline-Site Power
- Water Reservoir
- Main Sediment Pond
- Dam
- Spillway
- Diversion Ditch
- Clearing
- Additional Area
- Contingency Area
- Arterial/Collector Road
- Local/Resource Road
- Railway
- Transmission Line
- Watercourse
- Waterbody
- Wetland
- British Columbia/Alberta Border

0 1 2
Kilometres

N W E S

Scale 1:42,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada.
Imagery Provided By GeoBC OrthoImagery (Aug 2016).

Map Created By: RB
Map Checked By: HEB
Map Coordinate System: NAD 1983 UTM Zone 11N

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Project: 12-6231
Status: FINAL
Date: 2021-05-25

Document Path: G:\GIS\2012 and Prior\126231 Crown Mountain\EA_Report\ExistingConditions\Groundwater\126231_EC_GW_ProjectFootprintInfrastructure.mxd west of the Project. The south extent of the Groundwater LSA continues approximately 1.5 km south of the southernmost monitoring wells (GW-1-A and GW-1-B). The Groundwater LSA covers an area of approximately 11,774 ha. The Groundwater LSA can be thought of as the “zone of influence” of the Project on groundwater. The locations of Project facilities within the Project footprint and the extent of the Groundwater LSA is shown on Figure 9.2-1, and covers an area of approximately 35,000 ha. The Groundwater RSA is intended to encompass an area that will be used in the cumulative environmental effects assessment. The Groundwater RSA boundaries constrain the hydrogeologically relevant areas to the Project footprint, based on the groundwater catchment divides indicated by regional topography and watercourses. The Project is in close proximity to other metallurgical coal mines in the Elk Valley and Crowsnest coal fields, including Teck’s Elkview Operations (8 km southwest) and Line Creek Operations (12 km north). The Groundwater RSA boundary for the groundwater effects assessment is limited to the south by Michel Creek; to the West by the Elk River; and to the north by the Grave Creek, and includes these neighbouring projects and groundwater users such as supply wells that may potentially have interactions with and have cumulative effects on the Project.

Due to their distance from the Project and associated Project activities and components that may affect groundwater quantity and quality, and based on the groundwater catchment divides indicated by regional topography and watercourses, potential groundwater effects arising from the Project are not expected to occur in either the bordering province of Alberta, the bordering State of Montana, or on federal lands. As such, transboundary effects on groundwater quantity or quality arising from the Project are not expected to occur in either province or state or on federal lands, and the spatial boundaries considered in the groundwater assessment do not include transboundary lands.

9.2.3.2 Temporal Boundaries

Temporal boundaries include the time periods during which the Project is anticipated to result in potential effects on VCs (British Columbia Environmental Assessment Office [EAO], 2013). For the groundwater effects assessment, the temporal limits of the Project have been applied as temporal boundaries, and include the timing of Project phases and activities, as outlined in Table 9.2-3. Additional detail of the phases and activities related to the Project are outlined in Chapter 3.

Table 9.2-3: Temporal Boundaries for the Effects Assessment for Groundwater

Phase	Project Year	Length of Phase
Construction and Pre-Production	1 – 2	19 months
Operations	3 - 17	15 years
Reclamation and Closure	17 – 19	2 years
Post-Closure	19 – 34	15 years
Long Term Closure	34 – 101	67 years

For the groundwater effects assessment, potential changes to groundwater were estimated for the EOM (End of Mining, Year 17) period and Long-Term Closure (100 years after the start of Operations). Long-term closure (LTC) includes the period where open pits are flooded to decant level, and reclamation activities are conservatively assumed to have no impact on the groundwater system.

9.2.3.3 Administrative Boundaries

Administrative boundaries refer to the limitations imposed on the assessment by political, economic, or social constraints and consider the jurisdiction in which the Project is located. In addition to the applicable regulatory and policy framework as outlined in Table 9.1-1 and Table 9.1-2 the Project falls within the resource management area boundaries of Fisheries and Oceans Canada (DFO) Pacific Region and the B.C. Ministry of Forests, Lands, Natural Resources Operations and Rural Development (FLNRORD) Rocky Mountain District in Kootenay Region 4. The Project is located within Management Unit 4 under the EVWQP (Teck Resources Limited, 2014) for the Elk Valley, where site-specific water quality target values are applicable to the Groundwater LSA.

9.2.3.4 Technical Boundaries

Technical boundaries represent constraints imposed on the assessment due to limitations in the ability to predict the effects of the Project (EAO, 2013). Technical boundaries for the assessment of potential effects to groundwater quality and quantity include:

- Limitations imposed by the constraints of the baseline data collection and related spatial and temporal data coverage;
- Assumptions required in the predictive models, specifically the groundwater quality and load balance model, as well as the inherent uncertainty of groundwater models; and
- While specific results are calculated during the modelling process, there always remains a degree of uncertainty associated with these estimates. Attempts to quantify the uncertainty by providing a range of estimates has been completed (Appendix 9-A); however, these ranges should not be viewed as definitive.

For the purposes of this assessment, notable levels of conservatism are built into the assessment methodology to minimize/eliminate under-prediction. Details on the modelling, including assumptions and limitations, are provided in the Groundwater Technical Report (Appendix 9-A; SRK Consulting, Inc. [SRK], 2021a).

9.3 Regional and Local Overview

Within the Groundwater LSA and RSA, current land uses include: residential; recreational (e.g., hunting, all-terrain vehicle [ATV] trails, fishing, hiking, etc.); exploration; resource; industrial; rangeland; agriculture; and forestry. Mining in the East Kootenay region has been ongoing for well over a century, with coal being the dominant resource extracted in the area. Additional information on past and present land uses is provided in Chapter 1, Section 1.3.2.

Historical and current mining activities in the Elk Valley have resulted in elevated concentrations of selenium, nitrate, sulphate and cadmium in local surface waters, as well as calcite formation in some watercourses (Teck Resources Limited, 2014). Other sources of water quality impacts include local municipalities, agriculture, forestry, and natural and anthropogenic air emissions.

9.3.1 Topography

The Project is located within the Front Ranges Physiographic Region of the Rocky Mountains and covers an area with elevation ranging between 1,850 and 2,200 metres above sea level (m asl). Alexander Creek and West Alexander Creek are the two main drainages within the catchment area of the Project, with

Upper Alexander Creek to the east of the Project. However, Grave Creek drains a small portion of the northern part of the property. Alexander Creek flows into Michel Creek, a tributary of the Elk River; Grave Creek flows directly into the Elk River.

Steep sided ridges are observed to the west of the Project where Gaff Peak is located, reaching an elevation of 2,500 m asl. To the east, Upper Alexander Creek runs north-south with elevations that range from 1,400 to 1,500 m asl. The proposed open pits are located on a topographic high between West Alexander and Upper Alexander Creeks. Internal mine rock dumps are located over the North and East Pit footprints, while the external mine rock facility is in the West Alexander Creek valley at lower elevations relative to the open pits.

9.3.2 Climate

A meteorological baseline study was conducted for the Crown Mountain climate station for air temperature, barometric pressure, relative humidity, solar radiation, wind speed, wind direction, and precipitation. The mean daily average, minimum, and maximum air temperature values for the LSA were derived for January 2014 to May 2016 based on continuous data collected at the Crown Mountain climate station and include the following:

- Mean daily average temperature ranged from a low of -13.4 degrees Celsius (°C) in February 2014 to a maximum of 16.6 °C in June 2015;
- Mean daily minimum air temperature ranged from a low of -16.9 °C in February 2014 to a high of 10.2 °C in July 2015;
- Mean daily maximum air temperature ranged from a low of -9.0 °C in February 2014 to a high of 23.9 °C in July 2014; and
- The extreme minimum temperature at the Crown Mountain climate station was -32.3°C on March 1, 2014 and the extreme maximum temperature was 35.2°C on June 7, 2015.

Barometric pressure measurements ranged from 78.3 to 82.5 kilopascal (kPa). The average daily and monthly barometric pressure were generally higher in the warmer summer months, and lower with greater variability in the colder winter months, which was anticipated as there are typically more active low pressure weather systems in the winter.

Precipitation data was collected at the Crown Mountain climate station between January 2014 and May 2016; however, due to a malfunction of the precipitation gauge caused by high winds, some of the data were deemed to be inaccurate. To characterize the precipitation conditions for Project footprint and LSA, a regional analysis was conducted using data collected at nearby climate stations (Sparwood; 11557630 and Natal Harmer Ridge; 1155402) for the common period of record (1980 to 1990).

The results of the analysis indicate that the mean summer precipitation at the Crown Mountain climate station (1,920 m asl) is 14.9 millimeters (mm) higher than at the Sparwood climate station (1,138 m asl), and the mean winter precipitation is 23.9 mm lower, respectively. The seasonal relationships for mean summer and winter precipitation were applied to derive the monthly precipitation for the vicinity of the Project. The monthly mean precipitation varied throughout the assessment period, with the lowest values generally corresponding to the summer months (a lowest mean of 35.4 mm in August) and higher precipitation in the early winter months (a highest mean of 89.6 mm in November). The maximum monthly precipitation was 268.6 mm in December, and the minimum monthly precipitation was 2.9 mm in February. The total annual precipitation for January 2014 to May 2016 was approximately 760 mm (2014) and 700 mm (2015).

There was significant variability in the average daily humidity measured at the Crown Mountain climate station. The average monthly relative humidity ranged from 50.1% (August 2015) and 93.1% (January 2016). Average monthly humidity was typically lowest in the summer months and highest in the winter.

Typical wind speeds are between 2 and 6 kilometres per hour (km/hr), and were most frequently recorded between January 2014 and May 2016. Wind speeds below 3.6 km/hr or 1 metres per second (m/s) (i.e., calm winds) occurred 33.6% of the time, and wind speeds over 21.6 km/hr or 6 m/s (i.e., strong winds) occurred 1.4% of the time. The maximum instantaneous wind speed was 58.4 km/hr on February 6, 2016. The most frequent wind direction was traveling west-northwesterly (i.e., from the south-east), at approximately 22.9% of the recorded entries.

There are no known snow survey stations located within the Project footprint or LSA. Accordingly, an assessment of snow pack data was not completed for these areas.

Additional meteorological and climate results, including pressure, precipitation, relative humidity, wind speed, and wind direction, are provided in Chapter 6 and Appendix 6-B: Meteorological Baseline Report.

9.3.3 Hydrology

Key watercourses in the Groundwater LSA include the Elk River, Michel Creek, Alexander Creek, West Alexander Creek, Harmer Creek, and Grave Creek. Waterbodies in the immediate vicinity include Grave Lake, Harriet Lake, Mite Lake, and Barren Lake. The Alexander Creek watershed is the largest drainage basin in the Groundwater LSA and covers a watershed area of approximately 18,490 ha, which is oriented in a north to south direction. Alexander Creek flows in a southerly direction from its headwaters to its confluence with Michel Creek, approximately 10.7 km southeast of Sparwood. Michel Creek flows north-westerly along Highway 3 and ultimately discharges to the Elk River near Sparwood. The total length of Alexander Creek is approximately 25 km. Alexander Creek has numerous tributaries that generally consist of high-gradient mountain streams, with the most significant tributary being West Alexander Creek.

The West Alexander Creek watershed covers an area of approximately 1,470 ha within the boundaries of the Alexander Creek watershed. West Alexander Creek flows in a south to southeast direction over a distance of approximately 6 km to its confluence with Alexander Creek. The watercourse has several tributaries that generally consist of small, high-gradient mountain streams. The Grave Creek watershed covers an area of approximately 8,090 ha and is oriented in an east to west direction. Grave Creek generally flows westerly and drains into the Elk River, approximately 12.5 km north of Sparwood. Several tributaries drain into Grave Creek, the largest of which being Harmer Creek. The Harmer Creek watershed covers an area of approximately 3,900 ha within the boundaries of the Grave Creek watershed. Harmer Creek generally flows northerly and drains into Grave Creek approximately 12 km northeast of Sparwood.

In October 2018, Swiftwater Consulting Ltd. (Swiftwater) conducted a flow accretion survey along West, Upper, and Alexander Creek to characterize flow losses and gains (Swiftwater Consulting Ltd. [Swiftwater], 2018). Measured discharge and uncertainty of the measurements are shown in Table 9.3-1.

Table 9.3-1: Flow Survey Locations Reported by Swiftwater (2018)

Location		Easting (UTM NAD 1983)	Northing (UTM NAD 1983)	Date	Time	Discharge (L/s)	Uncertainty (%)[a]	Distance (km)[b]	Comments
Upper Alexander Creek	SW8	664,815	5,519,596	10/2/2018	11:20	48	5.1	4.6	-
	SW7.8	664,777	5,519,542	10/2/2018	13:00	54	6.3	4.6	-
	SW7.1	664,349	5,516,650	10/2/2018	15:47	318	3.2	1.4	-
	EAST	664,355	5,515,744	10/2/2018	16:54	216	5.1	0.3	-
	SW1.9	664,384	5,515,478	10/4/2018	9:01	184	4.7	0.0	-
West Alexander Creek	SW6	662,710	5,520,782	10/3/2018	9:02	0	-	7.0	Visual Estimate
	SW6.5	662,677	5,520,753	10/3/2018	9:11	1	-	6.8	Visual Estimate
	SW6.4	662,536	5,520,670	10/3/2018	10:17	5	0.0	6.6	Visual Estimate
	SW5.9	662,325	5,520,585	10/3/2018	11:09-11:30	7	12.5	6.5	-
	SW5.1	662,232	5,519,903	10/3/2018	12:17-12:42	11	3.8	5.8	-
	SW4.5	662,479	5,519,327	10/3/2018	13:36-13:54	15	11.9	5.1	-
	SW4.5	662,479	5,516,994	10/3/2018	16:42	30	25.0	2.3	-
	SW3	664,011	5,516,173	10/4/2018	18:48-19:10	28	2.9	1.0	-
	SW2.1	664,323	5,515,471	10/4/2018	8:19	28	-	0.0	Same Flow as SW3
Alexander Creek	SW1.9	664,384	5,515,478	10/4/2018	8:11-9:01	184	4.7	-	-
	SW1.5	664,359	5,514,654	10/4/2018	9:34-10:25	169	2.1	-	-

Source: Swiftwater, 2018.

a – Percent uncertainty of the measured discharge values.

b – Distance from confluence between West Alexander and Alexander Creek.

Based only on this flow survey, West Alexander Creek is a gaining stream (groundwater discharge to surface water) in its upper reaches where overburden thickness is least and transitions to a losing stream (surface water lost to groundwater) at the SW4 survey location where overburden becomes thicker. Upper Alexander Creek is a gaining stream between stations SW8 and SW7.1, transitioning to a losing stream further downstream. A detailed hydrological analysis is included in SRK (2021a).

9.3.4 Bedrock Geology

The Project is underlain by strata of the Kootenay and Fernie Groups. A stratigraphic column for the bedrock geology of the area is presented in Figure 9.3-1. The Kootenay Group can be subdivided into three formations: the Morrissey Formation, Mist Mountain Formation, and Elk Formation. The Morrissey Formation (MF) consists of medium-thick cross bedded sandstone with interbeds of shale and siltstone. The Mist Mountain Formation (MMF) consists of interbedded sandstone, siltstone, and shale and is host to the coal seams to be exploited at Crown Mountain. Underlying the Kootenay Group, the Fernie Formation (FF) consists of a thick sequence of marine sediments, including the Grey Beds at its base, which are an interbedded shale and siltstone sequence. These units were deposited mainly in a freshwater paleo-environment, with increased marine influence downward.

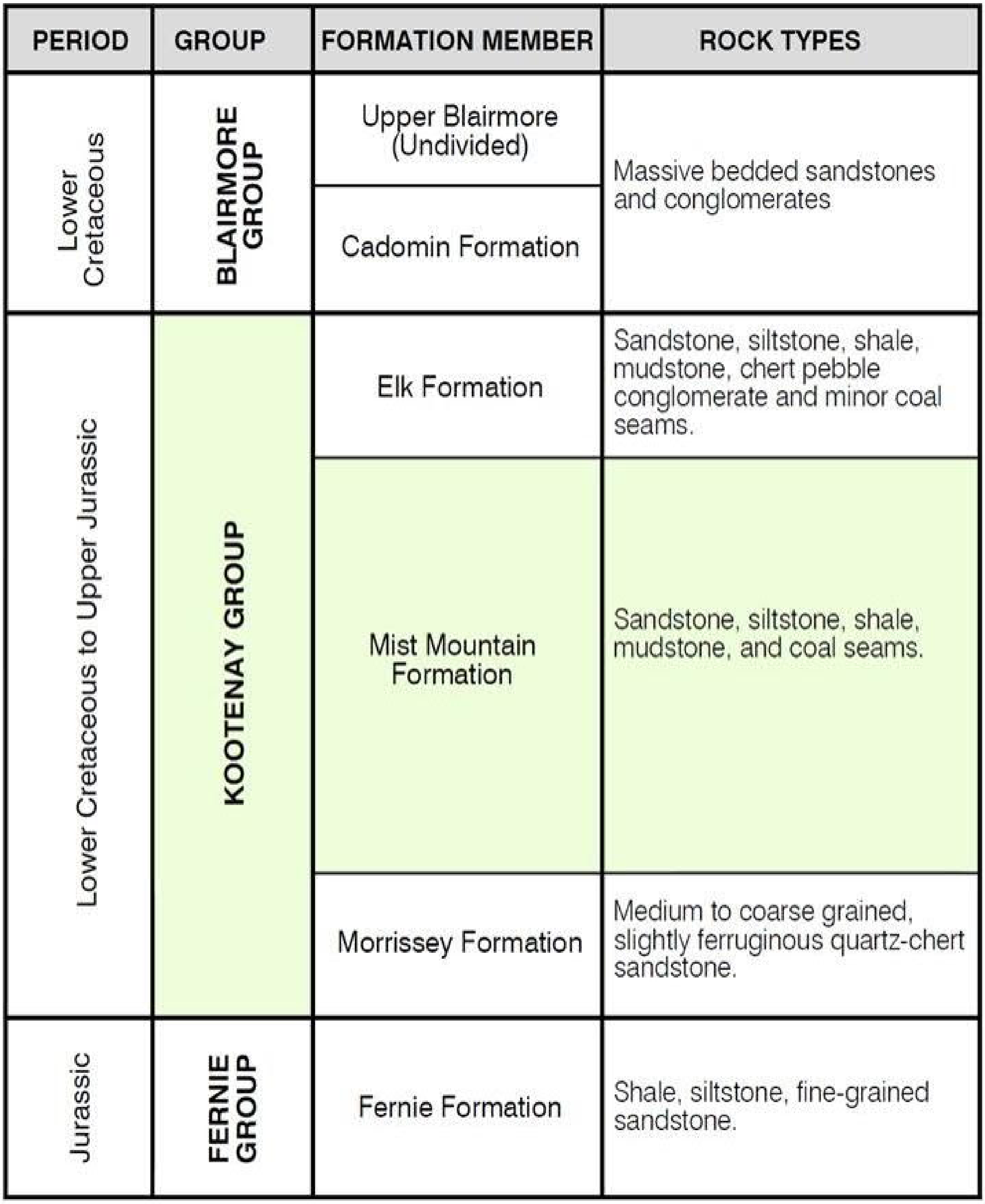
The majority of groundwater flow is inferred to flow within bedrock units via major fault zones and within secondary structures such as fractures and joints (Teck, 2011). Bedrock joint set and discontinuity data are provided in the Crown Mountain Joint Set Summary (Stantec, 2022), which summarizes the findings of the geotechnical core drilling and exploration program of 2018. The geotechnical drilling program consisted of drilling seven boreholes. Joint sets were assigned a rock mass rating (RMR) based on the classification system for the distance between discontinuities observed in the drill core. The RMR classification scheme is provided in Table 9.3-2 below.

Table 9.3-2: Bedrock Joint Set Classification Scheme

Spacing of Discontinuities/Joints/ Fractures	> 2 m	0.6 – 2 m	200 – 600 mm	60 – 200 m	< 60m
RMR Rating	20	15	10	8	5

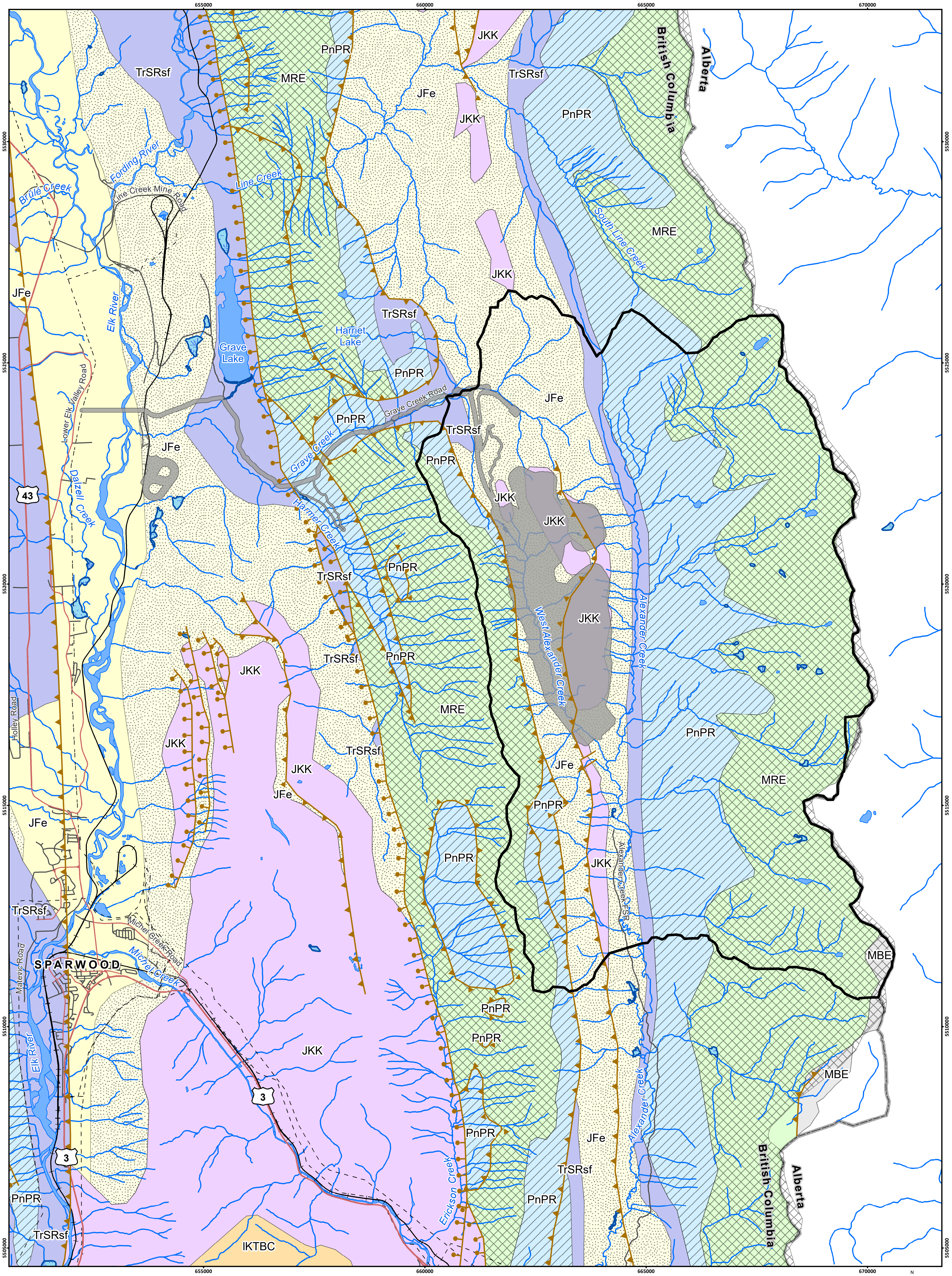
The findings of the geotechnical drilling program indicated that majority of the joint sets/discontinuities identified from drill core had a rating of 8 or above, meaning that the spacing between joint sets/discontinuities is 60 mm or greater (Stantec, 2022). Joint set and discontinuity results for the seven geotechnical boreholes are provided in Table 9.3-3 below.

To the east and west of the proposed facilities, regional bedrock mapping and karst potential from the iMapBC database shows areas identified as having more than 50% of soluble bedrock, but these data do not necessarily have field truthing in any specific area. There have been no carbonate rocks identified in the geological mapping and drill core for the Project (Figure 9.3-2).



PERIOD	GROUP	FORMATION MEMBER	ROCK TYPES
Lower Cretaceous	**BLAIRMORE GROUP**	Upper Blairmore (Undivided)	Massive bedded sandstones and conglomerates
		Cadomin Formation	
Lower Cretaceous to Upper Jurassic	**KOOTENAY GROUP**	Elk Formation	Sandstone, siltstone, shale, mudstone, chert pebble conglomerate and minor coal seams.
		Mist Mountain Formation	Sandstone, siltstone, shale, mudstone, and coal seams.
		Morrissey Formation	Medium to coarse grained, slightly ferruginous quartz-chert sandstone.
Jurassic	**FERNIE GROUP**	Fernie Formation	Shale, siltstone, fine-grained sandstone.

Figure 9.3-1: Stratigraphic Column



Crown Mountain Coking Coal Project

Figure 9.3-2
Crown Mountain Bedrock Geology

LEGEND

Faults

- Fault
- Normal Fault
- Thrust Fault

Karst Likelihood

- ☒ >50% soluble bedrock
- ▨ 20 to 49% soluble bedrock
- ⬚ 5 to 19% soluble bedrock

Bedrock Regional Geology

- IKTBC - Blairmore Group - Crowsnest Formation: Cretaceous to Neogene sandstone, siltstone and tuffs
- JKK - Kootenay Group: Jurassic to Cretaceous sandstone, siltstone and coal
- JFe - Fernie Formation: Jurassic shale, sandstone; limestone
- TrSRsf - Spray River Group: Triassic calcareous siltstone, orthoquartzite and shale
- MBE - Banff and Exshaw Formations: Carboniferous carbonate, shale
- PnPR - Rocky Mountain Group: Carboniferous to Permian dolomitic siltstone; sandy dolomite; orthoquartzite and limestone
- MRE - Rundle Group: Carboniferous Dolomite, limestone and chert

- Groundwater Local Study Area
- Project Footprint
- Highway
- Arterial/Collector Road
- Local/Resource Road
- Railway
- Transmission Line
- Watercourse
- Waterbody
- Wetland
- British Columbia/Alberta Border

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Scale 1:80,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Geology provided by BC Geological Survey, Forest Analysis and Inventory 2019, and SRK Consulting (Canada) Inc.

Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231

Status: FINAL

Date: 2021-05-25

Document Path: G:\GIS\2012 and Prior\126231 Crown Mountain\EA_Report\ExistingConditions\Groundwater\Figure_9_3_2_Bedrock_Geology_rev03\v10\126231_EC_GW_BedrockGeology.mxd

Table 9.3-3: Bedrock Fractures and Joint Set Results; 2018 Geotechnical Drilling (Stantec, 2022)

Borehole ID	Total Borehole Depth (m)	Length of core with same joint set rating (m)	Percentage of total borehole length (%)	Joint Set / Discontinuity Rating
CM18-03-GC	194.3	116	60	5
		50	26	8
		15	8	10
CM18-05-GC2	150.5	145	96	8
CM18-10-GC	125.8	10	8	5
		66	53	8
		41	32	10
CM18-16-GC-RF	167.4	46	27	5
		86	51	8
		27	16	10
CM18-16-LDC3-GC-RF	189.9[2] (21)	2	7	8
		6	28	10
		13	64	15
CM18-25-GC	132.5	77	58	8
		33	13	Rubble Zone[3]
		17	25	No Recovery
CM18-27-GC	189.4	111	59	8
		11	6	15
		10	5	Rubble Zone[3]
		42	22	No Recovery

Notes:
1. All boreholes were collared vertical in orientation (dip -90°, azimuth 000°).
2. This borehole started at 167.4 m depth, so total length of the hole is 21 m.
3. The rubble zone was an intersection of highly fractured/disturbed rock.

The Alexander Creek Syncline and the Crown Mountain Fault are the main structural features at the site and define separate structural domains termed the North Block, South Block, and Southern Extension Block (Figure 9.3-3). The North Block is located to the west of the Crown Mountain Fault and occupies the Alexander Creek Syncline axial region as well as the hanging wall side of the fault. The South and Southern Extension Block are located to the east of the Alexander Creek Fault, occupying the footwall side of the fault (NWP, 2013). The presence of the Alexander Creek Syncline results in coal seams dipping variably to the east and to the west. On the east side of the fold axes, coal seams dip 40 degrees to the west at a plunge of N15W; on the west side of the axis, coal seams dip 50 degrees to the east at approximately 180 degrees offset plunge to the east side. In the South and Southern Extension blocks, coal seams have an average dip of 20 degrees to the west and plunge between N50W and N20E. At the Project, the Crown Mountain Thrust passes underneath the proposed pits at a dip of 25 degrees to 270W. Structural geological cross-sections are provided in Figure 9.3-4.

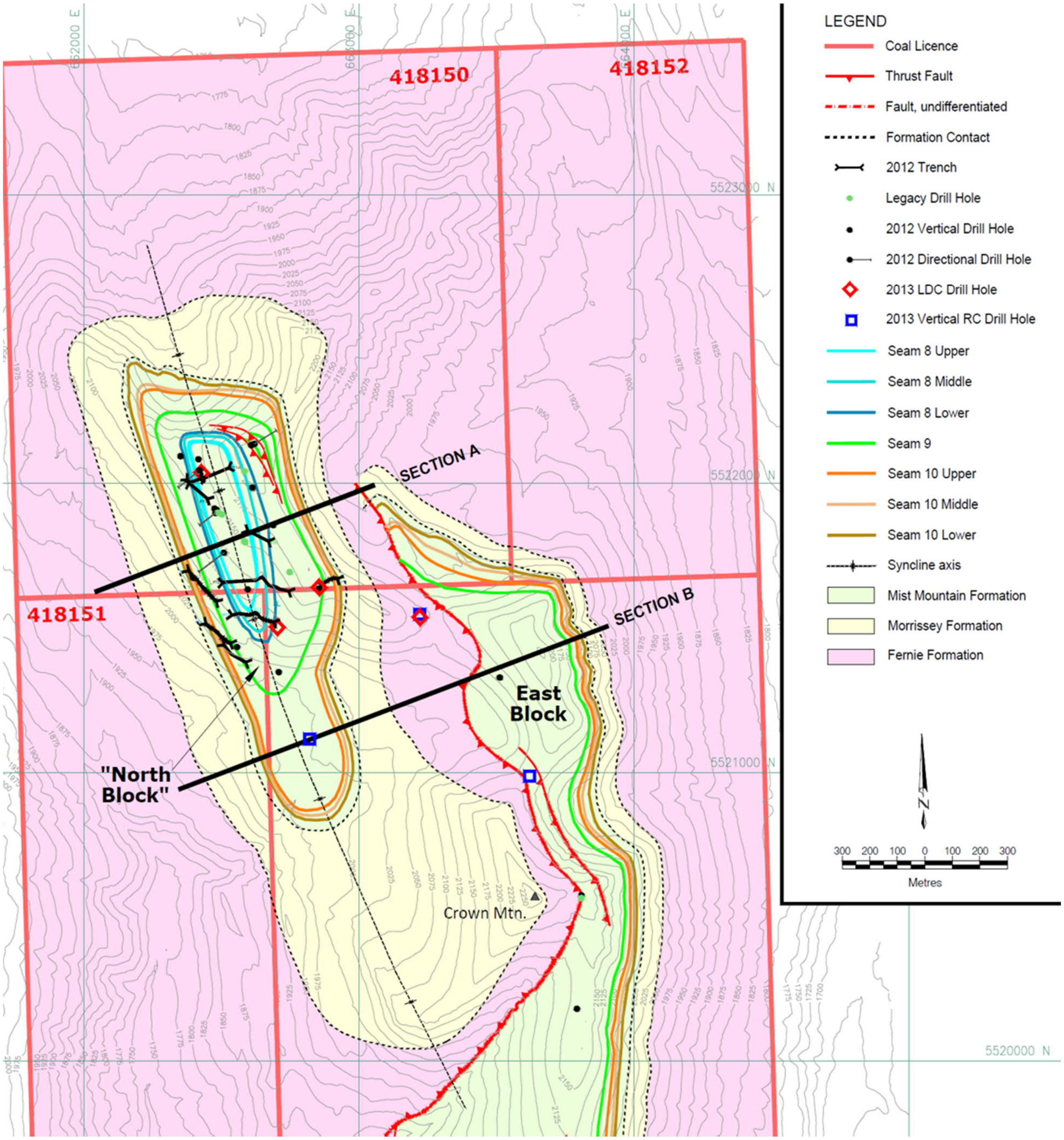


Figure 9.3-3: Major Faults in the Vicinity of the Project

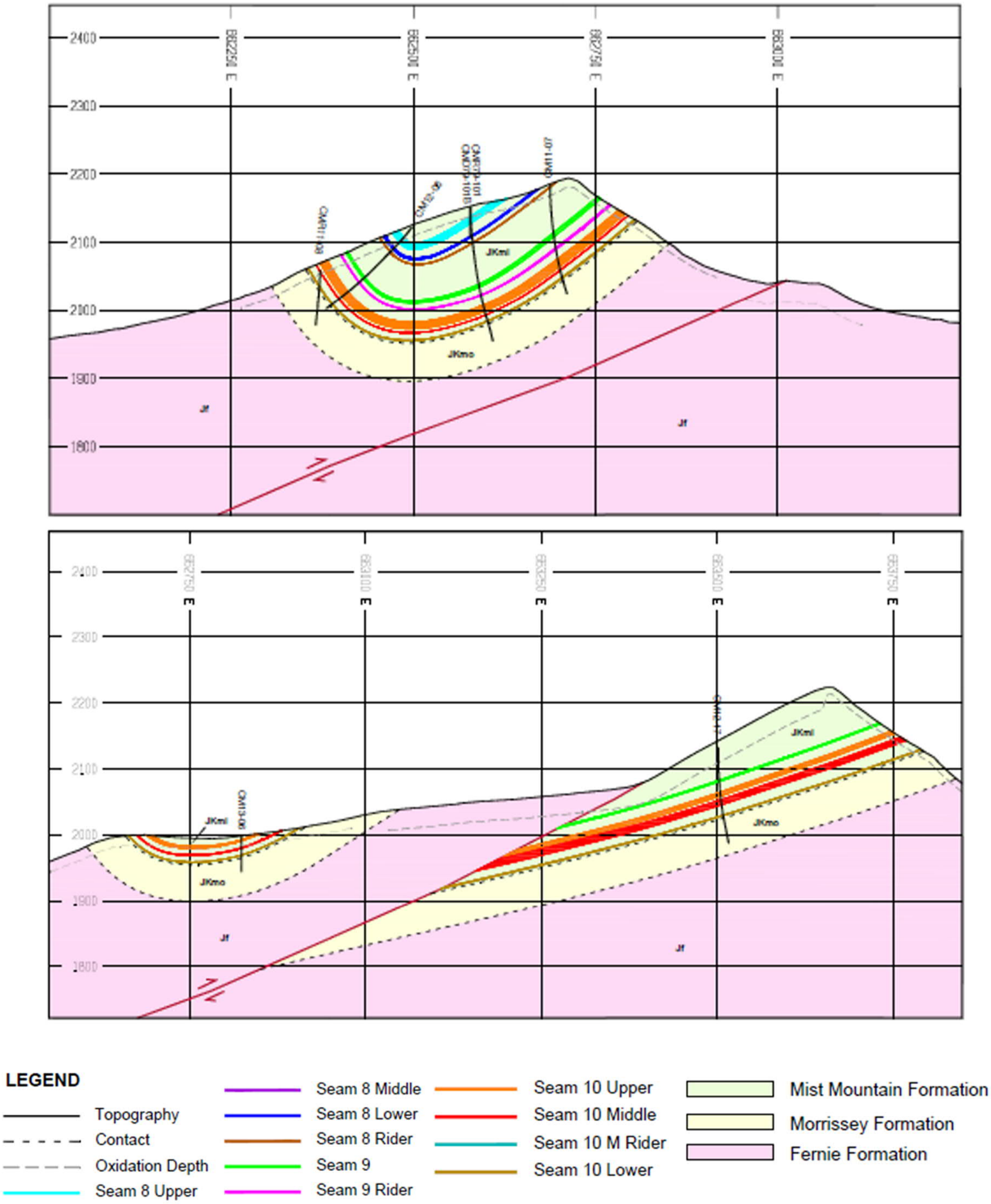


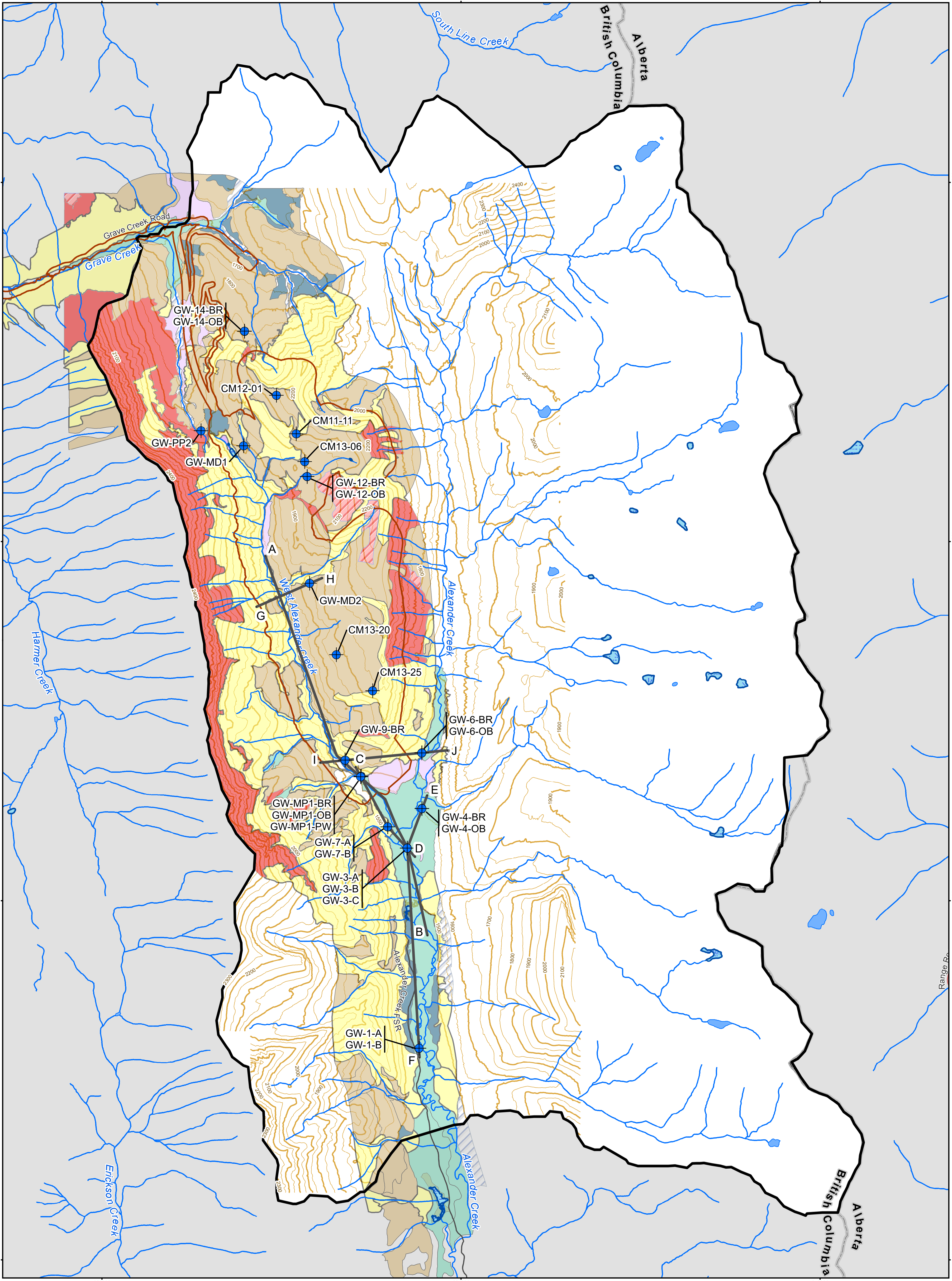
Figure 9.3-4: Crown Mountain Geological Cross-Sections

9.3.5 Overburden Geology

Characteristics of overburden sediments in the general vicinity of the Project were assessed as part of the 2018 field program (SRK, 2019). Overburden is generally thin at higher elevations, with thickness increasing up to 38 m in the Alexander Creek valley south of the mining area. Overburden in this area generally consists of colluvium (12 to 20 m thick), fluvial sediments (0 to 30 m thick), and glacial sediments associated with the Fraser Glaciation (0 to 38 m thick). Colluvium includes mainly sand and gravel, with cemented till lenses. Fluvial sediments consist of gravel, interbedded with sand and silty sands, and can overlap with glaciofluvial deposits.

Glacial sediments include glaciofluvial, glaciolacustrine, and till deposits. Glaciofluvial deposits consist mainly of sand and gravel, while glaciolacustrine deposits consist of fine, poorly-graded sand transitioning to high plastic clay. These are typically overlain by till deposits characterized by high-density silty materials.

Surface mapping was conducted in 2018 by BGC Engineering Inc. (BGC) in order to characterize terrain stability and geohazards (BGC, 2019), and included surficial material characterization. BGC generated a 1:10,000 map of the area of the Project, including the colluvium, till, fluvial, glaciofluvial, lacustrine, and glaciolacustrine sediment units. Figure 9.3-5 presents site geology, overburden units, and the main structural features.



Crown Mountain Coking Coal Project

Figure 9.3-5
Crown Mountain Overburden Geology

LEGEND

Overburden Geology

- ▨ Weathered Bedrock
- 🟥 Bedrock
- 🟨 Colluvium
- 🟩 Fluvial
- ■ Glaciofluvial
- 🟪 Lacustrine
- ■ Glaciolacustrine
- 🟫 Till
- 🟩 Organic Materials
- ▨ Undifferentiated Materials

- ⊕ Drill hole
- — Cross-section
- — Topographic Contours (50 m)
- — Topographic Contours (100 m)
- □ Groundwater Local Study Area
- □ Project Footprint
- — Local/Resource Road
- — Watercourse
- ■ Waterbody
- ▦ Wetland
- □ British Columbia/Alberta Border

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Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada.
Geology data provided by BGC, 2019 and SRK Consulting (Canada) Inc.

Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 2021-05-25

9.4 Existing Conditions

This section describes the existing conditions in the LSA in sufficient detail to enable potential effects of the Project on groundwater quality and quantity to be identified, understood, and assessed. Groundwater quantity and quality are assessed directly, but potential effects to surface water, to which groundwater contributes, are assessed separately in Chapter 10 and Chapter 11. Details of field investigations, data analyses and modelling was used to assess potential impacts to groundwater (Appendix 9-A). The major mine components included in the assessment are the North, East, and South open pits; mine rock management areas (external and internal); and the lined Main Sediment Pond.

9.4.1 Existing Regional and Local Information

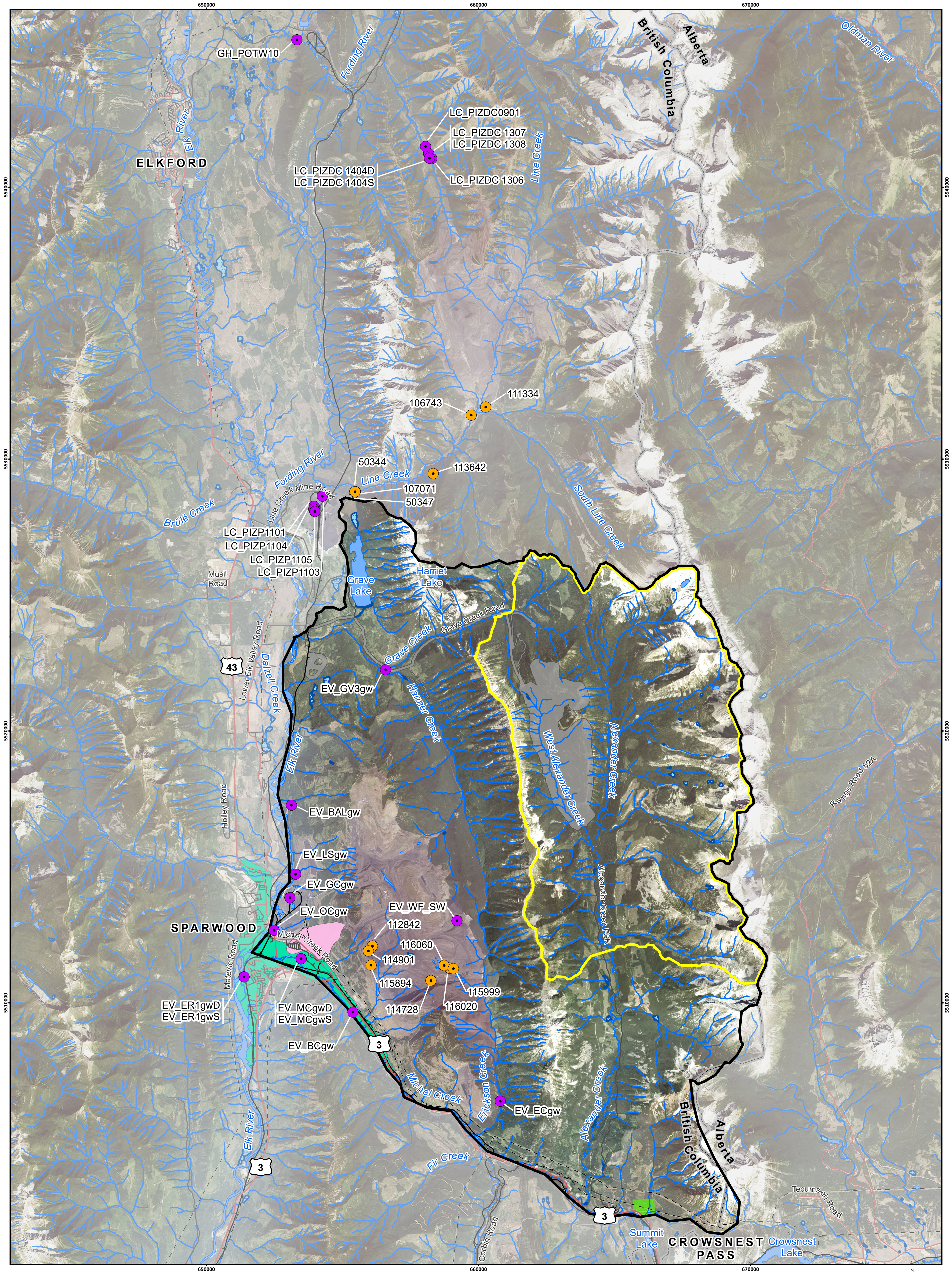
Existing local groundwater quality and quality data were compiled during the baseline program by conducting a desktop assessment of background information on regional water quality data in the Groundwater LSA and RSA. The following documents were reviewed:

- Groundwater Technical Report, Crown Mountain Coking Coal Project (SRK, 2021a);
- Water Quality Prediction Model, Crown Mountain Coking Coal Project, British Columbia (SRK, 2021b);
- Terrain Stability and Geohazards Mapping. Crown Mountain Project (BGC, 2019);
- Application Information Requirements. Crown Mountain Coking Coal Project (EAO, 2018);
- Assessment Report for The Crown Mountain Area (NWP, 2013);
- Crown Mountain Coking Coal Project. Project Description. (NWP, 2014);
- Crown Mountain Property Baseline Groundwater Investigation Results (Norwest Corporation [Norwest], 2016);
- Crown Mountain Project, Alexander Creek Streamflows (Swiftwater, 2018);
- 2018 Hydrogeological Field Data Report. Crown Mountain Project, B.C. (SRK, 2019);
- 2018 Regional Groundwater Monitoring Program Annual Report. Prepared for Teck (SNC-Lavalin [SNC], 2019); and
- B.C. GWELLS Database (B.C. MOE, n.d.).

9.4.1.1 Regional Groundwater Resources and Users

There are two mapped aquifers identified within the catchments of Grave Creek and Erickson Creek in the GWELLS database (B.C. MOE, n.d.). Both are located to the southwest of the Project, close to the Town of Sparwood. The bedrock aquifer (1082) and the sand and gravel aquifer (1078), and the Teck regional groundwater monitoring network is shown on Figure 9.4-1 (SNC, 2019). Details of these wells can be found in Table 9.4-1.

The B.C. GWELLS Database (B.C. MOE, n.d.) does not indicate any registered private wells within the Grave Creek, Erickson Creek, and Alexander Creek catchments, but there are 13 private wells within 7 km of the Groundwater LSA. Twelve of the wells are owned by Teck; five of these are located close to the Line Creek Operation, and the other seven are part of the Elkview Operations. Additionally, there is a cabin (referred to as ‘Podrasky Cabin’) located approximately 2,000 m downgradient the projected Main Sediment Pond, close to Alexander Creek. A groundwater well has not been identified at this location; however, the Podrasky Cabin has been considered as a ‘Control Point’ in the Project Effects Assessment (Section 9.5) since it represents a potential future groundwater user for drinking water purposes within the Groundwater LSA.



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Crown Mountain Coking Coal Project

Figure 9.4-1
Regional Groundwater Monitoring Network

LEGEND

Aquifer Name

- 🟩 1078
- 🟪 1082
- ● Regional Groundwater Monitoring Location
- ● Groundwater Users
- ▭ Groundwater Regional Study Area
- ▭ Groundwater Local Study Area
- ▨ Project Footprint
- — Highway
- — Arterial/Collector Road
- — Local/Resource Road
- ┼ Railway
- - - Transmission Line
- — Watercourse
- 🟦 Waterbody
- ▨ Wetland
- 🟩 Provincial Park/Protected Area
- ▭ British Columbia/Alberta Border

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada, BC GWELLS Database, Teck, 2018.
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

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Table 9.4-1: Regional Monitoring Network

Well Name	Alternate Well Name	UTM NAD 1983		General Location
		Easting	Northing	
LC_PIZP1101	MW11(P)-01	653956	5528265	Line Creek Operations
LC_PIZP1103	MW11(P)-03	654250	5528634	Line Creek Operations
LC_PIZP1104	MW11(P)-04	653940	5528165	Line Creek Operations
LC_PIZP1105	MW11(P)-05	653984	5528075	Line Creek Operations
LC_PIZDC 1306	MW13-3S	658278	5541059	Line Creek Operations
LC_PIZDC 1307	MW13-1D	658169	5541230	Line Creek Operations
LC_PIZDC 1308	MW13-1S	658168	5541232	Line Creek Operations
LC_PIZDC 1404S	MW14-045 LC-PIZDC1402	658192	5541069	Line Creek Operations
LC_PIZDC 1404D	MW14-04D LC-PIZDC1401	658192	5541069	Line Creek Operations
LC_PIZDC0901	GA-DC1-A	658048	5541500	Line Creek Operations
GH_POTW10	-	653321	5545426	Greenhills Operations
EV_GV3gw	-	656580	5522255	Elkview Operations
EV_BALgw	-	653121	5517271	Elkview Operations
EV_LSgw	-	653274	5514731	Elkview Operations
EV_GCgw	-	653061	5513870	Elkview Operations
EV_OCgw	-	652480	5512671	Elkview Operations
EV_WF_SW	-	659208	5513023	Elkview Operations
EV_ECgw	-	660795	5506384	Elkview Operations
EV_MCgwS	-	653476	5511624	Elkview Operations
EV_MCgwD	-	653476	5511624	Elkview Operations
EV_BCgw	-	655381	5509659	Elkview Operations
EV_ER1gwS	-	651374	5510955	Elkview Operations
EV_ER1gwD	-	651379	5510952	Elkview Operations

Aquifer 1078 was mapped in 2015, has a size of 8.5 km^2, and overlies the 1082 aquifer at its west end. This confined aquifer is comprised of glaciofluvial sands and gravels, and it is located underneath till, in between layers, or underlying glaciolacustrine deposits. The reported yield for the wells screened in this aquifer ranges between 0.3 and 2.5 litres per second (L/s) while their depth to water ranges from 24 to 40 m below ground surface (m bgs). The groundwater flow pattern (i.e., flow direction) is not clear but is likely towards the Elk River. Recharge sources are precipitation, snow melt, and infiltration of surface water.

Aquifer 1082 is a confined bedrock aquifer with an area of 1.8 km^2 and a median well yield of 0.41 L/s. Groundwater within this aquifer flows to the southwest through fractured sedimentary rocks, including shale, sandstone, and limestone of the Fernie Formation.

Table 9.4-2 summarizes the well ID, their owner (as indicated in the database but assumed to be partly representative of previous owners), locations, use, depth, drilling method, depth to bedrock, reported well yield, and static water level. Teck's wells are used for water supply systems, monitoring, and industrial purposes, and the only well that is not the property of Teck is used for commercial and industrial purposes. Wells with water use listed as 'Water Supply' have the potential to be used for drinking water purposes. Therefore, current and potential future potable water use applies to the Groundwater LSA, and groundwater quality analytical results have been compared to provincial drinking water standards.

9.4.2 Baseline Program Methods

Multiple groundwater field investigations have been completed for the Project. The groundwater dataset incorporates information from drilling, hydraulic testing, flow accretion, and seepage assessments from field programs in 2013 and 2018 as well as groundwater sampling and water level monitoring from 28 monitoring wells across the Groundwater LSA, as seen in Figure 9.4-1. The following sections describe the methodology and findings of the baseline program; additional details are provided in Appendix 9-A.

9.4.2.1 Drilling, Monitoring Well Installation and Development

Drilling programs for groundwater characterization were completed in 2013 and 2018. In 2013, Norwest completed drilling and testing of five monitoring wells in the area of the South Pit and North Pit. In 2018, SRK completed a drilling program focused on characterization of overburden and shallow bedrock properties at relatively lower elevations. Boreholes were completed as monitoring wells using standard drilling, monitoring well construction, and development methods. Further details regarding borehole drilling and monitoring well installation, including borehole logs, are provided in Appendix A of the 2018 Hydrogeological Field Data Report (SRK, 2019; Appendix 9-B) and Appendix A of the Crown Mountain Property Baseline Groundwater Investigation Results (Norwest, 2016; Appendix 9-C).

Table 9.4-3 summarizes information for each of the monitoring wells at the Project. Monitoring well locations are presented in Figure 9.4-2.

9.4.2.2 Groundwater Quality Monitoring Protocols and Quality Assurance/Quality Control

Sampling for groundwater quality has been completed over multiple events between September 2013 and August 2020. During sampling events conducted by Okane between September 2013 and June 2016, wells were purged of three well volumes or until dry and sampled using disposable bailers or a HydraSleeve Interval sampler. Analyzed parameters for this period of sampling included the following:

- Routine potability parameters, including major ions;
- Selected total and dissolved heavy metals;
- Selected hydrocarbon compounds; and
- Cyanide.

Groundwater quality sampling frequency at Crown Mountain between 2013 and 2016 is summarized in Table 9.4-4.

Table 9.4-2: Nearby Water Supply Wells Database

Well ID	UTM NAD 1983		Owner	Use	Drilling Method	Depth (m bgs[a])	Reported Well Yield		Static Water Level (m TOC[d])	Depth to bedrock (m bgs[a])
	Northing	Easting					(gpm[b])	(L/s[c])		
113642	5529468	658334	Teck - Line Creek	Unknown	Dual Rotary	29.3	100	6.3	9.1	23.8
111334	5531919	660261	Line Creek Operations	Water Supply System	-	0.0	-	-	0.0	0.0
50347	5528774	655441	Line Creek Operations	Water Supply System	-	29.0	-	-	-	-
107071	5528800	655460	Line Creek Operations	Water Supply System	-	3.0	-	-	-	-
50344	5528804	655469	Line Creek Operations	Unknown	-	31.1	-	-	0.0	0.0
106743	5531619	659729	Thurber Engineering LTD	Commercial and Industrial	-	212.8	2	0.1	18.3	19.8
116060	5511376	658731	SRF Teck Elk Valley Operations	Monitoring	Dual Rotary	138.4	50	3.2	82.3	-
115999	5511259	659074	Teck Elk Valley Operations	Monitoring	Dual Rotary	138.4	50	3.2	54.3	135.6
116020	5511275	658938	Teck Elk Valley Operations	Water Supply	Dual Rotary	85.2	100	6.3	68.0	0.0
114728	5510818	658251	Teck Elk Valley Operations	Unknown	Dual Rotary	57.6	100	6.3	44.2	0.0
115894	5511387	656045	Teck Elk Valley Operations	Unknown	Dual Rotary	23.2	100	6.3	9.1	20.7
112842	5512093	656095	Teck Elkview Operations	Commercial and Industrial	Dual Rotary	28.3	1,000	63.1	3.0	0.0
114901	5511910	655950	Teck Elkview Operations	Unknown	Dual Rotary	29.3	-	-	15.2	21.3

Notes:
(a) Metres below ground surface
(b) Gallons per minute
(c) Litres per second
(d) Metres below top of casing

Table 9.4-3: Monitoring Well Completion Details

Monitoring Well	Date Completed	UTM NAD 1983		Ground Elevation	Borehole Diameter	Well Diameter	Borehole Depth	Bedrock Depth	Screen Top	Screen Bottom	Midpoint Screen	Screen Length	TOC [d] Elevation	PVC Stickup	Midpoint Screen Elev.	Screen Geology	Hydrostratigraphic Unit (BR – Bedrock, OVB - Overburden)	Hydraulic Conductivity	Water Level (2018)
		Easting (m)	Northing (m)	(m asl) [a]	(mm) [b]	(mm) [b]	(m bgs) [c]	(m bgs) [c]	(m bgs) [c]	(m bgs) [c]	(m)	(m)	(m asl) [a]	(m ags) [e]	(m asl) [a]			(m/d)[f]	(m asl) [a]
GW1-A	2018	664,416	5,512,947	1,466.7	140	51	27.4	no BR	24.4	27.4	25.9	3.0	1,467.5	0.8	1,440.8	Sand, silty, fine	OVB – glaciolacustrine	3E-02 – Slug	1,464.947
GW1-B	2018	664,415	5,512,947	1,466.7	178	51	27.4	no BR	5.9	9.0	7.5	3.0	1,467.5	0.8	1,459.2	Sand	OVB – fluvial	4E+00 – Slug	1,465.645
GW3-A	2018	664,250	5,515,734	1,516.0	140	51	47.2	no BR	41.5	44.5	43.0	3.0	1,517.1	1.2	1,473.0	Gravel and cobbles, sand	OVB – glaciofluvial	2E+01 – Slug	1,509.304
GW3-B	2018	664,252	5,515,733	1,516.0	140	51	24.4	no BR	21.0	24.1	22.6	3.0	1,516.8	0.8	1,493.4	Cobbles, gravel and sand	OVB – glaciofluvial	5E+01 – Slug	1,509.304
GW3-C	2018	664,250	5,515,734	1,516.0	178	51	47.2	no BR	8.8	11.9	10.4	3.0	1,517.2	1.2	1,505.6	Sand and gravel, cobbley	OVB – fluvial/glaciofluvial	2E+02 – Slug	1,509.241
GW4-OB	2018	664,456	5,516,285	1,546.8	140	51	13.7	no BR	10.7	13.7	12.2	3.0	1,547.8	1.0	1,534.6	Sand and gravel, silt	OVB – till	3E-01 – Slug	1,535.411
GW4-BR	2018	664,456	5,516,283	1,546.7	140	51	36.6	31.7	32.0	35.1	33.5	3.0	1,547.8	1.0	1,513.2	Bedrock (Sandstone)	BR – sandstone	3E-02 – Slug	1,529.029
GW6-OB	2018	664,455	5,517,060	1,562.8	140	51	6.1	no BR	2.4	5.5	4.0	3.0	1,563.7	0.9	1,558.8	Sand & Gravel	OVB – fluvial	4E+00 – Slug	1,560.024
GW6-BR	2018	664,454	5,517,059	1,562.7	140	51	15.2	6.1	11.3	14.3	12.8	3.0	1,563.7	1.0	1,549.9	Bedrock (Sandstone)	BR – sandstone	2E-03 – Slug	1,559.342
GW7-A	2018	663,979	5,516,030	1,532.4	140	51	36.6	no BR	29.9	32.9	31.4	3.0	1,533.1	0.9	1,501.0	Cobbles and sand, sand	OVB – glaciofluvial	7E+00 – Slug	1,511.09
GW7-B	2018	663,980	5,516,029	1,532.4	140	51	14.5	no BR	10.5	13.6	12.0	3.0	1,533.3	1.0	1,520.3	Sand and gravel, silty	OVB – till	2E-02 – Slug	1,518.311
GW-MP1-OB	2018	663,609	5,516,735	1,554.5	178	51	32.0	no BR	7.3	10.4	8.8	3.0	1,555.3	0.9	1,545.6	Gravel, sandy with clay	OVB – fluvial	4E+00 – Slug 5E+01 – Ptest	1,546.766
GW-MP1-BR	2018	663,609	5,516,735	1,554.5	140	51	32.0	26.5	28.0	31.1	29.6	3.0	1,555.3	0.8	1,524.9	Bedrock (Mudstone)	BR – mudstone	4E-03 – Slug	1,542.006
GW-MP1-PW	2018	663,602	5,516,727	1,554.3	178	102	32.0	28.9	7.8	10.8	9.3	3.0	1,555.3	1.0	1,545.0	Gravel, sandy with silt/clay	OVB – till	3E+00 – Ptest	1,547.18
GW9-OB	2018	663,385	5,516,960	1,592.2	140	51	24.4	no BR	21.0	24.1	22.6	3.0	1,593.0	0.8	1,569.6	Clayey Sand and Gravel/Clay	OVB – colluvium	7E+00 – Slug	1,571.838
GW9-BR	2018	663,386	5,516,959	1,592.0	140	51	42.7	40.5	39.6	42.7	41.1	3.0	1,592.9	0.9	1,550.8	Sand/Fractured Bedrock	OVB/BR – sand over BR	9E-01 – Slug	1,573.277
GW12-OB	2018	662,858	5,520,908	1,983.5	140	51	10.6	no BR	4.6	7.6	6.1	3.0	1,984.4	0.9	1,977.4	Sand & Gravel/Fractured Bedrock	OVB/BR – till over BR	N/A	dry
GW12-BR	2018	662,857	5,520,907	1,983.5	140	51	15.2	7.0	13.7	15.2	14.5	1.5	1,984.5	0.9	1,969.1	Bedrock (Sandstone)	BR – sandstone	9E+00 – Slug	1,968.385
GW14-OB	2018	661,986	5,522,929	1,865.6	140	51	16.8	no BR	12.2	15.2	13.7	3.0	1,866.4	0.8	1,851.8	Sand & Gravel/Fractured Bedrock	OVB/BR – till over BR	3E+00 – Slug	1,852.642
GW14-BR	2018	661,986	5,522,931	1,865.6	140	51	22.6	16.2	19.5	22.6	21.0	3.0	1,866.5	0.9	1,844.6	Bedrock (Mudstone)	BR – mudstone	3E-01 – Slug	1,852.463
GW-MD1	2018	661,972	5,521,336	1,916.2	140	51	6.1	1.2	1.8	4.9	3.4	3.0	1,917.2	0.9	1,912.9	Bedrock (Sandstone)	BR – sandstone	2E+00 – Slug	1,912.99601
GW-MD2	2018	662,891	5,519,422	1,827.6	140	51	21.3	18.3	17.1	20.1	18.6	3.0	1,828.4	0.8	1,809.0	Silt/Gravel/Fractured Bedrock	OVB/BR – till over BR	3E-01 – Slug	1,821.79249
GW-PP2	2018	661,380	5,521,545	1,870.6	140	51	7.9	5.5	5.5	7.0	6.2	1.5	1,871.5	0.9	1,864.3	Bedrock (Sandstone)	BR – sandstone	4E-03 – Slug	1,865.61503
CM-11-11	2013	662,704	5,521,503	2,087.0	152	51	126.4	8.7	119.0	126.0	122.5	7.0	ground	na	1,964.5	Sandstone and Coal	BR – sandstone/coal	7E-03 – Slug	nm
CM-12-01	2013	662,429	5,522,037	2,142.0	152	51	152.0	0.0	117.0	125.0	121.0	8.0	ground	na	2,021.0	Sandstone and Shale	BR – sandstone/shale	1E-02 – Slug	2,096.168
CM-13-06	2013	662,823	5,521,114	1,998.0	152	51	54.2	0.0	31.0	36.0	33.5	5.0	ground	na	1,964.5	Sandstone and Shale	BR – sandstone/shale	5E-02 – Slug	1,988.507
CM-13-20	2013	663,264	5,518,426	1,877.0	152	51	158.0	0.0	19.0	24.0	21.5	5.0	ground	na	1,855.5	Sandstone and Shale	BR – sandstone/shale	N/A	dry
CM-13-25	2013	663,769	5,517,924	1,936.0	152	51	102.5	14.2	87.0	92.0	89.5	5.0	ground	na	1,846.5	Coal and Shale	BR – shale/coal	2E-03 – Slug	No measurement

Source: SRK (2021a).

Notes: a. meters above sea level; b. millimetres; c. meters below ground surface; d. Top Of Casing (PVC Pipe); e. metres above ground surface; f. metres per day; na –not applicable; Ptest – pumping test

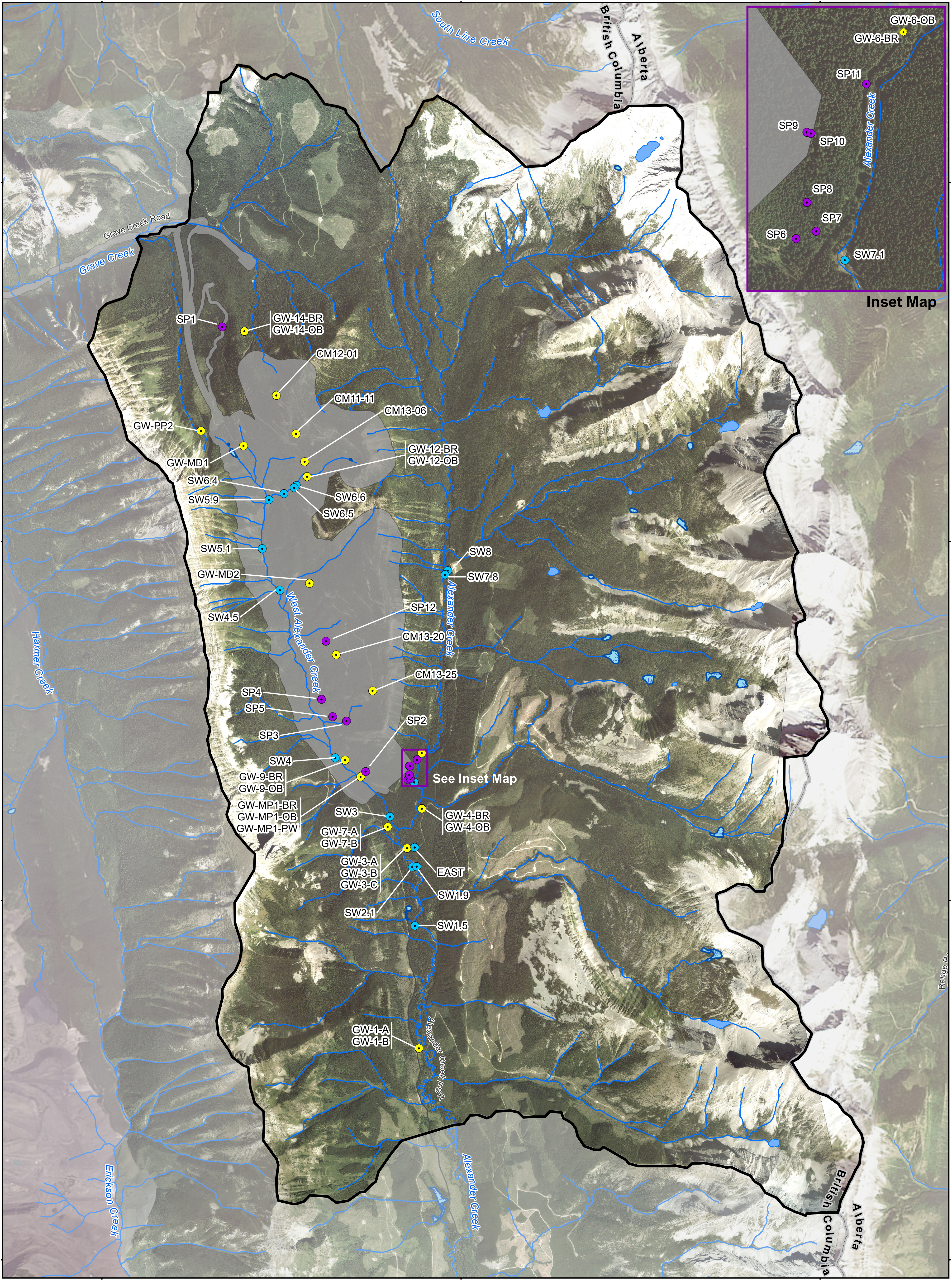

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Figure 9.4-2
Local Groundwater Monitoring Network

LEGEND

- ● Local Groundwater Monitoring Location
- ● Flow Survey Location
- ● Seepage Point
- ▭ Groundwater Local Study Area
- ▨ Project Footprint
- — Local/Resource Road
- — Watercourse
- 🟦 Waterbody
- ▨ Wetland
- ▭ British Columbia/Alberta Border

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada, Swiftwater Consulting, 2018, SRK Consulting (Canada) Inc.
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 2021-06-09

Document Path: G:\GIS\2012 and Prior\126231 Crown Mountain\EA_Report\ExistingConditions\Groundwater\Figure_9_4_2_Local_GW_Monitoring_Network_rev00\v10\126231_EC_GW_LocalGroundwaterMonitoringNetwork.mxd

Table 9.4-4: Historical Groundwater Samples Collected 2013 to 2014

Well ID	# of samples	Events (2013-2014)	Sampled by
CM-11-11	5 (+1 duplicate)	Sep-13, Jan-14, Aug-14, Nov-14, Oct-15	Norwest[1]
	1	Jun-16	O'Kane[2]
CM-12-01	6 (+ 4 duplicate)	Sep-13, Jan-14, Apr-14, Aug-14, Nov-14, Oct-15	Norwest
	1	Jun-16	O'Kane
CM-13-06	5	Sep-13, Jan-14, Apr-14, Nov-14, Oct-15	Norwest
	1 (+ 1 duplicate)	Jun-16	O'Kane
CM-13-25	3	Sep-13, Aug-14, Oct-15	Norwest
	1	Jun-16	O'Kane

Notes:
(1) Norwest Corporation; Appendix 9-C;
(2) O'Kane Consultants; Appendix 9-B.

For sampling conducted since 2018, groundwater samples were submitted for laboratory analysis of the following parameters:

- Physical parameters – electrical conductivity (EC), hardness, pH, and total dissolved solids (TDS);
- Anions and nutrients;
- Total organic and inorganic carbon;
- Total and dissolved metals; and
- Select polycyclic aromatic hydrocarbons (PAHs).

Groundwater quality sampling frequency for the second period of sampling between 2018 and 2020 is summarized in Table 9.4-5. The latter period included quarterly sampling at 26 monitoring wells between September 2018 and August 2020, for a total of 149 samples.

Table 9.4-5: Summary of Groundwater Samples Collected 2018 to 2020

Well ID	2018		2019				2020		# of Samples
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
CM-11-11			X	X	X	X		X	5
CM-12-01				X	X	X		X	4
CM-13-06				X	X	X		X	4
CM-13-25				X	X	X		X	4
GW-12-BR				X					1
GW-14-BR	X(1)	X(2)		X	X(2)	X(2)		X	9
GW-14-OB	X(1)	X		X	X	X		X	6
GW-1-A		X	X	X	X	X	X	X	7
GW-1-B		X	X	X	X	X	X(2)	X	8
GW-3-A		X(2)	X	X	X	X	X	X	8

Well ID	2018		2019				2020		# of Samples
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
GW-3-B		X	X	X	X	X	X	X	7
GW-3-C		X	X	X	X	X	X	X	7
GW-4-BR		X	X	X(2)	X	X	X	X	8
GW-4-OB		X		X	X	X			4
GW-6-BR		X(1)		X	X	X		X	5
GW-6-OB	X(1)		X	X(2)	X	X	X	X	8
GW-7-A		X	X	X	X	X	X	X	7
GW-7-B		X							1
GW-9-BR		X(1)		X	X	X(2)		X	6
GW-9-OB	X(1)		X(2)	X	X(2)	X	X	X	9
GW-MD1				X					1
GW-MD2		X		X	X	X		X	5
GW-MP1-BR		X(1)		X	X	X	X	X	6
GW-MP1-OB	X(3)		X	X	X	X	X	X	8
GW-MP1-PW	X(1)		X	X	X	X	X	X	7
GW-PP2				X	X	X		X	4
Total Samples	7	17	13	27	25	25	13	22	149

Notes:
(1) These samples were collected by SRK;
(2) Two samples were collected;
(3) Two samples were collected, one by SRK and one by Okane Consultants Inc.

Prior to sampling, water levels were measured, and wells were purged with continuous monitoring of field parameters including temperature, dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, and specific conductivity (SPC) at a minimum, with TDS, salinity, and turbidity measured during some sampling events. Samples were taken when field parameters stabilized, and, in most cases, flow rates during purging were recorded. Dissolved parameters were field-filtered using 45 micrometre (µm) in-line filters or 45 µm filters syringe sets, and field-preserved. Groundwater samples were collected in laboratory-supplied bottles and delivered to Maxxam Analytics Inc. in Calgary, Alberta, or ALS laboratories of Burnaby, B.C. or Calgary. Field duplicates and blanks were also collected for Quality Assurance/Quality Control (QA/QC).

9.4.2.3 Groundwater Level Data Collection

Groundwater level has been measured either manually or with continuous water level dataloggers since the wells were installed. Six Solinst Leveloggers and one Barologger were installed in selected monitoring wells to monitor long-term water levels at hourly to daily frequency, depending on location. Data downloads as well as manual readings were taken quarterly during sampling rounds. Groundwater level measurements from 2018 to 2020 are provided in Table 9.4-6 below.

Table 9.4-6: Groundwater Level Measurements for 2018 to 2020

Well ID	Groundwater Elevation (m asl[a])			Groundwater Depth (m bgs[b])			Transducer Data	2018		2019				2020	
	Min.	Average	Max.	Min.	Average	Max.		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
CM11-11	1,994.7	2,009.3	2,043.6	43.4	77.7	92.3	Yes(1)		X	X	X	X	X		X
CM12-01	2,087.6	2,096.0	2,112.4	29.6	46.0	54.4	Yes(1)		X	X	X	X	X		X
CM13-06	1,974.2	1,980.3	1,998.0	0.0	17.7	23.8	Yes(2)		X		X	X	X		X
CM13-20 (4)	-	-	-	-	-	-	Yes(3)		X	X	X				
CM13-25	1,855.3	1,856.3	1,859.4	76.6	79.7	80.7	Yes(1)		X	X	X	X	X		X
GW12-BR	1,968.4	1,969.0	1,972.1	11.4	14.5	15.1	Yes(4)	X	X	X	X	X	X		
GW12-OB	1,975.9	1,975.9	1,975.9	7.6	7.6	7.6	No		X						
GW14-BR	1,852.4	1,853.2	1,855.1	10.5	12.4	13.2	No	X	X		X	X	X		
GW14-OB	1,852.3	1,853.6	1,855.7	9.9	11.9	13.3	No	X	X		X	X	X		
GW1-A	1,464.4	1,465.1	1,466.1	1.4	1.7	2.3	No		X	X	X	X		X	X
GW1-B	1,449.6	1,465.1	1,466.3	0.5	1.6	17.1	Yes(5)		X	X	X	X	X	X	X
GW3-A	1,508.6	1,510.1	1,513.3	2.6	5.9	7.4	No		X	X	X	X		X	X
GW3-B	1,508.6	1,510.1	1,513.4	2.6	5.9	7.3	No		X	X	X	X		X	X
GW3-C	1,496.0	1,510.8	1,515.9	0.1	5.2	20.0	Yes(5)		X	X	X	X	X	X	X
GW4-BR	1,529.0	1,529.7	1,530.4	16.3	17.0	17.7	No		X	X	X	X		X	X

Well ID	Groundwater Elevation (m asl[a])			Groundwater Depth (m bgs[b])			Transducer Data	2018		2019				2020	
	Min.	Average	Max.	Min.	Average	Max.		Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
GW4-OB	1,535.0	1,537.4	1,547.1	11.1	11.4	11.8	No		X	X	X	X			
GW6-BR	1,551.4	1,558.3	1,560.3	2.4	4.4	11.3	No	X	X	X	X	X	X		X
GW6-OB	1,548.7	1,560.2	1,560.8	1.9	2.6	14.0	Yes(5)	X	X	X	X	X	X	X	X
GW7-A	1,510.4	1,512.0	1,516.3	16.1	20.4	22.0	No		X	X	X	X	X	X	X
GW7-B	1,518.2	1,518.4	1,518.8	13.6	13.9	14.1	No		X						
GW9-BR	1,571.0	1,573.6	1,576.4	15.6	18.4	21.0	No	X	X	X	X	X	X		X
GW9-OB	1,571.4	1,572.5	1,575.1	17.1	19.7	20.7	No	X	X	X	X	X	X	X	X
GW-MD1	1,912.0	1,913.1	1,914.6	1.6	3.2	4.2	No	X	X		X	X	X		
GW-MD2	1,821.7	1,822.5	1,824.4	3.2	5.1	5.9	No	X	X		X	X	X		X
GW-MP1-BR	1,539.6	1,542.1	1,544.4	10.0	12.4	14.9	Yes(5)	X	X	X	X	X	X	X	X
GW-MP1-OB	1,546.4	1,547.6	1,550.5	4.0	6.9	8.1	Yes(5)	X	X	X	X	X	X	X	X
GW-MP1-PW	1,546.7	1,548.0	1,551.2	3.1	6.3	7.7	No	X	X	X	X	X	X	X	X
GW-PP2	1,865.5	1,866.3	1,868.6	1.9	4.2	5.0	No	X	X		X	X	X		X

Notes:

(a) metres above sea level

(b) metres below ground surface

(1) Continue barometric corrected data every 24 hours since October 2018 to May 2019

(2) Continue barometric corrected data every 1 hour since October 2018 to May 2019

(3) Continue barometric corrected data every 24 hours since October 2018 to May 2019. The well is dry.

(4) Well most of the time dry.

(5) Continue barometric corrected data every hour since October 2018 to March 2020

9.4.2.4 Seepage Survey

Between September 12 and October 26, 2018, SRK field staff conducted a reconnaissance seep survey in order to better understand localized groundwater discharge zones. The survey consisted of a site walk-around and the recording of any visual water flow observed coming out of the ground. Information recorded included Global Positioning System (GPS) coordinates, flow rate of seepage/spring and descriptions with photographic record. A summary of the seepage survey is provided in Table 9.4-7. The locations of seepage points are illustrated on Figure 9.4-2.

Table 9.4-7: Seepage Survey Summary

Seepage Point	Easting	Northing	Estimated Flow	Note	Date
ID	UTM NAD 1983	UTM NAD 1983	(L/min)		
SP1	661676.0	5522992.8	< 1	Small seep near GW14	9/14/2018
SP2	663672.2	5516800.9	< 1	Small seep above MP1, on road	9/24/2018
SP3	663404.6	5517502.7	< 1	Small seepage on branch C km 105-106	9/27/2018
SP4	663059.0	5517806.0	15	Potential spring 3-4 m	10/20/2018
SP5	663211.8	5517564.7	0.5	Small seep	10/20/2018
SP6	664261.4	5516688.6	< 1	Small seep, marsh area	10/27/2018
SP7	664297.8	5516702.0	8	Small creek	10/27/2018
SP8	664281.0	5516753.8	8	Small creek	10/27/2018
SP9	664280.8	5516879.5	8	Small creek	10/27/2018
SP10	664288.1	5516877.5	8	Possible spring	10/27/2018
SP11	664387.7	5516966.2	8	Water seepage, small creek	10/27/2018
SP12	663119.6	5518614.5	< 1	Small seep below pad CM-22	10/27/2018

Notes:
SP – Seepage Point
L/min – Litres per minute

Identified seeps are all on the lower elevation flanks of the ridge where the proposed open pits will be located. These locations are believed to represent groundwater discharge and could be related to bedrock bedding planes outcropping in this area or geological structures.

9.4.2.5 Determination of Hydraulic Properties

Hydraulic testing using slug testing methods was conducted for five monitoring wells in the area of the South Pit and North Pit in 2013. A single well response test was completed at CM13-06, CM12-01 and CM11-11 in the spring of 2014 using a manual weighted slug, and well response was recorded for both the drawdown and recovery test. The Hvorslev method was used to interpret the data, which gave a hydraulic conductivity of 5.79×10^{-7} m/s, 1.30×10^{-7} m/s, and 7.56×10^{-8} m/s, respectively, for CM13-06, CM12-01, and CM11-11. Slug tests were completed in August 2014 at CM12-01, CM11-11, and CM13-25. The results were 3.38×10^{-7} m/s, 9.71×10^{-8} m/s, and 2.24×10^{-8} m/s respectively. Results for locations CM12-01 and CM11-11 were to the same order of magnitude as tests previously completed in April 2014.

In 2018, the remainder of hydraulic testing was completed included slug tests and one pumping test for a total of 17 boreholes at nine different locations. Detailed methodology for the determination of hydraulic properties is provided in Section 2.4 of the 2018 Hydrogeological Field Data Report (SRK, 2019; Appendix 9-B). Hydraulic conductivity results obtained in 2018 from a pumping test are provided in Table 9.4-8. Figure 9.4-3 provides hydraulic conductivities estimated for the different hydrostratigraphic units.

9.4.2.6 Conceptual Model Methodology

The conceptual model combines the available hydrogeological data and knowledge to illustrate interpretations or important aspects of how the groundwater system functions to inform a specific technical objective. Components of the conceptual model include the various hydrostratigraphic units, groundwater flow properties, and groundwater quality for current baseline conditions. These models can be expanded to assess potential future groundwater conditions at various future mine life stages. The conceptual model formed the framework for a groundwater numerical model for the Project site used to estimate groundwater quantities and, then, assess potential changes to groundwater quantity and quality for future conditions (i.e., the Project).

9.4.2.7 Numerical Modelling Methodology

A 3D groundwater numerical model for the Groundwater LSA was constructed and calibrated to available data for baseline conditions (Appendix 9-A).

9.4.2.7.1 Model Software

Groundwater numerical modelling was completed using the software FEFLOW v.7.3 (DHI, 2019). FEFLOW is a professional software package for modelling fluid flow and transport of dissolved constituents and/or heat transport processes in the subsurface. This program is used extensively for characterizing groundwater conditions for mining projects around the world. The code is based on a finite element solution of the partial differential equations for flow and transport.

9.4.2.7.2 Model Domain and Model Mesh

The model domain covers an area of approximately 8 km x 14 km, with a total area of 112 km^2. The domain is set to encompass the East Alexander, West Alexander, Lower Alexander and the upper portion of the Grave Creek catchments, with the external boundaries considered to be sufficiently distant from the mining area to minimize the influence of the boundary conditions on model predictions. The upper surface of the model is defined based on digital elevation model (DEM) coverages from light detection and ranging (LiDAR) images and from the Shuttle Land Elevation Mission (SRTM), and the base of the model is set at a constant elevation of 800 m asl. The model domain coincides with the Groundwater LSA.

The model mesh is composed of 1,231,956 nodes and 2,308,736 elements, which are approximately 100 m wide over most of the model area, with a finer mesh resolution of 5 to 10 m near the creeks and proposed pit areas. The model is divided into 16 layers, at varying thicknesses from 10 to 300 m approximately.

Table 9.4-8: Measured Hydraulic Conductivity and Storage Properties

Well ID	Analysis	Satuated Thickness	Inferred K	S	Inferred S_s	Transmissivity	Literature Porosity [b]	Literature Range for S_S [c]
		b (m)	(m/s)	(-)	(m^{-1})	(m^2/s [a])	(-)	(m^{-1})
GW-MP1-PW	Constant Test DD Analysis & Recovery Analysis	3.5	$4x10^{-5}$	$1x10^{-3}$	$3x10^{-4}$	$1.4x10^{-4}$	0.25 – 0.70	$1x10^{-5}$ to $1x10^{-3}$
	Unconfined Aquifer (Neuman 1974)							
GW-MP1-OB	Constant Test DD Analysis & Recovery Analysis	3.5	$5.x10^{-4}$	$1x10^{-5}$	$3x10^{-6}$	$1.75x10^{-3}$		
	Unconfined Aquifer (Neuman 1974)							

Notes:

(a) Domenico and Mifflin, 1965.

(b) Computed using the aquifer nominal thickness and the inferred K, given as a value between 0 and 1.

(c) Freeze and Cherry, 1979

S – Storativity

S_S – Specific storage

m^2/s – metres squared per second

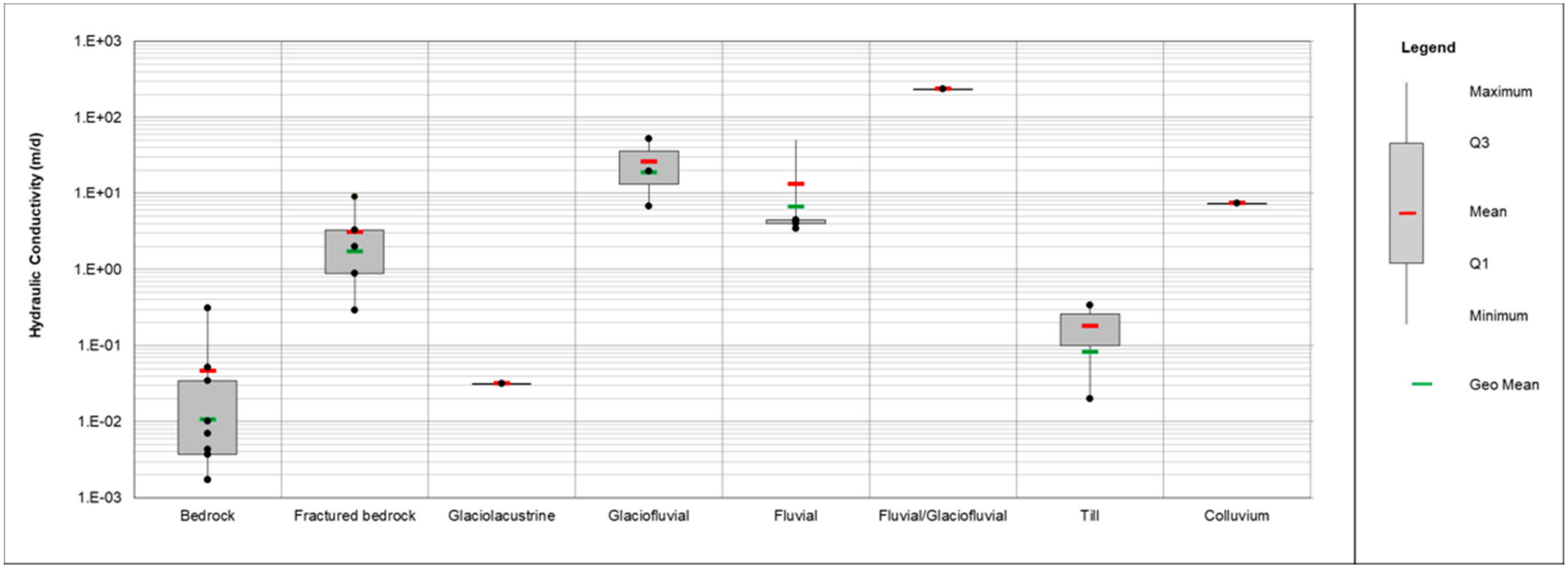


Figure 9.4-3: Hydraulic Conductivity across the Local Groundwater Monitoring Network

9.4.2.7.3 Boundary Conditions

Model boundary conditions include external boundaries, such as the western and eastern model edges, which coincide with ridges forming surface water catchment divides. These boundaries are assigned no-flow (or zero-flux) boundary conditions. Groundwater flow through the northern and southern model edges is outwards from the model area, via the creek channels which are simulated using seepage boundary conditions. Early model simulations highlighted the likelihood for deep groundwater flow below the creeks, particularly in the lower Alexander Creek, where flow is southwards out of the model area.

Therefore, to simulate potential deep regional aquifer flow out of the model area to the south, seepage boundary conditions were introduced at depth. The base of the model is defined as a no-flow boundary. Several internal boundaries have been assigned, including recharge, rivers/creeks and the mine pit.

Recharge applied on the top layer of the model was equivalent to 15% of mean annual precipitation (MAP) for the overburden and 10% of MAP where bedrock outcrops. These values were adjusted during the calibration process.

9.4.2.7.4 Model Parameterization and Calibration

The results of analyses of the hydraulic tests were used as the starting values and calibration range for the modelled hydraulic parameters per hydrostratigraphic unit. The model calibration was completed in two phases. In the first phase, hydraulic conductivities were varied while keeping the recharge constant until head predictions matched the water levels measured since 2018. In the second phase, the recharge and hydraulic conductivity values were varied while keeping a constant K/R ratio (hydraulic conductivity/recharge) until the simulated baseflows matched the baseflow estimates for the East Alexander, West Alexander, and Lower Alexander creeks. Additional details, including the assignment of the model properties and calibration methodology, are provided in Appendix B of the Groundwater Technical Report (SRK, 2021a), provided in Appendix 9-A. Calibrated model hydraulic properties for each model zone (lithology) are provided in Table 9.4-9.

Table 9.4-9: Calibrated Model Hydraulic Properties

Zone	Geology	Approximate K Range from Field Data & Conceptual (m/s)	K1 & K2 (horizontal) (m/s)	K3 (perpendicular/ vertical) (m/s)	Specific Storage (m^{-1})	Specific Yield (-)
1	Bedrock	$2x10^{-8}$ to $2x10^{-5}$	$1x10^{-7}$ (decreasing with depth)	$4x10^{-8}$ (decreasing with depth)	$1x10^{-6}$	0.001
2	Till/Colluvium	$5x10^{-8}$ to $1x10^{-5}$	$1x10^{-7}$	$1x10^{-7}$	$5x10^{-5}$	0.01
3	Glaciofluvial (set = fluvial)	$1x10^{-4}$ to $2x10^{-3}$	$5x10^{-4}$	$5x10^{-5}$	$1x10^{-4}$	0.20
4	Glaciolacustrine	$2x10^{-7}$ to $1x10^{-6}$	$4x10^{-7}$	$4x10^{-7}$	$1x10^{-5}$	0.005
5	Fluvial	$5x10^{-5}$ to $5x10^{-4}$	$5x10^{-5}$	$5x10^{-6}$	$1x10^{-4}$	0.05

The model results are compared to the measured heads in Table 9.4-10. The final calibrated model reproduces the regional behaviour reasonably well. The calibration statistics on heads are considered acceptable. The normalized root mean squared error (NRMSE) is 0.3%. The largest maximum errors (>30 m) are reported at CM11-11 and CM12-01, both of which are collared at high elevations within the South Pit. Variation in observed water levels could be indicative of compartmentalization associated with a coal seam, as they are both located within 500 m of one another and at a similar height on a ridge (inside the pit footprint area) but have an 87 m difference in observed water levels. Model calibration water levels are between both values at this location.

Table 9.4-10: Observed and Modelled Water Levels

No.	Borehole ID	Observed Water Level (m asl)	Modelled Water Level (m asl)	Residual
1	GW1-A	1,465	1,464	-1
2	GW1-B	1,466	1,464	-2
3	GW3-A	1,510	1,512	2
4	GW3-B	1,510	1,512	2
5	GW3-C	1,510	1,512	2
6	GW4-OB	1,537	1,518	-20
7	GW4-BR	1,530	1,518	-12
8	GW6-OB	1,560	1,539	-21
9	GW6-BR	1,558	1,539	-19
10	GW7-A	1,512	1,516	3
11	GW7-B	1,518	1,516	-3
12	GW-MP1-OB	1,548	1,521	-26
13	GW-MP1-BR	1,542	1,530	-12
14	GW-MP1-PW	1,548	1,524	-25
15	GW9-OB	1,573	1,582	9
16	GW9-BR	1,574	1,585	12
18	GW12-BR	1,969	1,988	19
19	GW14-OB	1,854	1,844	-10
20	GW14-BR	1,853	1,843	-10
21	GW-MD1	1,913	1,910	-3
22	GW-MD2	1,823	1,818	-4
23	GW-PP2	1,866	1,867	1
25	CM12-01	2,100	2,067	-33
26	CM13-06	1,993	2,001	8
27	CM11-11	2,013	2,052	39
28	CM13-25	1,857	1,860	3
29	GW12-OB	1,976	1,989	13
30	CM13-20	<1,853	1,841	Within range

The baseflow predictions compare reasonably well to the baseflow estimations (Figure 9.4-4). The largest variation between modelled and observed baseflows occurs between SW7.8 and SW7.1 on East Alexander Creek, where the observed flow rate increases significantly. The reason for the sudden increase in observed flow is not clear. Despite testing of multiple parameter variations to the model setup, this significant flow increase could not be represented in the model.

9.4.2.7.5 Sensitivity Analysis

Multiple model runs were conducted to assess the sensitivity of the model to the hydraulic conductivity/recharge (K/R) ratio and K anisotropy. Relative sensitivity definition for High: more than 30% change; Medium: 15 to 30% change; Low: 5 to 15% change; and Insignificant: less than 5% change.

Groundwater recharge is constrained in the model by calibration to baseflow. Some baseflow data are available to which the model is calibrated, but it is acknowledged that the dataset is limited. Understanding of groundwater recharge should improve over time as more data become available. This sensitivity is considered most important in regards to how it could affect the quantity and location of recharge to the groundwater system under the Mine Rock Storage Facility (MRSF). Additional methodology and results of the sensitivity analysis are described in Appendix B of the Groundwater Technical Report (SRK, 2021a), provided in Appendix 9-A.

Modelled Faults and Seepage

Seepage footprints were assessed using transient contaminant transport simulations for the following conditions:

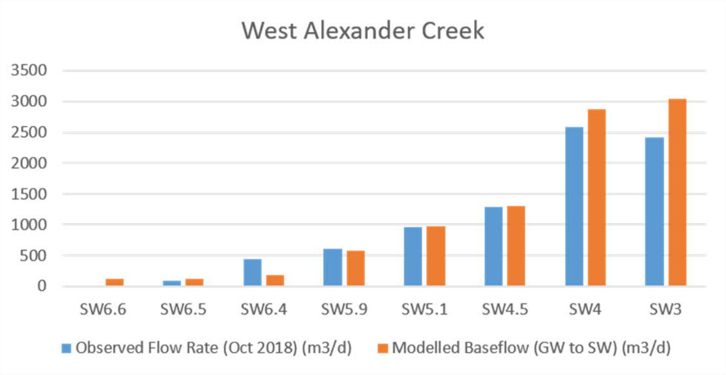
- Base case (potential for contaminant seepage from the MRSF only, with all other facilities being lined);
- Both the MRSF and pond as potential contaminant seepage sources; and
- Sensitivity test of above scenario, assuming no fault structures.

Faults are assumed to have K values one order of magnitude higher than their calibrated formation K parallel to the fault and one order of magnitude lower than their calibrated formation K perpendicular to the fault. Faults are represented in all transport scenarios, except for the final sensitivity test without faults. Mapped fault geometries are provided in Appendix 9-A.

9.4.2.7.6 Model Assumptions

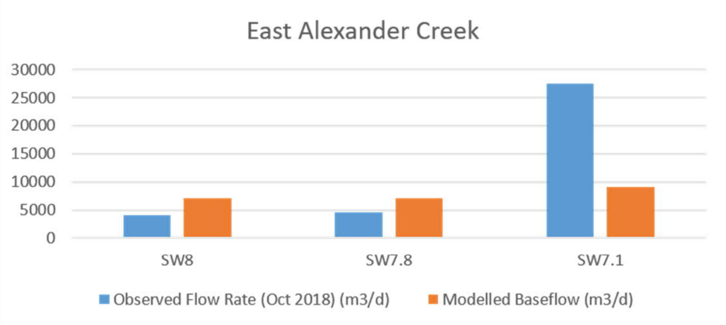
The model assumptions are as follows:

- At the scale of the assessment, groundwater system flow in bedrock can be approximated by an Equivalent Porous Media (EPM) model;
- Bedrock hydraulic conductivity (K) is anisotropic, with highest K parallel to bedding planes/ coal seams and to thrust fault strike with lowest K perpendicular to bedding. K, in all orientations, decreases with depth, according to the model proposed by Wei et al. (1995);
- Apart from preferential flow parallel to mapped fault strike, there are no major faults acting as conduits and no major regional deep flow influences;
- Recharge follows the same spatial trend with elevation as precipitation. The evaporation and evapotranspiration mechanisms are not explicitly modeled but assumed to be integrated as “net recharge”. It is assumed that this approach will not unduly bias the model;



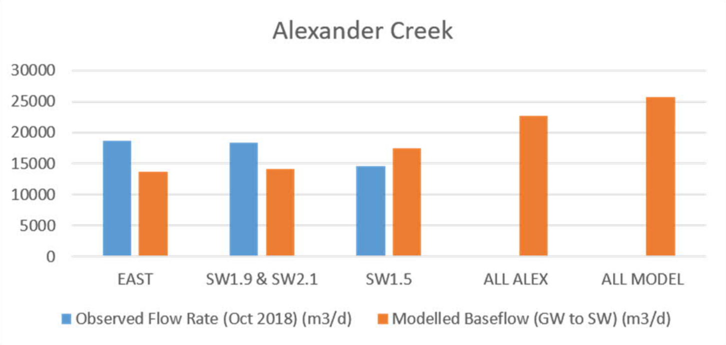
West Alexander Creek

ID	X	Y	Flow Rate (L/s)	ID	Observed Flow Rate (Oct 2018) (m3/d)	Modelled Baseflow (GW to SW) (m3/d)
SW6.6	662710	5520782	0	SW6.6	0	120
SW6.5	662677	5520753	1	SW6.5	86	122
SW6.4	662536	5520670	5	SW6.4	432	177
SW5.9	662325	5520585	7	SW5.9	605	570
SW5.1	662232	5519903	11	SW5.1	950	970
SW4.5	662479	5519327	15	SW4.5	1296	1311
SW4	663249	5516994	30	SW4	2592	2870
SW3	664011	5516173	28	SW3	2419	3043



East Alexander Creek

ID	X	Y	Flow Rate (L/s)	ID	Observed Flow Rate (Oct 2018) (m3/d)	Modelled Baseflow (m3/d)
SW8	664815	5519596	48	SW8	4147	7051
SW7.8	664777	5519542	54	SW7.8	4666	7140
SW7.1	664349	5516650	318	SW7.1	27475	9177



Alexander Creek

ID	X	Y	Flow Rate (L/s)	ID	Observed Flow Rate (Oct 2018) (m3/d)	Modelled Baseflow (GW to SW) (m3/d)
EAST	664355	5515744	216	EAST	18662	13607
SW1.9 & SW2.1	664384	5515478	212	SW1.9 & SW2.1	18317	14089
SW1.5	664359	5514654	169	SW1.5	14602	17406
ALL ALEX				ALL ALEX		22743
ALL MODEL				ALL MODEL		25710

Figure 9.4-4: Calibration to Baseflow

- Water level data collected in 2018 and 2019 are representative of the pre-mining steady-state conditions; and
- Steady-state models are adequate to define current conditions and predict mine effects to groundwater at a scale appropriate for assessment of potential environmental effects.

9.4.3 Baseline Program and Groundwater Modelling Results

9.4.3.1 Hydraulic Conductivity and Storage Properties

Hydraulic testing through slug tests and a single pumping test indicate fluvial sands have the highest conductivity with lower values in confining units. Consistent with other projects in the Elk Valley, bedrock conductivity is assumed to decrease with depth due to lithostatic pressure, and bedding planes impart anisotropy. A few large geological structures cross the site with limited characterization data. An estimate of the change in bedrock hydraulic conductivity with depth was made based on the depth model developed by Wei et al. (1995) and data from Snow (1968). Kz (vertical hydraulic conductivity or hydraulic conductivity perpendicular to bedding) is assumed to be one order of magnitude lower than Kx or Ky (horizontal hydraulic conductivity or hydraulic conductivity parallel to bedding). This anisotropy is related to preferential flow parallel to bedding planes, the orientation of which can vary across the Groundwater LSA. Pumping tests conducted on wells GW-MP1-PW and GW-MP1-OB provided estimates of storage parameters for tested overburden materials (gravel, sandy with silts and clays). Values derived from the hydraulic conductivity tests applied to each hydrostratigraphic unit within the model are listed in Table 9.4-11. The estimated change in average hydraulic conductivity with depth through bedrock is shown in Figure 9.4-5.

Table 9.4-11: Range of Hydraulic Conductivity for Modelled Hydrostratigraphic Units

Primary Hydrostratigraphic Unit	Secondary Hydrostratigraphic Unit	Description	Saturated Thickness (m)	Hydraulic Horizontal Conductivity (m/d)
Overburden Aquifer	Colluvium	Sands, gravels and cemented till lenses	10 – 20	Measured: 7 to 9
	Fluvial	Gravels interbedded with sands and silty sands	0 – 30	Measured: 2 to 5×10^{1}
	Glaciofluvial	Sand and gravel	0 – 34	Measured: 1 to 1×10^{4}
Overburden Aquitards	Till	Pebbles, cobbles and boulders in a matrix of sand, silt and clay	<27	Measured: 2×10^{-1} to 6×10^{-1}
	Lacustrine	Fine sand, silt and clay	-	Measured: 4×10^{-2}
	Glaciolacustrine	Silts and plastic clays but also include some fine sands	<18	Measured: 2×10^{-2} to 8×10^{-2}
Bedrock	Fractured or Weathered Bedrock	Fractured or weathered sandstone, mudstone and shale	<10	Measured: 2×10^{-1} to 8

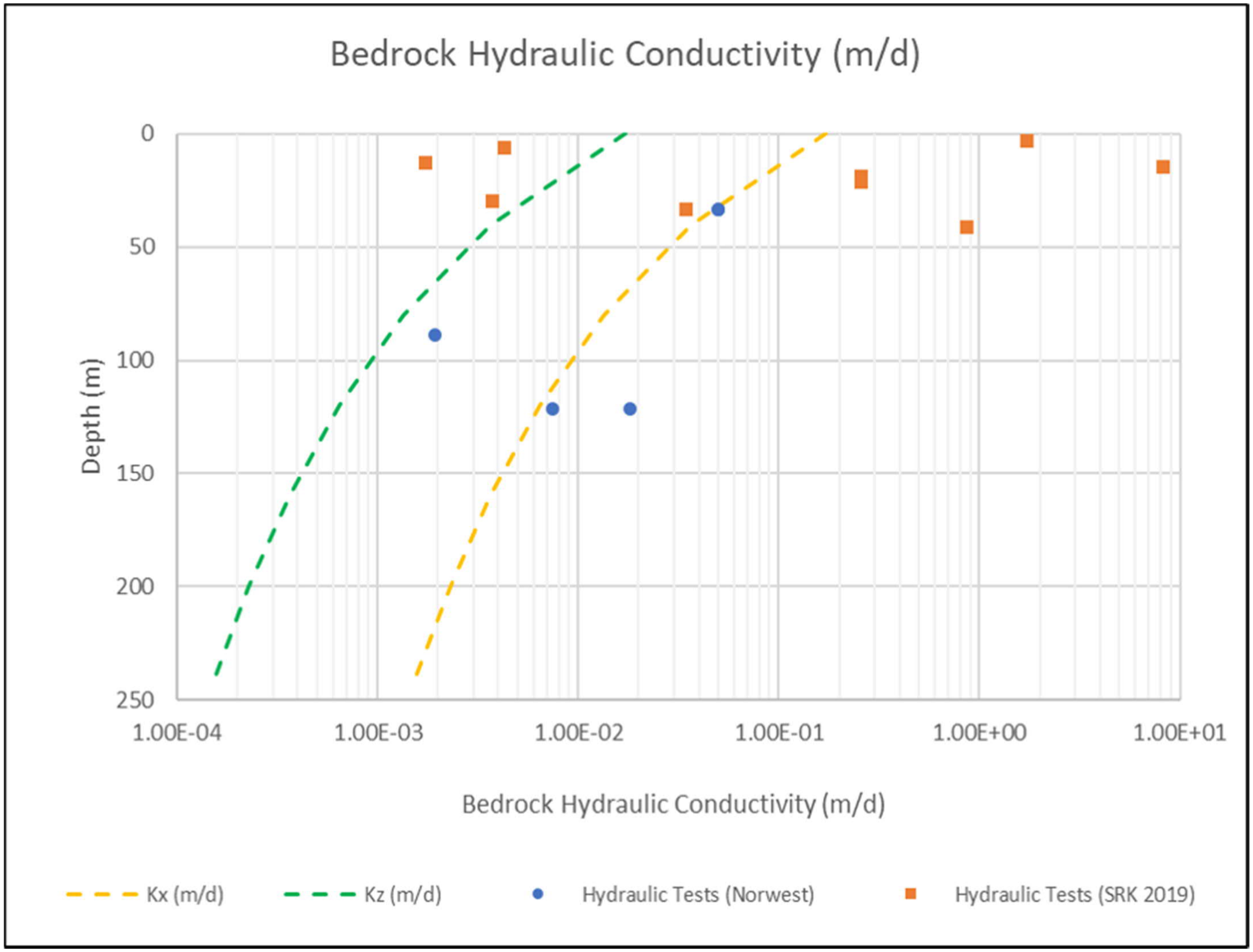


Figure 9.4-5: Bedrock Hydraulic Conductivity Estimate versus Depth

9.4.3.2 Groundwater Levels

Table 9.4-6 summarizes groundwater elevation measurements at the monitoring wells and piezometers described in Table 9.4-3.

Continuous groundwater levels at different areas of the Project is summarized in Figure 9.4-6. Groundwater level elevations are high at higher topographic areas and lower in valley bottoms, as expected in mountainous terrain. At high elevations, where the proposed pits are located, groundwater levels show some seasonal variations with peaks in May to June 2019 and June 2020 associated with spring freshet. Seasonal changes in groundwater elevations range from 30 m in CM-11-11 to 3 m in CM-13-25. Seasonal variations are also observed at lower elevations in the West Alexander Creek and Upper Alexander Creek valleys; however, peaks occur earlier in May.

9.4.3.3 Hydraulic Gradients

Figure 9.4-7 and Figure 9.4-8 show water level data at individual well clusters, illustrating vertical gradients as well as horizontal head differences.

Downwards gradients are observed at:

- Between GW12-BR (bedrock) and GW12-OB (overburden) near the North Pit (gradient of approximately 0.40);
- Between GW-MP1-BR (bedrock) and GW-MP1-OB (overburden) down-gradient of the external MRSF (estimated gradient of 0.25 to 0.41);
- Between GW6-OB (overburden) and GW6-BR (bedrock) in the Upper Alexander Creek valley (estimated gradient of 0.00 to 0.47);
- Between GW4-BR (screened in bedrock) and GW4-OB (screened in overburden) in the Upper Alexander Creek valley (estimated gradient of 0.29 to 0.94);
- Between GW7-B (overburden) and GW7-A (bedrock) in the West Alexander Creek valley (estimated gradient of 0.38 to 0.42); and
- Between GW1-A (confining layer) and GW1-B (overburden aquifer) in the Alexander Creek valley (estimated gradient of 0.03 to 0.07).

Upwards gradients are observed at:

- Between GW9-BR (bedrock) and GW9-OB (overburden) in the West Alexander Creek valley upstream of GW-MP1 (0.39 on average).

Vertical gradients are variable at GW3-A, GW3-B and GW3-C, located near the confluence of West and Upper Alexander creeks, changing between downward and upward, though differences between the wells are relatively minor. All of these wells are screened in overburden. Vertical gradients are also variable between GW14-BR (bedrock) and GW14-OB (overburden) at the north end of the North Pit in the Grave Creek drainage. The majority of the measurements indicate a downwards gradient from overburden to bedrock, except for the readings in October 2018 and October 2019. Depth to water varies depending on location. For the monitoring wells screened in bedrock, depth to groundwater can range between 3 to 82 m, while depth to water in wells screened in overburden can range between 0 and 20 m. Depth to water does not necessarily correspond to specific topographic positions, but rather likely reflects characteristics of the groundwater system in a given area.

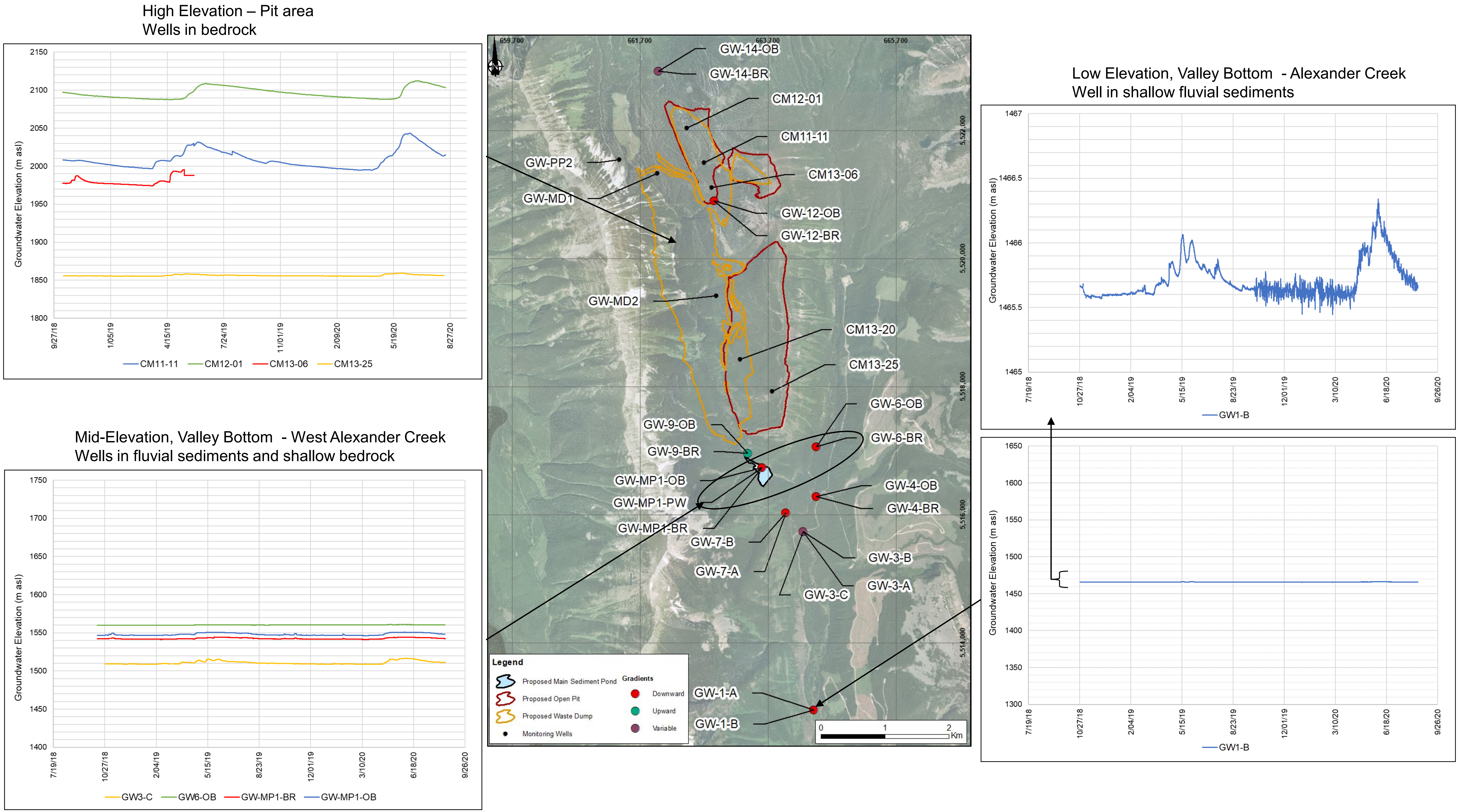


Figure 9.4-6: Continuous Water Level Data

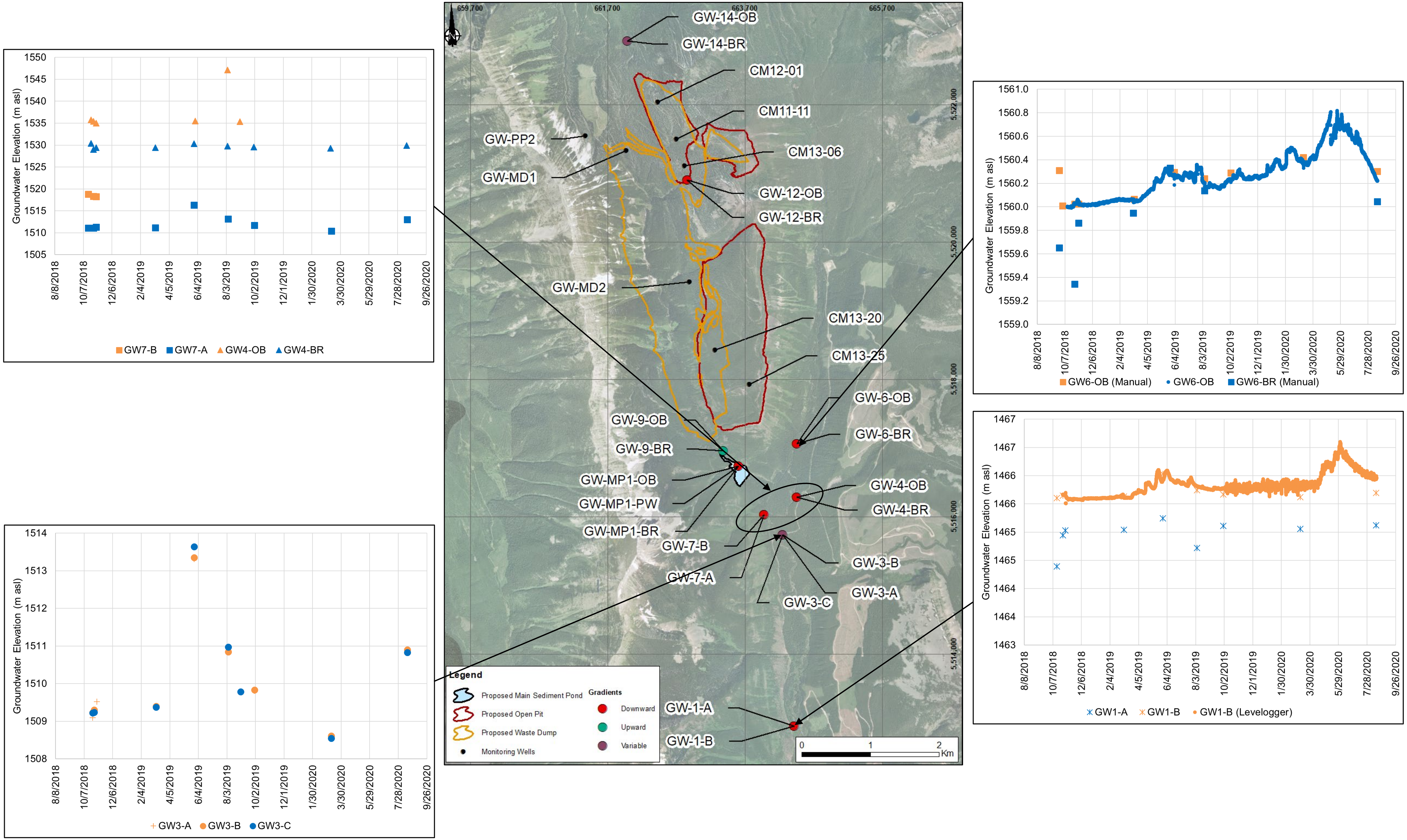


Figure 9.4-7: Water Levels and Gradients (I)

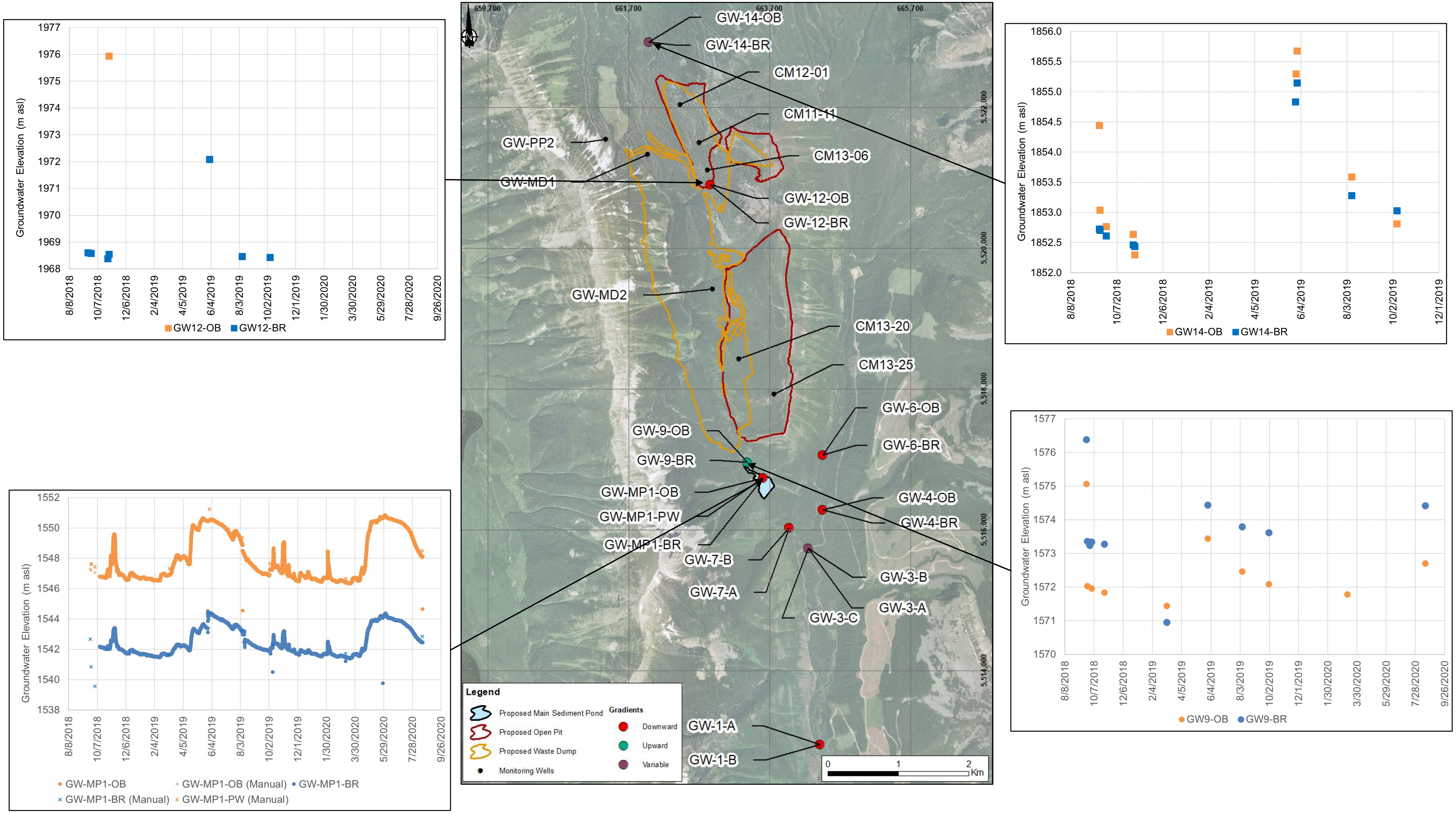


Figure 9.4-8: Water Levels and Gradients (II)

9.4.3.4 Groundwater Quality

Groundwater quality sampling at Crown Mountain has been completed over two broad periods, first between 2013 and 2016, and second between 2018 through 2020.

9.4.3.4.1 Physical Parameters

For samples collected from 2018, field pH values range between 5.5 and 8.9, with no substantive differences between hydrostratigraphic units, while average laboratory conductivity values are higher for samples collected from wells screened in bedrock (429 microsiemens per centimetre [µS/cm]) and lower in those collected from wells screened in overburden (337 µS/cm). A similar relationship to conductivity occurs with total dissolved solids (321 milligrams per litre [mg/L] for bedrock; 214 mg/L for overburden), as shown in Figure 9.4-9.

9.4.3.4.2 Major Ions

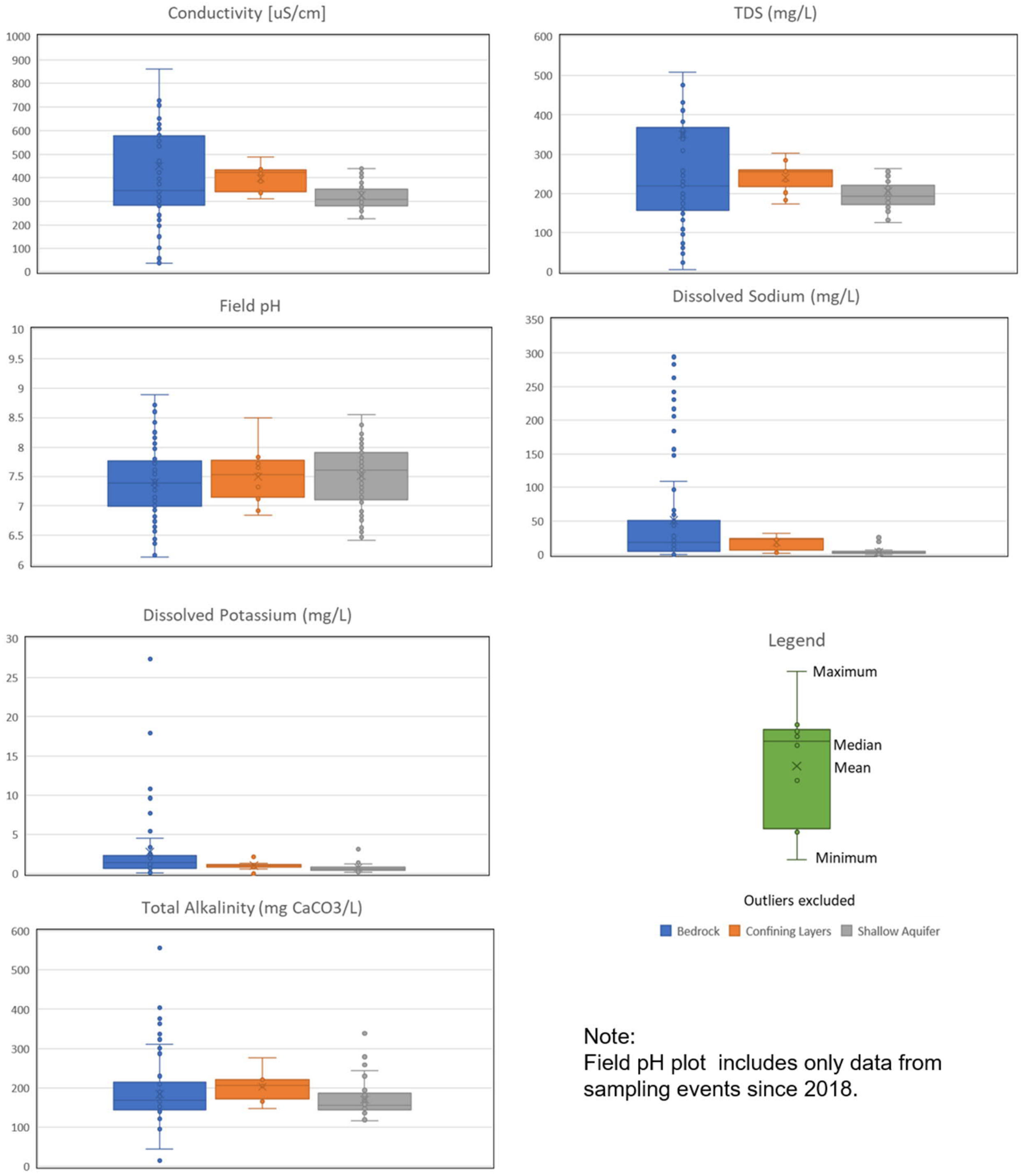
Dissolved sodium concentrations are usually below 50 mg/L, and bedrock screened wells have the higher concentrations, followed by the confining layers and, finally, the shallow aquifer. A similar distribution of dissolved potassium concentrations is observed but with values below 5 mg/L. Total alkalinity concentrations are mainly between 150 and 250 mg of calcium carbonate per litre ($CaCO_3$/L), and no significant difference between the hydrostratigraphic units has been observed, as seen on Figure 9.4-9.

Overburden waters tend to be calcium carbonate ($Ca\text{-}CO_3$) type, while bedrock water shows a wider range of type between $Ca\text{-}CO_3$ and sodium-potassium-chloride (Na-K-Cl), interpreted to indicate relatively shallow, immature water in overburden relative to older water in bedrock that has been in contact with rock for longer, increasing in TDS from 200 to 400 mg/L. Data in the form of a piper plot with samples categorized by hydrostratigraphic unit are presented in Figure 9.4-10.

Calcium and magnesium concentrations are below 85 and 45 mg/L, respectively, for the tested monitoring wells. Baseline sulfate concentrations are generally below 50 mg/L except for GW-04-BR, GW-6-BR and CM12-01. For CM12-01 higher sulfate concentrations have been observed until April 2014, and for this reason those high concentrations are thought to have to do with the development of the well; GW-04-BR and GW-6-BR have concentrations between 40 and 230 mg/L. Chloride concentrations are below 80 mg/L, except for GW-6-BR where concentrations are between 235 and 285 mg/L. This can be explained by poor development after installation because of insufficient water for that purpose. This condition has not improved during subsequent sampling events, and turbidity and foul smell has consistently been reported, because water has not been sufficient to achieve adequate purge volume prior to sampling.

9.4.3.4.3 Other Elements of Interest

A summary of parameters included in the Elk Valley Water Quality Plan (EVWQP) (cadmium, nitrate, sulfate, and selenium) and others that are regionally elevated in the Elk Valley (arsenic, iron, lithium, and nickel) is presented in Figure 9.4-11. A summary of guideline exceedances is presented in Table 9.4-12.



Note:
Field pH plot includes only data from sampling events since 2018.

Figure 9.4-9: Box and Whisker Plots for Select Inorganic Parameters by Hydrostratigraphic Unit

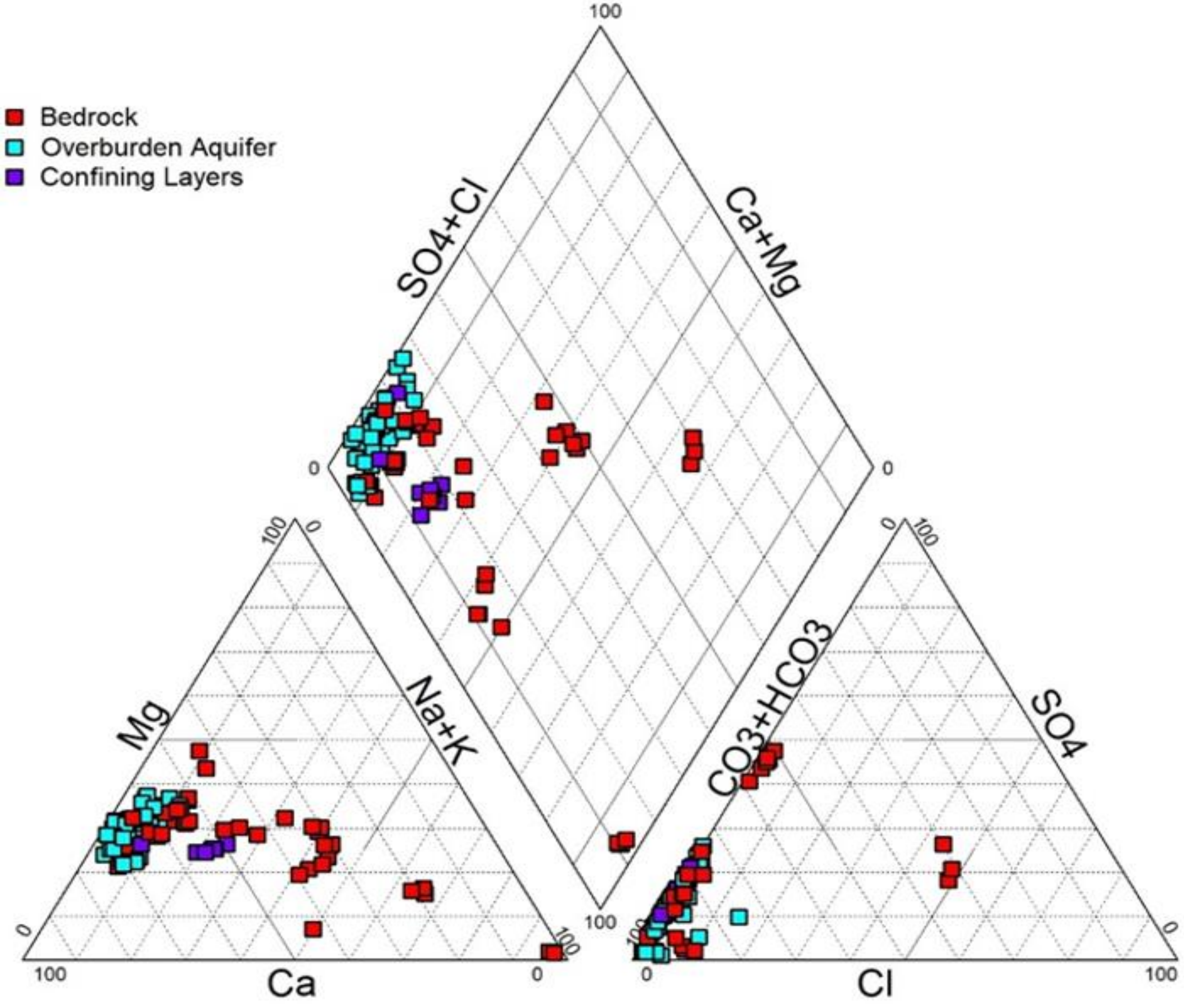


Figure 9.4-10: Piper Plot by Hydrostratigraphic Unit

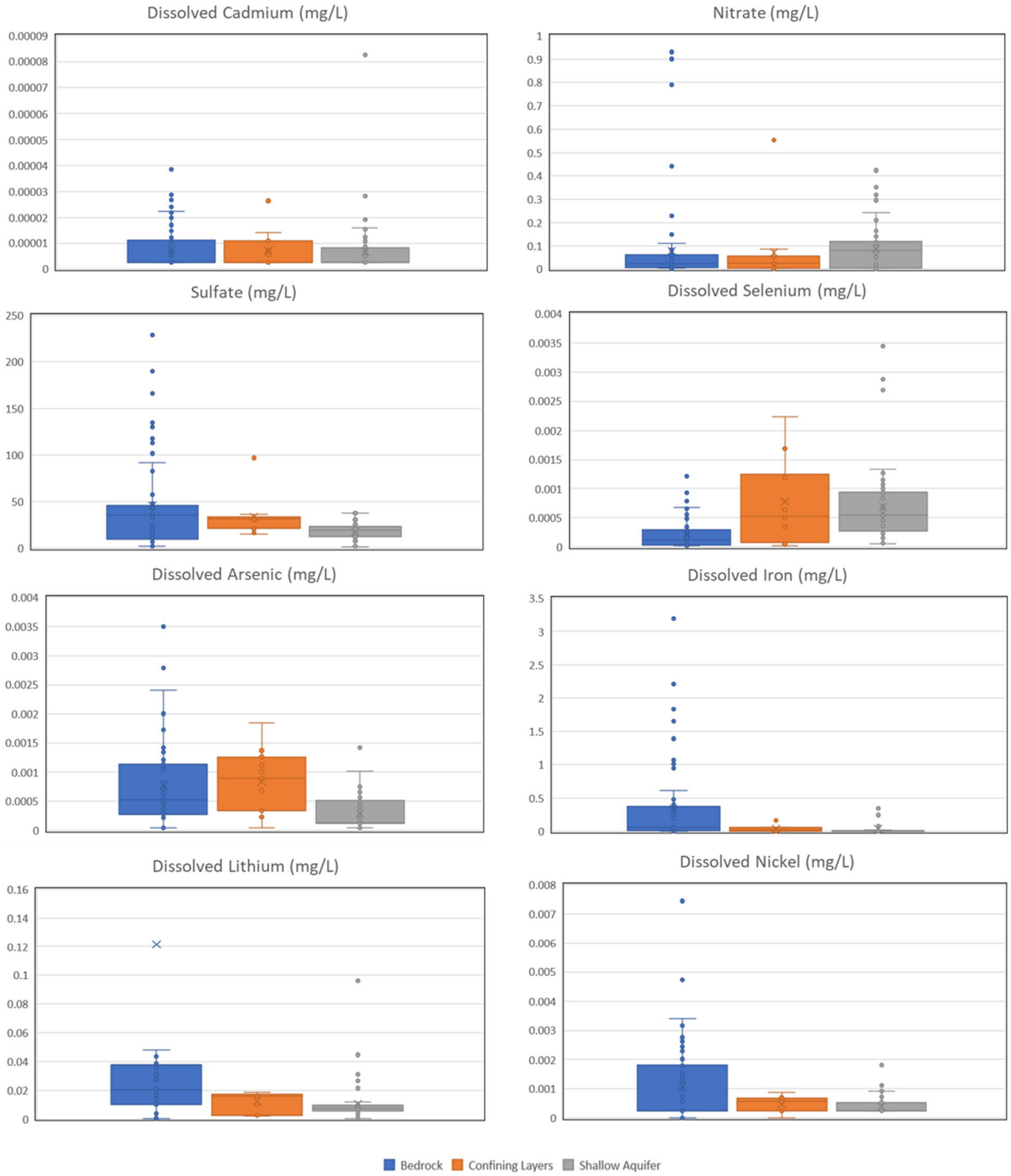


Figure 9.4-11: Box and Whisker Plots for Key Constituents of Concern

Wells have been grouped by hydrostratigraphic unit. Dissolved selenium and nitrate concentrations appear to be relatively higher in wells screened in overburden units relative to bedrock units while also having lower concentrations of arsenic, lithium, nickel, and iron. However, nitrate and selenium concentrations in wells screened in overburden are still low. Locally, groundwater hosted by bedrock seems to contain higher concentrations of lithium than overburden (confining layers plus shallow aquifer), while overburden seem to host groundwater with higher concentrations of selenium.

Temporal variations for the groundwater quality in wells located within the open pit footprint are presented in Figure 9.4-12; all these 5 wells were drilled in 2013 and have a longer dataset available. However, these wells were not sampled between July 2016 and February 2019 and because of that trends are not clearly observed.

The main temporal variations findings for other monitoring wells located outside the project footprint are presented in Figure 9.4-13. A decreasing trend over time has been observed for dissolved potassium and dissolved sodium in GW-MP1-BR; however, this may represent water quality stabilizing to background concentrations as cumulative well purging increases over time.

The expected dominant species for the average field pH and ORP conditions (measurement of REDOX) at various wells, assuming thermodynamic equilibrium is achieved, is presented in Figure 9.4-14. These figures are used to generally estimate the dominant species as oxidized or reduced, and aqueous or solid; actual aqueous species or solid minerals shown on the figures may not reflect the species present at this site, and rather reflect those available to the program and not controlled by the user.

Assuming there are available electron donors and microbial communities to catalyze reactions (or sufficient time for uncatalyzed reactions to occur), it is likely that nitrate present would be reduced to other nitrogen forms (e.g., N_2 gas or ammonium (NH_4^+)/ammonia (NH_3)), and selenium present would be in the form of selenite rather than selenate ($SeO^{2-}{}_4$). Selenite ($CaSO_4$ $2H_2O$) is considered to have a higher sorption capacity and is, therefore, more likely to be attenuated along subsurface flow paths than selenate.

Other indications of redox conditions have been noted at GW-6-OB and GW-6-BR. At both locations, increasing manganese concentrations have been measured from 2018 to recent data. Manganese is expected to have low solubility at neutral pH values unless reducing conditions are present; manganese reduction is expected to occur at lower ORP values than nitrate and selenate reduction, potentially indicating that nitrate and selenate at these locations would likely be attenuated through reductive processes. Furthermore, the presence of algae, high turbidity, and a foul smell noted at GW-6-OB may also support the theory that more strongly reducing conditions are present at this location.

Within the LSA, baseline groundwater quality exceeds B.C. CSR drinking water criteria for several parameters (cobalt, lithium, sodium, chloride, and fluoride). Most of the exceedances to these criteria occur in and around the projected footprint and above the confluence between West Alexander and Alexander Creeks.

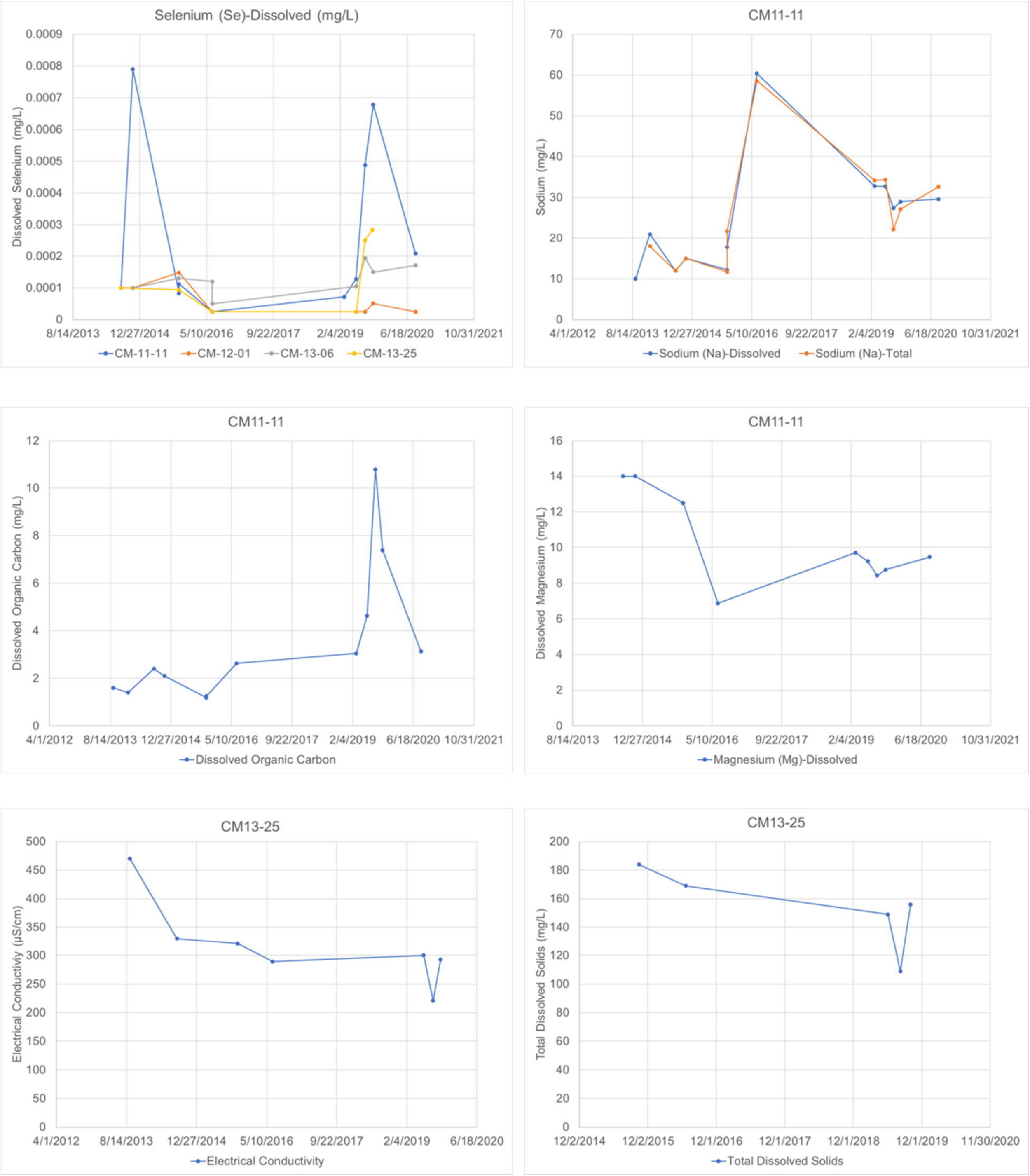


Figure 9.4-12: Temporal Variations for Select Parameters (1/2)

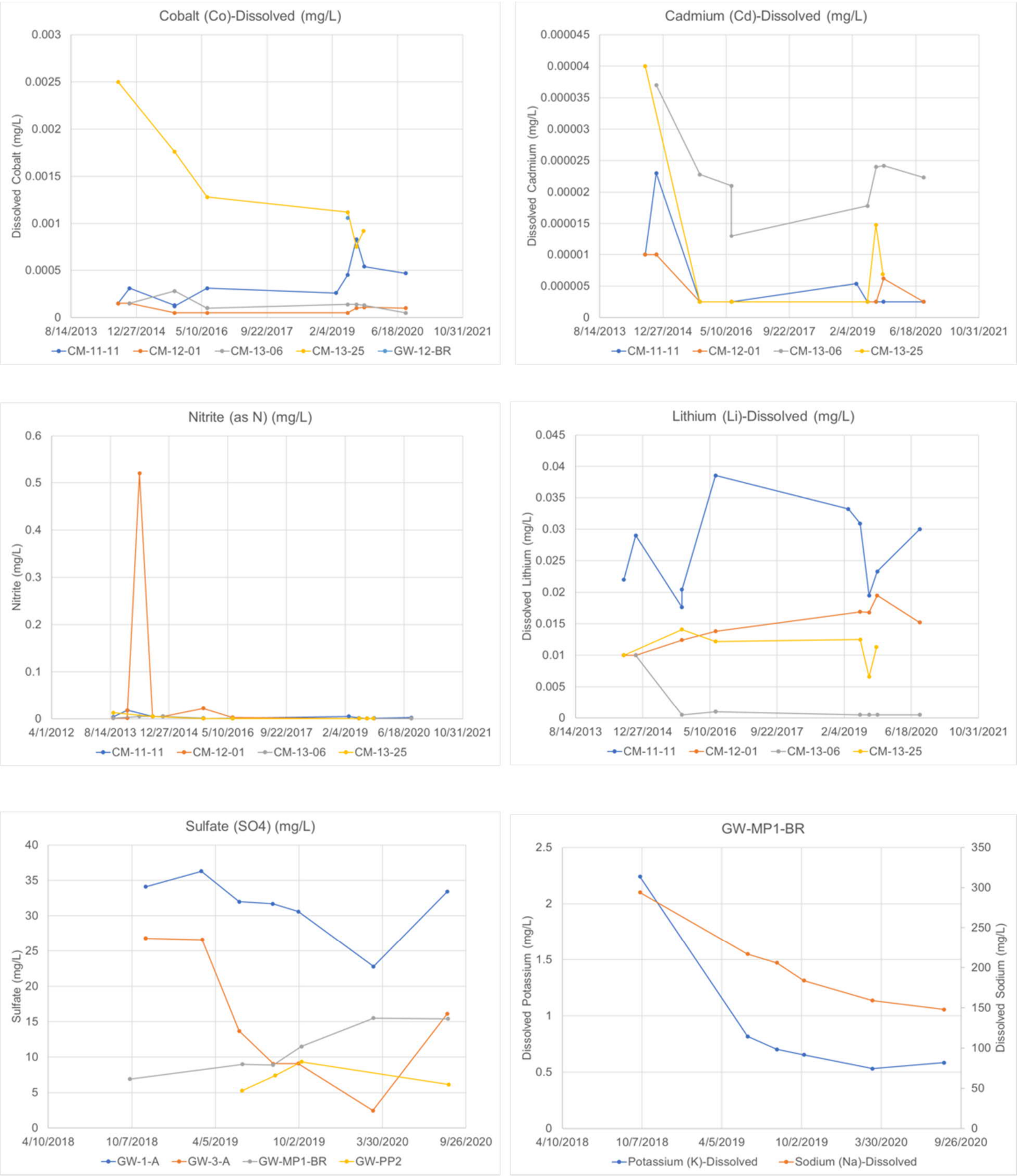
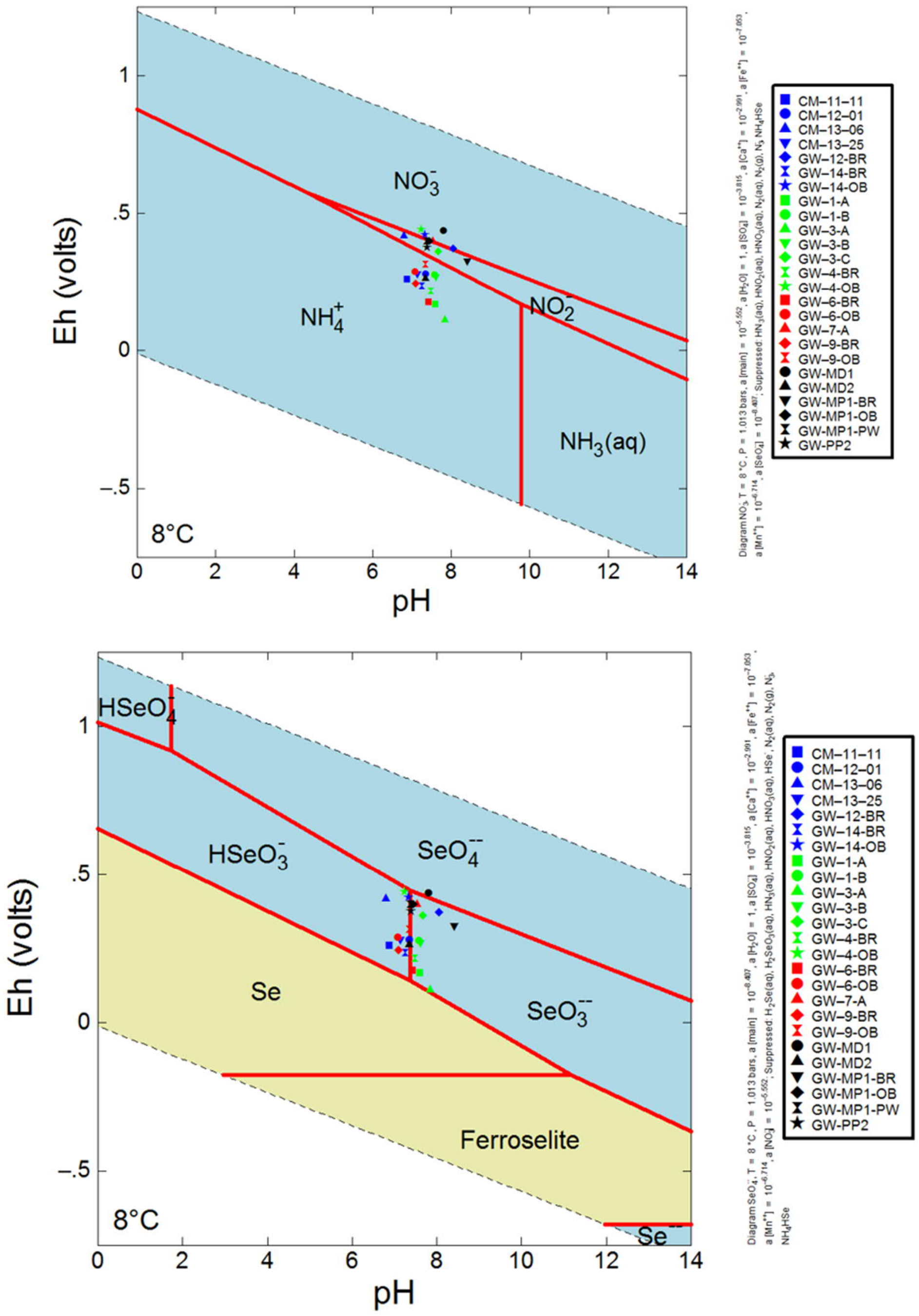


Figure 9.4-13: Temporal Variations for Select Parameters (2/2)



Suppressed
Species

$H_2Se(aq)$
$H_2SeO_3(aq)$
$HN_3(aq)$
$HNO_2(aq)$
$HNO_3(aq)$
HSe^-
$N_2(aq)$
$N_2(g)$
N_3^-
NH_4HSe

Notes: Diagram constructed using water quality results from GW-MP1-PW.
An assumed conversion of +220 mV was used to convert from field ORP to Eh.
Blue shading indicates aqueous species, whereas brown indicate solid minerals.

Figure 9.4-14: Temporal Variations in Redox Conditions

Table 9.4-12: Summary of Groundwater Quality Exceedances of the British Columbia Guidelines and EVWQP WQT

Chemical Name		Arsenic	Cadmium	Cobalt	Iron	Lithium	Nickel	Selenium	Sodium	Chloride	Fluoride	Nitrate As N	Nitrite As N	Sulfate (As So4)	Barium	Cobalt	Selenium	Manganese	Phosphorus
Fraction		Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Nutrient	Nutrient	Nutrient	Nutrient	Nutrient	Total	Total	Total	Dissolved	Dissolved
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
B.C.	Drinking Water	0.01	0.005	0.001	0.300	-	0.0800	0.01	-	250	1.5	45	3	500	-	0.001	0.01	0.12	0.01
	Freshwater Aquatic Life Long Term		-	0.004		-	-	0.001	-	150	-	-	0.02	309	-	0.004	0.001	1.65	0.005
	Freshwater Aquatic Life Short Term		-	0.11	0.350	-	-	-	-	600	-	-	0.06	-	-	0.11	-	1.75	-
	Freshwater Aquatic Life Maximum	0.005	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
B.C. CSR	Drinking Water	0.01	0.005	0.001	6.500	0.0080	0.0800	0.01	200	250	1.5	10	1	500	1	0.001	0.01	1.5	-
EVWQP		-	0.00024	-		-	-	0.019	-	-	-	3	-	429	-		0.019	-	-
CM-11-11 (n=12)	Average	0.00096	0.000006	0.0004	0.840	0.0264	0.0011	0.00030	25.0	1.0	0.13	0.030	0.0038	18.7	0.20	0.0007	0.00011	0.0896	0.030
	Minimum	0.00029	0.000003	0.0001	0.011	0.0176	0.0003	0.00003	10.0	0.5	0.09	0.003	0.0005	10.0	0.19	0.0004	0.00003	0.0554	0.025
	Maximum	0.00172	0.000023	0.0008	1.830	0.0385	0.0025	0.00080	60.4	1.8	0.16	0.160	0.0180	30.3	0.23	0.0009	0.00018	0.1270	0.050
CM-12-01 (n=16)	Average	0.00051	0.000006	0.0001	0.119	0.0135	0.0003	0.00010	48.5	1.7	0.22	0.324	0.0404	62.9	0.25	0.0001	0.00005	0.0481	0.035
	Minimum	0.00010	0.000003	0.0001	0.030	0.0100	0.0003	0.00000	4.1	0.3	0.20	0.003	0.0005	14.0	0.23	0.0001	0.00003	0.0278	0.025
	Maximum	0.00087	0.000010	0.0002	0.263	0.0195	0.0003	0.00010	150.0	6.6	0.24	0.940	0.5200	190.0	0.29	0.0002	0.00012	0.0665	0.050
CM-13-06 (n=10)	Average	0.00026	0.000023	0.0001	0.037	0.0018	0.0026	0.00010	2.3	0.6	0.03	0.042	0.0015	4.6	0.06	0.0009	0.00015	0.0021	0.038
	Minimum	0.00023	0.000013	0.0001	0.005	0.0005	0.0023	0.00010	0.2	0.3	0.01	0.023	0.0005	2.1	0.04	0.0001	0.00013	0.0007	0.025
	Maximum	0.00029	0.000037	0.0003	0.088	0.0100	0.0028	0.00020	20.0	1.7	0.04	0.089	0.0050	14.0	0.08	0.0021	0.00017	0.0036	0.053
CM-13-25 (n=7)	Average	0.00118	0.000012	0.0014	0.909	0.0111	0.0030	0.00010	9.6	0.7	0.14	0.117	0.0029	13.3	0.29	0.0024	0.00029	0.0632	0.029
	Minimum	0.00050	0.000003	0.0008	0.011	0.0066	0.0023	0.00003	1.9	0.3	0.01	0.003	0.0005	6.9	0.10	0.0009	0.00013	0.0046	0.025
	Maximum	0.00200	0.000040	0.0025	1.650	0.0141	0.0038	0.00030	28.0	1.9	0.19	0.441	0.0130	31.0	0.57	0.0050	0.00062	0.1800	0.050
GW-12-BR (n=1)	Average	0.00028	0.000039	0.0011	0.022	0.0020	0.0034	0.00030	2.0	0.3	0.07	0.015	0.0005	4.8	0.06	0.0021	0.00036	0.0567	0.025
	Minimum	0.00028	0.000039	0.0011	0.022	0.0020	0.0034	0.00030	2.0	0.3	0.07	0.015	0.0005	4.8	0.06	0.0021	0.00036	0.0567	0.025
	Maximum	0.00028	0.000039	0.0011	0.022	0.0020	0.0034	0.00030	2.0	0.3	0.07	0.015	0.0005	4.8	0.06	0.0021	0.00036	0.0567	0.025
GW-14-BR (n=10)	Average	0.00070	0.000006	0.0003	0.404	0.0192	0.0006	0.00010	11.0	0.7	0.20	0.012	0.0005	39.2	0.09	0.0017	0.00021	0.1007	0.033
	Minimum	0.00046	0.000003	0.0002	0.005	0.0162	0.0003	0.00003	8.0	0.3	0.17	0.003	0.0005	36.0	0.03	0.0003	0.00003	0.0684	0.025
	Maximum	0.00094	0.000022	0.0009	0.948	0.0226	0.0020	0.00020	14.6	2.0	0.25	0.055	0.0005	44.3	0.14	0.0033	0.00073	0.1630	0.078
GW-14-OB (n=5)	Average	0.00009	0.000008	0.0001	0.005	0.0094	0.0008	0.00100	3.8	0.3	0.15	0.075	0.0006	26.9	0.13	0.0036	0.00109	0.0092	0.025
	Minimum	0.00005	0.000003	0.0001	0.005	0.0017	0.0006	0.00040	2.8	0.3	0.12	0.040	0.0005	11.5	0.07	0.0003	0.00038	0.0002	0.025
	Maximum	0.00027	0.000015	0.0003	0.005	0.0129	0.0011	0.00160	6.3	0.3	0.16	0.137	0.0011	32.1	0.26	0.0097	0.00183	0.0176	0.025
GW-1-A (n=7)	Average	0.00117	0.000004	0.0002	0.054	0.0169	0.0004	0.00070	25.1	0.5	0.64	0.010	0.0006	31.6	0.06	0.0005	0.00012	0.1223	0.025
	Minimum	0.00069	0.000003	0.0001	0.005	0.0158	0.0003	0.00003	22.3	0.3	0.58	0.003	0.0005	22.8	0.05	0.0003	0.00003	0.1020	0.025
	Maximum	0.00184	0.000007	0.0003	0.163	0.0184	0.0009	0.00220	32.2	1.4	0.73	0.029	0.0014	36.3	0.07	0.0010	0.00037	0.1340	0.025
GW-1-B (n=8)	Average	0.00069	0.000007	0.0001	0.026	0.0056	0.0006	0.00030	2.6	0.3	0.16	0.012	0.0006	20.0	0.28	0.0077	0.00146	0.0431	0.025
	Minimum	0.00042	0.000003	0.0001	0.005	0.0052	0.0003	0.00010	2.2	0.3	0.12	0.003	0.0005	18.7	0.05	0.0001	0.00013	0.0225	0.025
	Maximum	0.00102	0.000028	0.0002	0.084	0.0066	0.0008	0.00050	3.3	0.3	0.19	0.050	0.0010	20.9	1.24	0.0423	0.00672	0.0644	0.025
GW-3-A (n=8)	Average	0.00061	0.000003	0.0001	0.022	0.0090	0.0003	0.00130	4.9	0.8	0.30	0.023	0.0014	14.8	0.08	0.0002	0.00013	0.0974	0.025
	Minimum	0.00049	0.000003	0.0001	0.005	0.0081	0.0003	0.00010	3.6	0.3	0.18	0.003	0.0005	2.5	0.06	0.0001	0.00003	0.0452	0.025
	Maximum	0.00078	0.000006	0.0002	0.064	0.0099	0.0005	0.00340	6.2	1.4	0.39	0.145	0.0069	26.8	0.11	0.0006	0.00023	0.1370	0.025

Chemical Name		Arsenic	Cadmium	Cobalt	Iron	Lithium	Nickel	Selenium	Sodium	Chloride	Fluoride	Nitrate As N	Nitrite As N	Sulfate (As So4)	Barium	Cobalt	Selenium	Manganese	Phosphorus
Fraction		Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Nutrient	Nutrient	Nutrient	Nutrient	Nutrient	Total	Total	Total	Dissolved	Dissolved
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
B.C.	Drinking Water	0.01	0.005	0.001	0.300	-	0.0800	0.01	-	250	1.5	45	3	500	-	0.001	0.01	0.12	0.01
	Freshwater Aquatic Life Long Term		-	0.004		-	-	0.001	-	150	-	-	0.02	309	-	0.004	0.001	1.65	0.005
	Freshwater Aquatic Life Short Term		-	0.11	0.350	-	-	-	-	600	-	-	0.06	-	-	0.11	-	1.75	-
	Freshwater Aquatic Life Maximum	0.005	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
B.C. CSR	Drinking Water	0.01	0.005	0.001	6.500	0.0080	0.0800	0.01	200	250	1.5	10	1	500	1	0.001	0.01	1.5	-
EVWQP		-	0.00024	-		-	-	0.019	-	-	-	3	-	429	-		0.019	-	-
GW-3-B (n=7)	Average	0.00008	0.000015	0.0001	0.019	0.0055	0.0003	0.00090	1.9	0.3	0.21	0.062	0.0021	24.0	0.07	0.0002	0.00058	0.2193	0.025
	Minimum	0.00005	0.000003	0.0001	0.005	0.0049	0.0003	0.00010	1.3	0.3	0.19	0.003	0.0005	21.3	0.06	0.0001	0.00013	0.0003	0.025
	Maximum	0.00014	0.000083	0.0002	0.052	0.0060	0.0003	0.00270	2.6	0.3	0.25	0.319	0.0086	26.2	0.08	0.0003	0.00231	0.3400	0.025
GW-3-C (n=7)	Average	0.00014	0.000005	0.0001	0.005	0.0012	0.0003	0.00080	1.1	0.3	0.19	0.132	0.0051	20.6	0.04	0.0001	0.00063	0.0010	0.025
	Minimum	0.00012	0.000003	0.0001	0.005	0.0005	0.0003	0.00040	0.5	0.3	0.17	0.071	0.0005	7.7	0.04	0.0001	0.00013	0.0001	0.025
	Maximum	0.00015	0.000007	0.0001	0.005	0.0015	0.0003	0.00130	3.8	0.3	0.21	0.210	0.0307	37.8	0.05	0.0003	0.00102	0.0039	0.025
GW-4-BR (n=8)	Average	0.00101	0.000004	0.0003	0.037	0.0310	0.0007	0.00040	51.4	3.4	0.83	0.020	0.0009	116.1	0.04	0.0008	0.00022	0.2880	0.025
	Minimum	0.00046	0.000003	0.0001	0.005	0.0275	0.0003	0.00010	39.1	1.6	0.63	0.003	0.0005	92.4	0.03	0.0003	0.00003	0.1110	0.025
	Maximum	0.00140	0.000010	0.0005	0.080	0.0354	0.0018	0.00080	66.2	4.7	0.94	0.090	0.0023	131.0	0.05	0.0017	0.00050	0.5030	0.025
GW-4-OB (n=4)	Average	0.00025	0.000013	0.0002	0.019	0.0043	0.0007	0.00090	6.8	0.4	0.15	0.182	0.0094	20.9	0.07	0.0003	0.00071	0.0261	0.025
	Minimum	0.00005	0.000003	0.0001	0.005	0.0021	0.0006	0.00040	1.8	0.3	0.15	0.032	0.0005	15.3	0.05	0.0002	0.00028	0.0011	0.025
	Maximum	0.00039	0.000026	0.0003	0.062	0.0103	0.0007	0.00170	14.8	1.0	0.16	0.554	0.0352	31.1	0.08	0.0006	0.00148	0.0598	0.025
GW-6-BR (n=5)	Average	0.00226	0.000009	0.0072	1.260	0.6922	0.0041	0.00050	235.2	267.6	0.33	0.078	0.0042	135.2	0.25	0.0163	0.00040	1.0384	0.045
	Minimum	0.00053	0.000003	0.0053	0.011	0.4740	0.0023	0.00010	157.0	235.0	0.25	0.033	0.0025	44.2	0.13	0.0054	0.00013	0.4920	0.025
	Maximum	0.00350	0.000029	0.0101	3.190	0.9780	0.0074	0.00130	283.0	285.0	0.39	0.232	0.0065	229.0	0.42	0.0403	0.00119	1.3800	0.085
GW-6-OB (n=7)	Average	0.00066	0.000004	0.0004	0.278	0.0382	0.0009	0.00010	11.2	6.8	0.16	0.023	0.0078	3.9	0.32	0.0011	0.00023	0.8825	0.097
	Minimum	0.00034	0.000003	0.0002	0.105	0.0215	0.0005	0.00010	6.6	1.9	0.08	0.003	0.0005	1.4	0.26	0.0007	0.00010	0.4680	0.025
	Maximum	0.00142	0.000011	0.0010	0.395	0.0962	0.0018	0.00030	25.6	22.9	0.31	0.086	0.0344	8.2	0.37	0.0021	0.00047	1.2300	0.424
GW-7-A (n=8)	Average	0.00015	0.000006	0.0001	0.006	0.0076	0.0003	0.00070	3.2	2.4	0.12	0.097	0.0011	15.9	0.09	0.0004	0.00057	0.0051	0.025
	Minimum	0.00012	0.000003	0.0001	0.005	0.0063	0.0003	0.00050	3.0	0.3	0.08	0.003	0.0005	14.5	0.08	0.0001	0.00048	0.0001	0.025
	Maximum	0.00022	0.000014	0.0001	0.014	0.0083	0.0003	0.00090	3.6	17.5	0.17	0.176	0.0045	18.9	0.11	0.0015	0.00066	0.0199	0.025
GW-9-BR (n=6)	Average	0.00005	0.000003	0.0001	0.314	0.0434	0.0003	0.00060	18.4	0.3	0.23	0.018	0.0005	36.9	0.08	0.0007	0.00009	0.0493	0.025
	Minimum	0.00005	0.000003	0.0001	0.277	0.0372	0.0003	0.00003	17.4	0.3	0.19	0.003	0.0005	32.9	0.04	0.0001	0.00003	0.0467	0.025
	Maximum	0.00005	0.000003	0.0002	0.351	0.0478	0.0003	0.00140	19.5	0.3	0.25	0.066	0.0005	39.6	0.19	0.0027	0.00027	0.0543	0.025
GW-9-OB (n=9)	Average	0.00006	0.000004	0.0001	0.005	0.0145	0.0003	0.00090	5.7	0.3	0.14	0.084	0.0009	26.7	0.09	0.0002	0.00116	0.0072	0.025
	Minimum	0.00005	0.000003	0.0001	0.005	0.0089	0.0003	0.00010	3.4	0.3	0.12	0.003	0.0005	21.1	0.04	0.0001	0.00003	0.0001	0.025
	Maximum	0.00016	0.000007	0.0002	0.005	0.0446	0.0009	0.00130	19.5	0.3	0.15	0.142	0.0024	37.5	0.29	0.0005	0.00405	0.0408	0.025
GW-MD1 (n=1)	Average	0.00022	0.000011	0.0001	0.005	0.0005	0.0014	0.00120	1.7	0.3	0.09	0.077	0.0005	7.8	0.23	0.0015	0.00141	0.0037	0.025
	Minimum	0.00022	0.000011	0.0001	0.005	0.0005	0.0014	0.00120	1.7	0.3	0.09	0.077	0.0005	7.8	0.23	0.0015	0.00141	0.0037	0.025
	Maximum	0.00022	0.000011	0.0001	0.005	0.0005	0.0014	0.00120	1.7	0.3	0.09	0.077	0.0005	7.8	0.23	0.0015	0.00141	0.0037	0.025

Chemical Name		Arsenic	Cadmium	Cobalt	Iron	Lithium	Nickel	Selenium	Sodium	Chloride	Fluoride	Nitrate As N	Nitrite As N	Sulfate (As So4)	Barium	Cobalt	Selenium	Manganese	Phosphorus
Fraction		Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Dissolved	Nutrient	Nutrient	Nutrient	Nutrient	Nutrient	Total	Total	Total	Dissolved	Dissolved
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
B.C.	Drinking Water	0.01	0.005	0.001	0.300	-	0.0800	0.01	-	250	1.5	45	3	500	-	0.001	0.01	0.12	0.01
	Freshwater Aquatic Life Long Term		-	0.004		-	-	0.001	-	150	-	-	0.02	309	-	0.004	0.001	1.65	0.005
	Freshwater Aquatic Life Short Term		-	0.11	0.350	-	-	-	-	600	-	-	0.06	-	-	0.11	-	1.75	-
	Freshwater Aquatic Life Maximum	0.005	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-
B.C. CSR	Drinking Water	0.01	0.005	0.001	6.500	0.0080	0.0800	0.01	200	250	1.5	10	1	500	1	0.001	0.01	1.5	-
EVWQP		-	0.00024	-		-	-	0.019	-	-	-	3	-	429	-		0.019	-	-
GW-MD2 (n=5)	Average	0.00019	0.000003	0.0001	0.126	0.0146	0.0003	0.00010	4.4	0.3	0.17	0.088	0.0007	27.1	0.10	0.0006	0.00006	0.0747	0.025
	Minimum	0.00016	0.000003	0.0001	0.020	0.0138	0.0003	0.00003	4.1	0.3	0.15	0.003	0.0005	26.0	0.04	0.0001	0.00003	0.0638	0.025
	Maximum	0.00024	0.000003	0.0001	0.237	0.0160	0.0003	0.00040	4.6	0.6	0.21	0.415	0.0014	28.5	0.27	0.0020	0.00013	0.0788	0.025
GW-MP1-BR (n=6)	Average	0.00067	0.000003	0.0001	0.015	0.5700	0.0004	0.00010	201.3	28.8	2.11	0.019	0.0012	11.2	0.11	0.0012	0.00029	0.0143	0.038
	Minimum	0.00040	0.000003	0.0001	0.005	0.4190	0.0003	0.00003	148.0	12.5	1.82	0.003	0.0005	6.9	0.08	0.0003	0.00003	0.0102	0.025
	Maximum	0.00147	0.000005	0.0002	0.032	0.7800	0.0010	0.00040	294.0	72.2	2.33	0.070	0.0025	15.5	0.20	0.0056	0.00128	0.0186	0.066
GW-MP1-OB (n=8)	Average	0.00013	0.000008	0.0001	0.005	0.0068	0.0003	0.00060	4.6	0.3	0.13	0.167	0.0027	15.5	0.25	0.0033	0.00058	0.0091	0.025
	Minimum	0.00005	0.000003	0.0001	0.005	0.0042	0.0003	0.00040	2.6	0.3	0.08	0.032	0.0005	7.7	0.14	0.0003	0.00038	0.0001	0.025
	Maximum	0.00017	0.000012	0.0003	0.005	0.0085	0.0009	0.00100	6.4	0.3	0.17	0.424	0.0155	22.0	0.53	0.0098	0.00078	0.0623	0.025
GW-MP1-PW (n=7)	Average	0.00016	0.000007	0.0001	0.005	0.0067	0.0003	0.00060	3.4	1.3	0.14	0.176	0.0006	14.9	0.09	0.0002	0.00051	0.0108	0.025
	Minimum	0.00011	0.000003	0.0001	0.005	0.0039	0.0003	0.00030	1.7	0.3	0.09	0.100	0.0005	5.9	0.08	0.0001	0.00029	0.0001	0.025
	Maximum	0.00027	0.000016	0.0003	0.005	0.0086	0.0008	0.00090	5.8	7.8	0.17	0.351	0.0012	20.4	0.14	0.0010	0.00067	0.0743	0.025
GW-PP2 (n=4)	Average	0.00005	0.000017	0.0001	0.005	0.0047	0.0003	0.00010	2.8	0.3	0.05	0.028	0.0005	7.0	0.09	0.0003	0.00014	0.0020	0.025
	Minimum	0.00005	0.000012	0.0001	0.005	0.0040	0.0003	0.00010	2.3	0.3	0.04	0.009	0.0005	5.3	0.08	0.0001	0.00012	0.0003	0.025
	Maximum	0.00005	0.000027	0.0001	0.005	0.0058	0.0003	0.00010	3.3	0.3	0.06	0.045	0.0005	9.4	0.11	0.0008	0.00016	0.0046	0.025

Notes:

Bold numbers indicate exceeding B.C. CSR Standard for Drinking Water

Underlined numbers indicate exceeding B.C. Drinking Water Quality Guideline for Drinking Water

Italic numbers indicate exceeding EVWQP Guideline

n indicates the number of samples

Monitoring wells that exceed selenium are also located below the confluence between West Alexander and Alexander creeks and are clearly explained by a regional groundwater signature. Several monitoring wells (CM-11-11, CM-12-01, CM-13-25, GW-14-BR, GW-14-OB, GW-1-A, GW-3-A, GW-4-BR, GW-4-OB, GW-6-BR and GW-6-OBGW-7-A) exceed the B.C. CSR for drinking water criteria for lithium. However, this parameter exhibits high concentrations regionally. From the literature (Vos et al., 2006; Finkelman et al., 2018), the primary mineralogical occurrence of this element in coal settings is related to clays and detrital micas as illite and kaolinite and feldspar, amphibole and biotite, all minerals widely distributed along the Elk Valley.

Samples collected from GW-6-BR exceed both B.C. CSR Drinking Water and B.C. Drinking Water criteria for chloride. This monitoring well is located upstream of the confluence between West Alexander and Alexander creeks, and the reason for this exceedance can be related to its poor development and the low water volume available to purge before each sampling.

9.4.3.5 Groundwater Quantity

9.4.3.5.1 Hydrostratigraphic Units

A baseline conceptual groundwater model was developed from the data presented in the previous sections of this chapter. The following sections summarize the conceptual groundwater model. Three main hydrostratigraphic units are defined and summarized in Table 9.4-13. Further description of the hydrostratigraphic units and cross-sections illustrating their distribution are provided in Appendix 9-A.

Table 9.4-13: Calibrated and Measured Hydraulic Conductivity by Hydrostratigraphic Unit

Primary Hydrostratigraphic Unit	Secondary Hydrostratigraphic Unit	Description	Saturated Thickness (m)	Horizontal Hydraulic Conductivity (m/d)
Overburden Aquifer	Colluvium	Sands, gravels and cemented till lenses	10 – 20	Calibrated: 9x10^{-3}
				Measured: 7 to 9
	Fluvial	Gravels interbedded with sands and silty sands	0 – 30	Calibrated: 4
				Measured: 2 to 5x10^{1}
	Glaciofluvial	Sand and gravel	0 – 34	Calibrated: 4x10^{1}
				Measured: 1 to 1x10^{4}
Overburden Aquitards	Till	Pebbles, cobbles and boulders in a matrix of sand, silt and clay	<27	Calibrated: 9x10^{-3}
				Measured: 2x10^{-1} to 6x10^{-1}
	Lacustrine	Fine sand, silt and clay	-	Calibrated: 3x10^{-2}
				Measured: 4x10^{-2}
	Glaciolacustrine	Silts and plastic clays but also include some fine sands	<18	Calibrated: 3x10^{-2}
				Measured: 2x10^{-2} to 8x10^{-2}
Bedrock			<10	Calibrated: 9x10^{-3}

Primary Hydrostratigraphic Unit	Secondary Hydrostratigraphic Unit	Description	Saturated Thickness (m)	Horizontal Hydraulic Conductivity (m/d)
	Fractured or Weathered Bedrock	Fractured or weathered sandstone, mudstone and shale		Measured: 2×10^{-1} to 8
	Coal seams	Coal seams	-	Calibrated: 9×10^{-3} Measured: 2×10^{-3} to 4×10^{-1}
	Competent Bedrock	Sandstone, mudstone and shale	-	Calibrated: 9×10^{-3} Measured: 2×10^{-3} to 2

9.4.3.5.2 Conceptual Groundwater Model

Groundwater recharge occurs at relatively high elevations from direct precipitation and at lower elevations by infiltration of runoff or stream loss through shallow, higher conductivity sediments along streams. Within the Alexander Creek valley downgradient of the Project, water that has infiltrated to the deeper bedrock or overburden systems is confined at depth, but vertical upwards gradients exist and may discharge to shallower permeable materials or surface waters; discharge of deeper groundwater does not appear to be significant close to the Project due to the presence of the glaciolacustrine confining unit, but could occur further downgradient in the Alexander Creek valley. A depiction of the hydrogeological conceptual model for baseline conditions is provided in Figure 9.4-15.

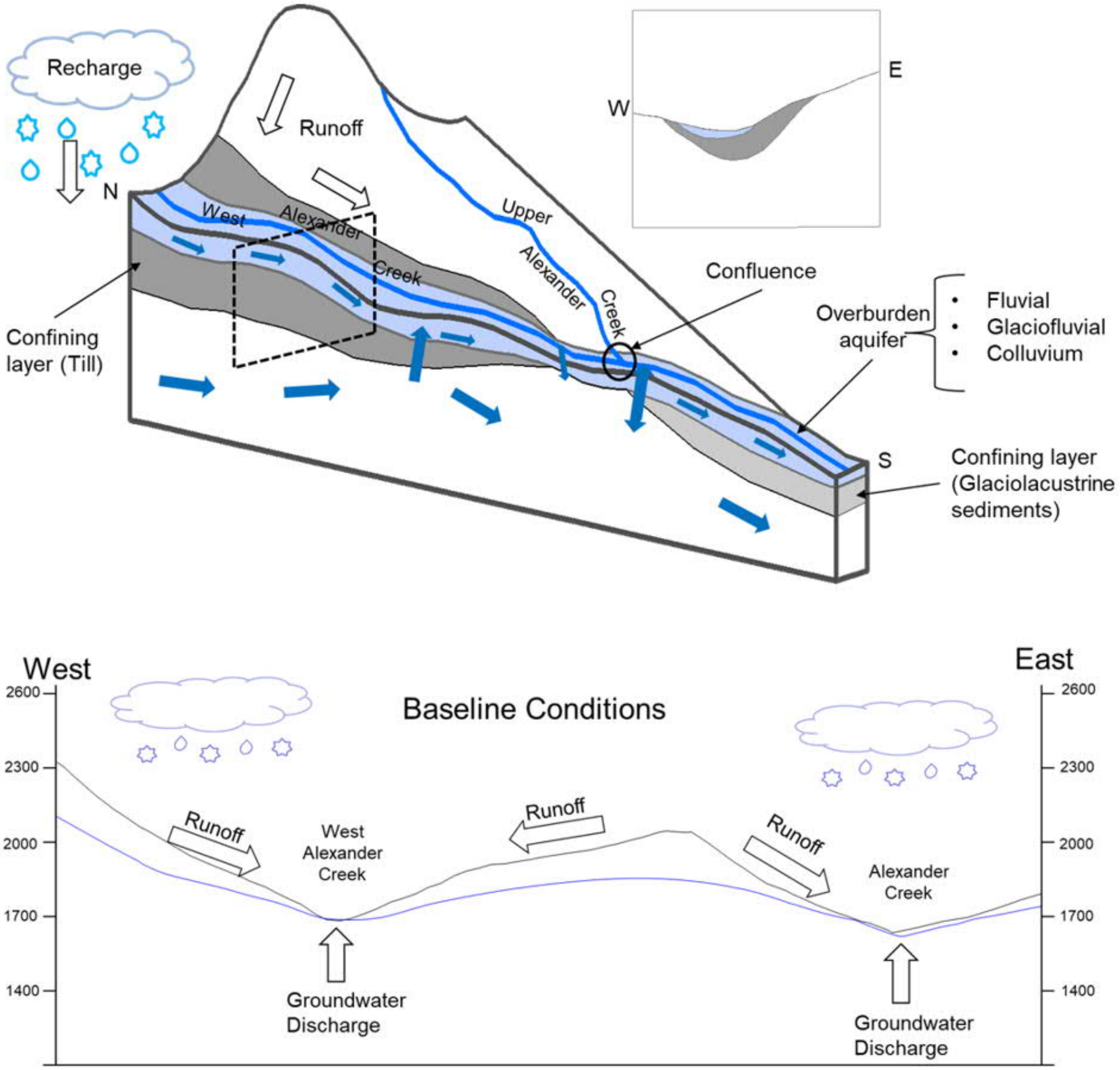
Baseline horizontal groundwater fluxes within the top 50 m in the local study area are about 200 cubic metre per day (m^3/d), 800 m^3/d, and 1,000 m^3/d along West Alexander Creek, Upper Alexander Creek and Alexander Creek, respectively.

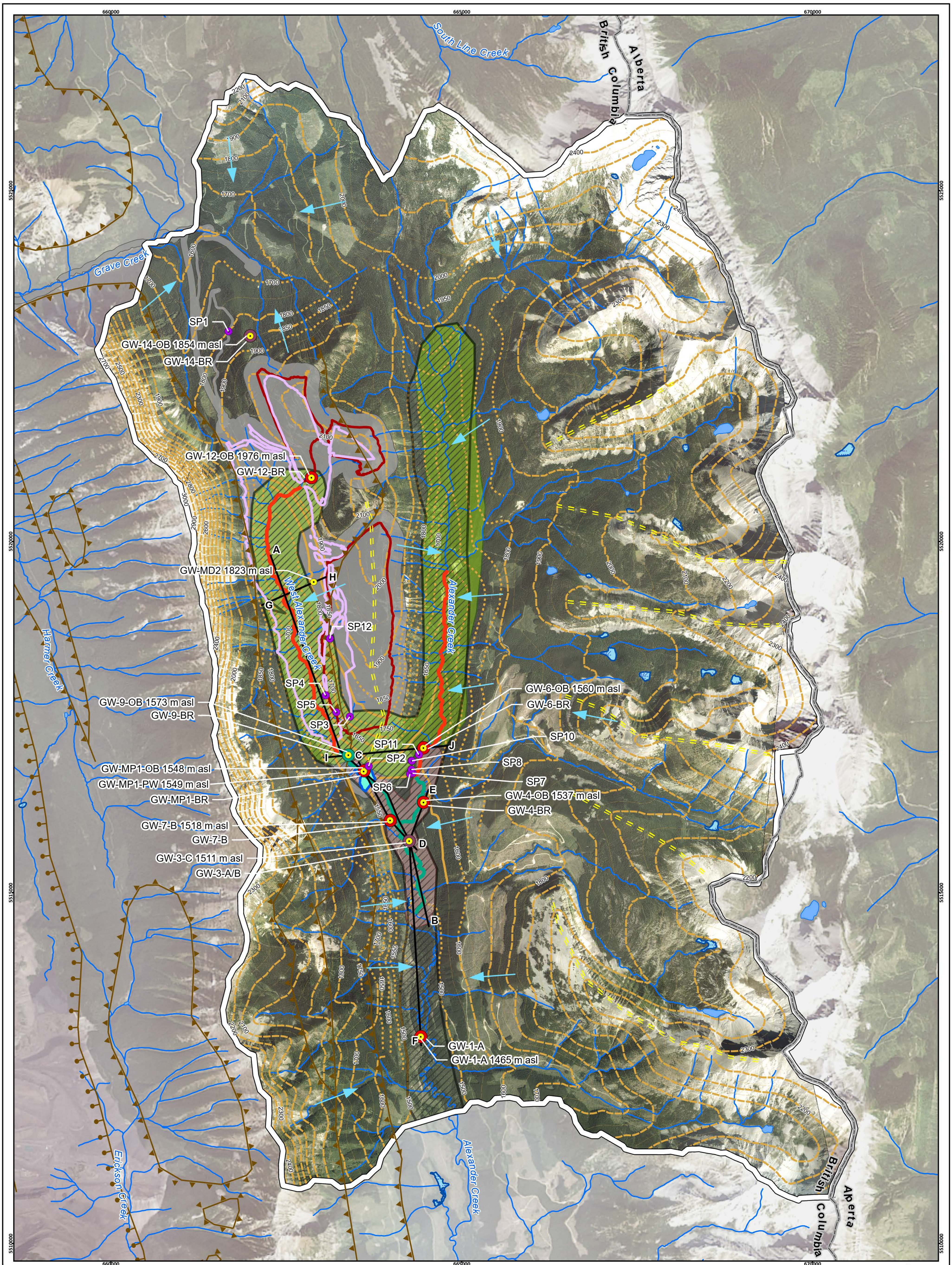
9.4.3.5.3 Groundwater Flow

In general, groundwater flows from recharge zones at higher elevations towards discharge zones in lower elevation valley bottoms. Hydrogeology key plans for the shallow aquifer and bedrock aquifer are shown in Figure 9.4-16 and Figure 9.4-17, respectively. Cross-sections labelled on the hydrogeology key plans are provided in Figure 9.4-18 to Figure 9.4-21.

Within the local valley bottoms, recharge and discharge zones can be different. For example, in Cross-Section A-B (Figure 9.4-18), groundwater discharges at higher elevations of the upper West Alexander Creek valley (upwards hydraulic gradient), while at lower elevations below the confluence with Alexander Creek changes to a recharge zone (downwards hydraulic gradient to variable hydraulic gradient). A groundwater divide is interpreted along the ridge between West Alexander and Alexander creeks based on water level observations, with groundwater flowing towards each creek similar to the topographic gradient. Below the confluence, groundwater flows towards the valley bottom.

Figure 9.4-15: Hydrogeological Conceptual Model





Crown Mountain Coking Coal Project

Figure 9.4-16

Hydrogeology Key Plan - Shallow Aquifer

Notes:
1. SP4 and SP10 identified as potential springs.
2. Flowing artesian conditions were encountered at the location of GW4-BR during drilling and near the location of the wells GW1-A and GW1-B. No well was installed at this last location and the drill hole was completely grouted.
3. m asl - meters above sea level.
4. Faults from British Columbia digital geology British Columbia Geological Survey Open File 2017-18, 9p. Data version 2019-12-19.

LEGEND

- ● Seepage Points
- ⊙ Monitoring Wells

Gradient

- ● Downward
- ● Upward
- ● Variable

Creek Nature

- Gaining Reach
- Losing Reach

Water Table Contours

- Measured
- Inferred
- Modelled
- Shallow Aquifer Flow Direction

- Groundwater Divide
- Cross Sections

Faults

- Undifferentiated Fault
- Normal Fault
- Thrust Fault
- Proposed Main Sediment Pond
- Proposed Open Pit
- Proposed Waste Dump
- Groundwater Local Study Area

RechargeZones

- Groundwater Discharge Zone
- Groundwater Recharge Zone
- Project Footprint

- Outline of Shallow Aquifer where Significant
- Watercourse
- Project Footprint
- Waterbody
- Wetland
- Watershed
- British Columbia/Alberta Border

0 1 2
Kilometres

Scale 1:

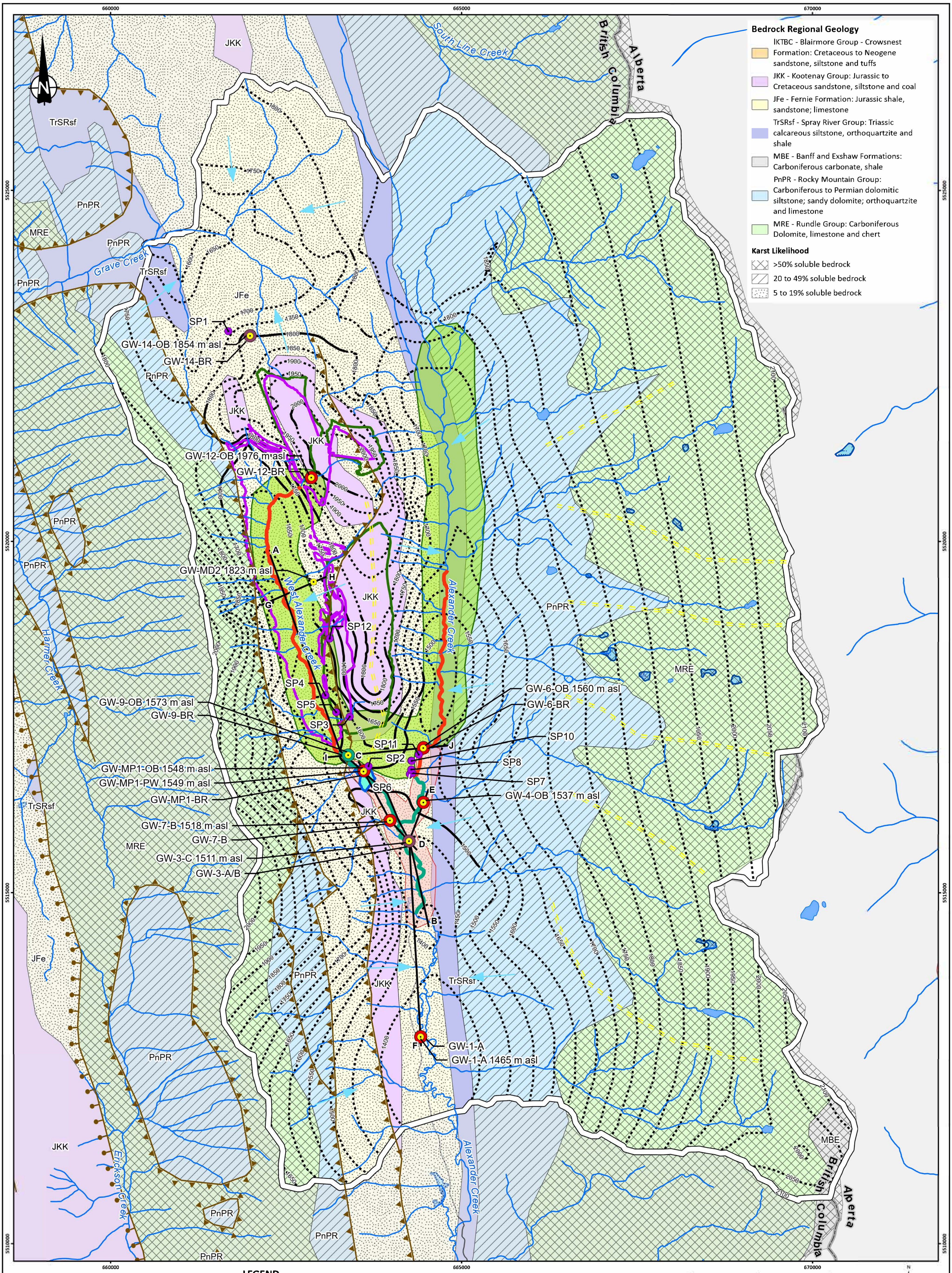
Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada.
Water level contours were interpreted from groundwater level readings (Sept 2018 - Aug 2020).
Creek Nature is an interpretation from flow survey conducted by Swiftwater Consulting in 2018.
Rechargeand discharge zones correspond to a study areascale interpretationand may have variations locally
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

Map Created By: MZS
Map Checked By: CH
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 1/9/2023

Document Path: C:\Users\MSMITH\SRK Consulting\FS1288 Crown Mountain - Internal\!040_AutoCAD\ArcGIS\20221219_CrownMtn_update\CrownMtn_CAPR000323_Aquifer.aprx



0 1 2
Kilometres

Scale 1:50,000

Crown Mountain Coking Coal Project

Figure 9.4-17
Hydrogeology Key Plan - Bedrock Aquifer

Notes:
1. SP4 and SP10 identified as potential springs.
2. Flowing artesian conditions were encountered at the location of GW-4-BR during drilling and near the location of the wells GW-1-A and GW-1-B. No well was installed at this last location and the drill hole was completely grouted.
3. m asl - meters above sea level.
4. Faults from British Columbia digital geology. British Columbia Geological Survey Open File 2017-18, 9p. Data version 2019-12-19.
5. Regional Bedrock Geology and Faults source: Cui, Y., Miller, D., Schiarizza, P. and Diakow, L.J., 2018. British Columbia digital geology. British Columbia Ministry of Energy, Mines and Petroleum Resources, British Columbia Geological Survey Open File 2017-18, 9p. Data version 2019-12-19. 4.
6. Karst Likelihood source: Forest Analysis and Inventory, 2019.

LEGEND

- ● Seepage Points
- ⊙ Monitoring Wells

Gradient
- ● Downward
- ● Upward
- ● Variable

Creek Nature
- Gaining Reach
- Losing Reach

Bedrock Potentiometric Surface Contours
- Measured
- Inferred
- ↙ Bedrock Aquifer Flow Direction

- Groundwater Divide
- Cross Sections

Faults
- Undifferentiated Fault
- Normal Fault
- Thrust Fault

- Proposed Main Sediment Pond
- Proposed Open Pit
- Proposed Waste Dump
- Groundwater Discharge Zone
- Groundwater Recharge Zone
- Groundwater Local Study Area

- Watercourse
- Waterbody
- Wetland
- Watershed
- British Columbia/Alberta Border

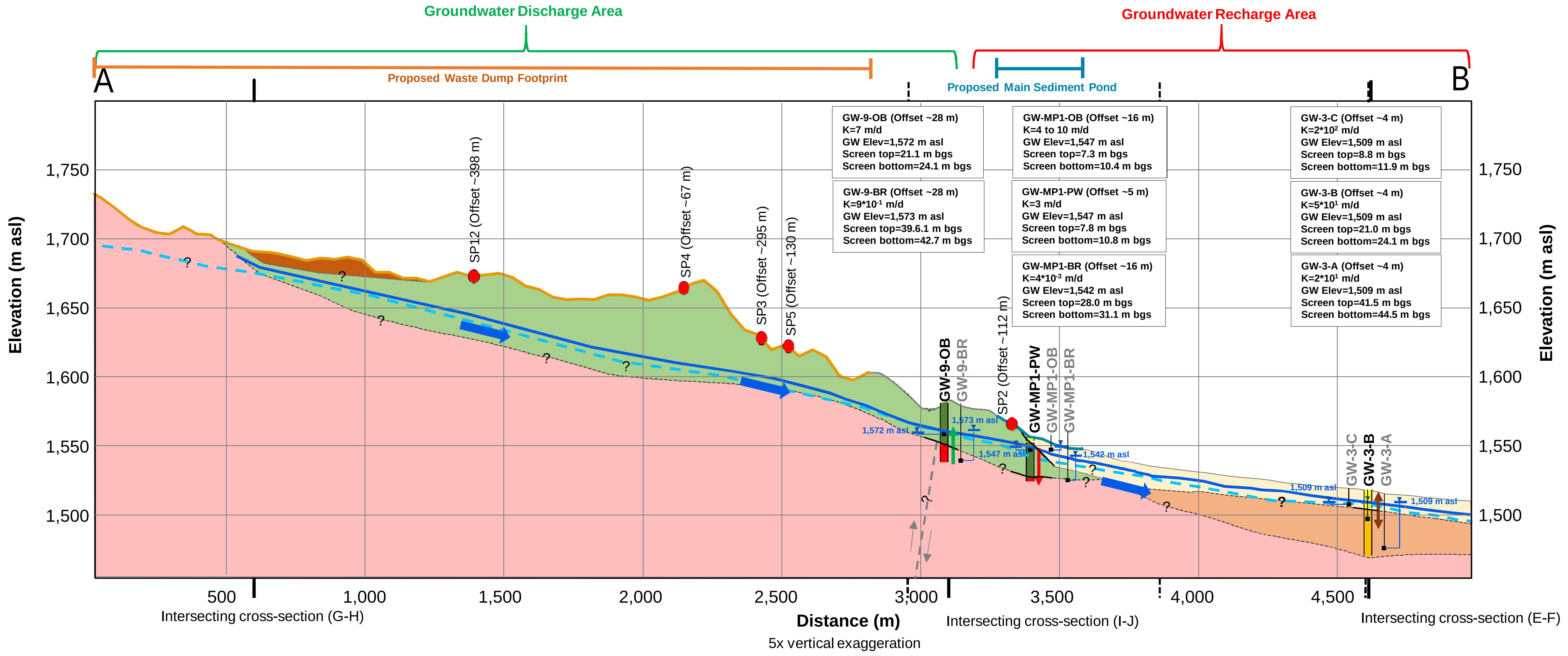
Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Seepage Points, Wells, Gradient, Creek Nature, Bedrock Contours, Discharge/Recharge Zones provided by SRK Canada Inc.
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

Map Created By: MZS
Map Checked By: CH
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 1/9/2023

Document Path: C:\Users\MSMITH\SRK Consulting\FS1288 Crown Mountain - Internal\!040_AutoCAD\ArcGIS\20221219_CrownMtn_update\CrownMtn_CAPR000323_Aquifer.aprx



Notes:

- Grey labels for well IDs are adjacent to black labels to show the elevation of the screen but those wells are at the same location in the cross-section as the wells whose labels are in black.
- Cross-section location is presented in Figure 9.4-16
- Cross-section A-B oriented parallel to West Alexander and Alexander Creeks
- Hydraulic conductivities from slug or pumping test
- GW Elev = average groundwater elevation in 2018
- SP4 identified as a potential spring
- m/d = meters / day
- m bgs = meters below ground surface
- m asl = meters above sea level
- Faults from British Columbia Digital Geology. British Columbia Geological Survey Open File 2017-18, 9p. Data version 2019-12-19.

Legend

— Proposed Main Sediment Pond – Footprint in Cross-section

— Proposed Waste Dump – Footprint in Cross-section

— Water Table

- - Inferred Bedrock Potentiometric Surface

➡ Groundwater flow direction

● Seeps

▌ Screen

- - - Interpreted Fault

Hydrostratigraphic Unit

Shallow Aquifer	🟫	Colluvial (Sands, gravels and cemented till lenses; K=7E+0 to 9E+0)
	▭	Fluvial (Gravel interbedded with sands and silty sands; K=2E+0 to 5E+4 m/d)
	🟧	Glaciofluvial (Sand and gravel; K=1E+0 to 1E+4 m/d)
Aquitards	🟩	Till (Pebbles, cobbles and boulders in a matrix of sand, silt and clay; K=2E-1 to 6E-1 m/d)
Deep Aquifer	🟥	Bedrock (K=2E-3 to 8E+0 m/d)

| Intersecting cross-section

¦ Cross-section orientation change

Lithology

🟩 Pebbles, cobbles, and boulders in a matrix of sand, silt, and clay

🟨 Gravels interbedded with sands and silty sands

🟧 Sand and gravel

🟥 Bedrock

Vertical Hydraulic Gradients

↑ Upward

↓ Downward

↕ Variable (depending on the season)

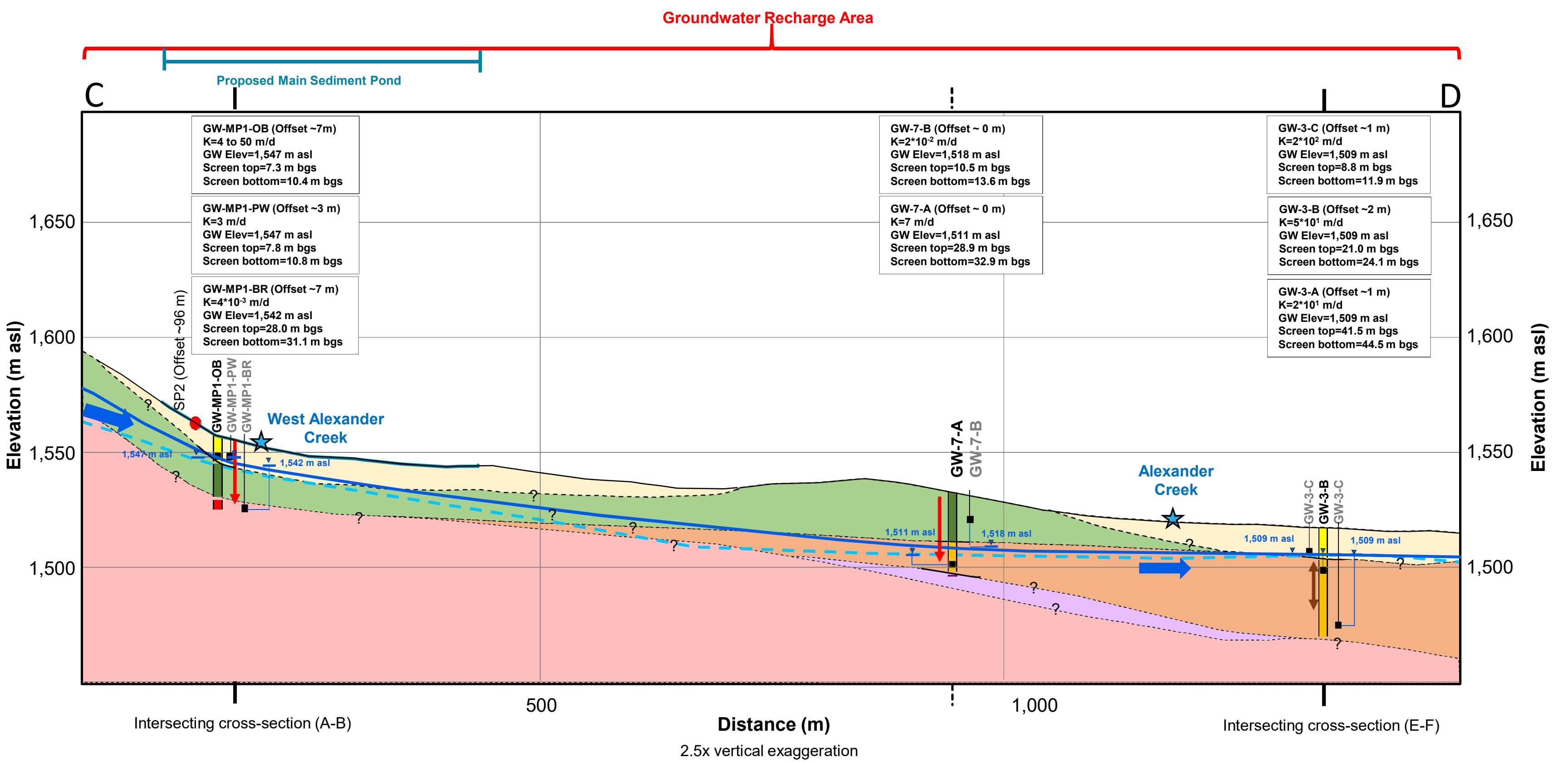
— Measured lithological contact

- - - - Inferred lithological contact

Figure 9.4-18: Cross-Section A-B

Crown Mountain Coking Coal Project
Application for an Environmental Assessment Certificate / Environmental Impact Statement

NWP Coal Canada Ltd



GW-MP1-OB (Offset ~7m)
K=4 to 50 m/d
GW Elev=1,547 m asl
Screen top=7.3 m bgs
Screen bottom=10.4 m bgs

GW-MP1-PW (Offset ~3 m)
K=3 m/d
GW Elev=1,547 m asl
Screen top=7.8 m bgs
Screen bottom=10.8 m bgs

GW-MP1-BR (Offset ~7 m)
K=4*10^{-3} m/d
GW Elev=1,542 m asl
Screen top=28.0 m bgs
Screen bottom=31.1 m bgs

GW-7-B (Offset ~ 0 m)
K=2*10^{2} m/d
GW Elev=1,518 m asl
Screen top=10.5 m bgs
Screen bottom=13.6 m bgs

GW-7-A (Offset ~ 0 m)
K=7 m/d
GW Elev=1,511 m asl
Screen top=28.9 m bgs
Screen bottom=32.9 m bgs

GW-3-C (Offset ~1 m)
K=2*10^{2} m/d
GW Elev=1,509 m asl
Screen top=8.8 m bgs
Screen bottom=11.9 m bgs

GW-3-B (Offset ~2 m)
K=5*10^{1} m/d
GW Elev=1,509 m asl
Screen top=21.0 m bgs
Screen bottom=24.1 m bgs

GW-3-A (Offset ~1 m)
K=2*10^{1} m/d
GW Elev=1,509 m asl
Screen top=41.5 m bgs
Screen bottom=44.5 m bgs

Notes:
- Grey labels for well IDs are adjacent to black labels to show the elevation of the screen but those wells are at the same location in the cross-section as the wells whose labels are in black.
- Cross-section location is presented in Figure 9.4-16
- Hydraulic conductivities from slug or pumping test
- GW Elev = average groundwater elevation in 2018
- No springs identified along this cross-section
- m/d = meters / day
- m bgs = meters below ground surface
- m asl = meters above sea level

Legend

― Proposed Main Sediment Pond – Footprint in the Cross-section
― Water Table
- - Inferred Bedrock Potentiometric Surface
➡ Groundwater flow direction
★ Cross-section intersects a creek
● Seeps
▮ Screen
| Intersecting cross-section (E-F)
⋮ Cross-section orientation change

Lithology

🟩 Pebbles, cobbles, and boulders in a matrix of sand, silt, and clay
🟨 Gravels interbedded with sands and silty sands
🟪 Silts and plastic clays with some fine sands
🟧 Sand and gravel
🟥 Bedrock

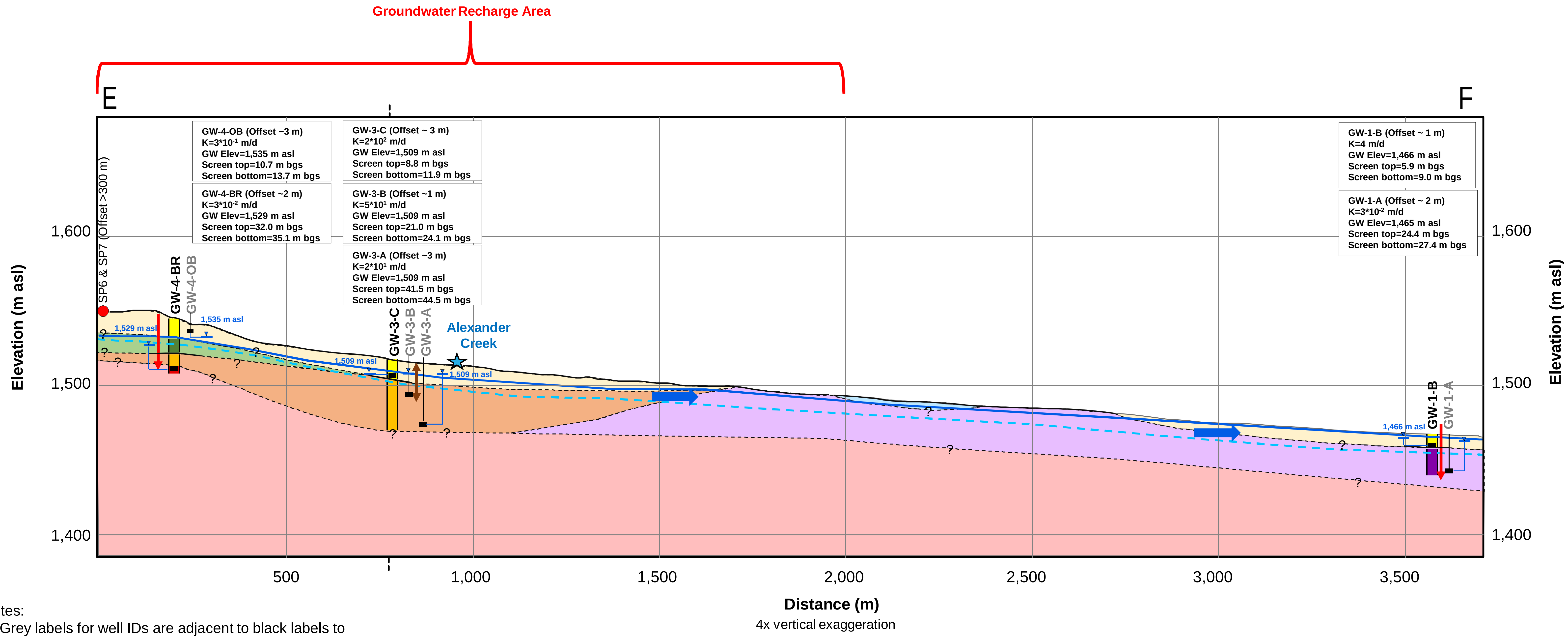
Vertical hydraulic gradients

↓ Downward
↕ Variable (depending on the season)

Hydrostratigraphic Unit

Shallow Aquifer	▨	Fluvial (Gravel interbedded with sands and silty sands; K=2E+0 to 5E+4 m/d)
	▨	Glaciofluvial (Sand and gravel; K=1E+0 to 1E+4 m/d)
Aquitards	▨	Glaciolacustrine (Silts and plastic clays; K=2E-2 to 8E-2 m/d)
	▨	Till (Pebbles, cobbles and boulders in a matrix of sand, silt and clay; K=2E-1 to 6E-1 m/d)
Deep Aquifer	▨	Bedrock (K=2E-3 to 8E+0 m/d)
	―	Measured lithological contact
	- - - -	Inferred lithological contact

Figure 9.4-19: Cross-Section C-D



GW-4-OB (Offset ~3 m)
$K=3*10^{-1}$ m/d
GW Elev=1,535 m asl
Screen top=10.7 m bgs
Screen bottom=13.7 m bgs

GW-4-BR (Offset ~2 m)
$K=3*10^{-2}$ m/d
GW Elev=1,529 m asl
Screen top=32.0 m bgs
Screen bottom=35.1 m bgs

GW-3-C (Offset ~ 3 m)
$K=2*10^{2}$ m/d
GW Elev=1,509 m asl
Screen top=8.8 m bgs
Screen bottom=11.9 m bgs

GW-3-B (Offset ~1 m)
$K=5*10^{1}$ m/d
GW Elev=1,509 m asl
Screen top=21.0 m bgs
Screen bottom=24.1 m bgs

GW-3-A (Offset ~3 m)
$K=2*10^{1}$ m/d
GW Elev=1,509 m asl
Screen top=41.5 m bgs
Screen bottom=44.5 m bgs

GW-1-B (Offset ~ 1 m)
K=4 m/d
GW Elev=1,466 m asl
Screen top=5.9 m bgs
Screen bottom=9.0 m bgs

GW-1-A (Offset ~ 2 m)
$K=3*10^{-2}$ m/d
GW Elev=1,465 m asl
Screen top=24.4 m bgs
Screen bottom=27.4 m bgs

Notes:

- Grey labels for well IDs are adjacent to black labels to show the elevation of the screen but those wells are at the same location in the cross-section as the wells whose labels are in black.
- Cross-section location is presented in Figure 9.4-16
- Hydraulic conductivities from slug or pumping test
- GW Elev = average groundwater elevation in 2018
- No springs identified along this cross-section
- m/d = meters / day
- m bgs = meters below ground surface
- m asl = meters above sea level
- Flowing artesian conditions were identified during drilling at the location of GW-4-BR. The water level at this location dropped quickly after drilling to below the ground surface.
- Flowing artesian conditions were identified at a location near GW-1-A and GW-1-B during drilling. No monitoring well was installed at that location and the drillhole was completely grouted instead.

Legend

— Water Table
- - - Inferred Bedrock Potentiometric Surface
➡ Groundwater flow direction
★ Cross-section intersects a creek
● Seeps
▮ Screen
¦ Cross-section changes direction

Lithology

🟩 Pebbles, cobbles, and boulders in a matrix of sand, silt, and clay
🟨 Gravels interbedded with sands and silty sands
🟪 Silts and plastic clays with some fine sands
🟧 Sand and gravel
🟥 Bedrock

Vertical hydraulic gradients

↓ Downward
↕ Variable (depending on the season)

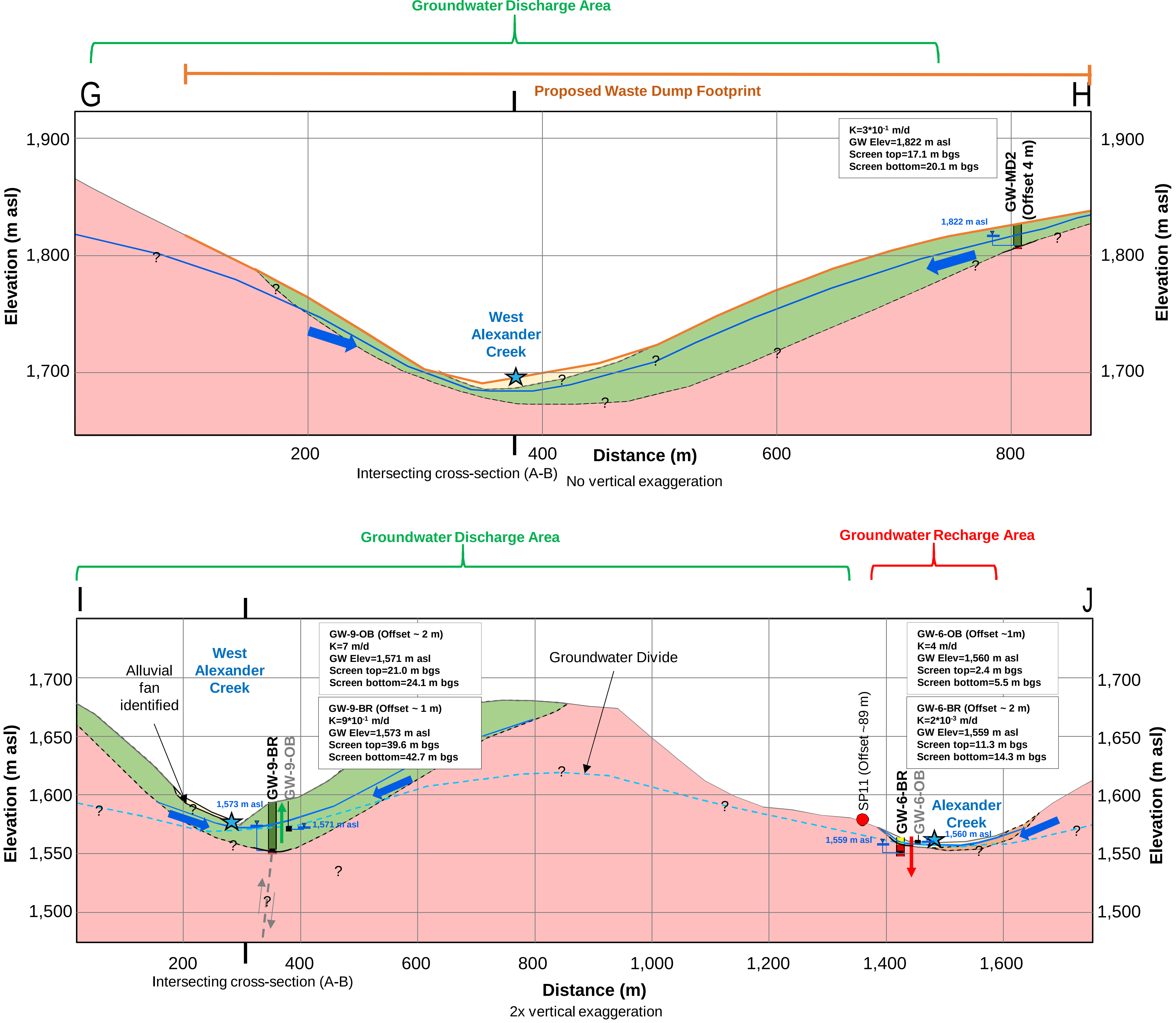
Hydrostratigraphic Unit

Shallow Aquifer
▨ Fluvial (Gravel interbedded with sands and silty sands; K=2E+0 to 5E+4 m/d)
🟧 Glaciofluvial (Sand and gravel; K=1E+0 to 1E+4 m/d)

Aquitards
🟪 Glaciolacustrine (Silts and plastic clays; K=2E-2 to 8E-2 m/d)
🟩 Till (Pebbles, cobbles, and boulders in a matrix of sand, silt and clay; K=2E-1 to 6E-1 m/d)

Deep Aquifer
🟥 Bedrock (K=2E-3 to 8E+0 m/d)

Figure 9.4-20: Cross-Section E-F



Legend

- Proposed Waste Dump – Footprint in Cross-section
- Water Table
- Inferred Bedrock Potentiometric Surface
- Groundwater flow direction
- ☆ Cross-section intersects a creek
- ● Seeps
- Screen
- Interpreted Fault
- Intersecting cross-section
- Measured lithological contact
- Inferred lithological contact

Vertical hydraulic gradients

- ↑ Upward
- ↓ Downward

Lithology

- 🟩 Pebbles, cobbles, and boulders in a matrix of sand, silt, and clay
- 🟨 Gravels interbedded with sands and silty sands
- 🟧 Sand and gravel
- 🟥 Bedrock

Hydrostratigraphic Unit

Shallow Aquifer	▨	Fluvial (Gravel interbedded with sands and silty sands; K=2E+0 to 5E+4 m/d)
	🟧	Glaciofluvial (Sand and gravel; K=1E+0 to 1E+4 m/d)
Aquitard	🟩	Till (Pebbles, cobbles and boulders in a matrix of sand, silt and clay; K=2E-1 to 6E-1 m/d)
Deep Aquifer	🟥	Bedrock (K=2E-3 to 8E+0 m/d)

Notes:

- Grey labels for well IDs are adjacent to black labels to show the elevation of the screen but those wells are at the same location in the cross-section as the wells whose labels are in black.
- Cross-section location is presented in Figure 9.4-16
- Hydraulic conductivities from slug or pumping test
- GW Elev = average groundwater elevation in 2018
- No springs identified along this cross-section
- m/d = meters / day
- m bgs = meters below ground surface
- m asl = meters above sea level
- Seeps presented in these cross-sections have a maximum offset of 100 m from the section.
- Faults from British Columbia Digital Geology. British Columbia Geological Survey Open File 2017-18, 9p. Data version 2019-12-19.

Figure 9.4-21: Cross-Sections G-H and I-J

The deepest hydrostratigraphic units are weathered, fractured, and fresh bedrock with a hydraulic conductivity between 10^{-3} and 1 m/d. Two units interpreted as aquitards overlie and confine groundwater in bedrock. One is till sediments, comprised of pebbles, cobbles, and boulders in a matrix of sand, silt, and clay. The second is a glaciolacustrine layer composed of silts and plastic clays. These units have hydraulic conductivities in the range of 10^{-2} to 10^{-1} m/d.

Two higher hydraulic conductivity units interpreted to represent the shallow aquifer occur at shallow depths or locally under till in the Alexander Creek valley bottom. These units are mixtures of sand and gravel in varying proportions. These units have hydraulic conductivities in the range of 1 to 10^{4} m/d.

Interpreted groundwater head contours (potentiometric contours) for the overburden aquifer hydrostratigraphic unit is presented in Figure 9.4-22; interpreted groundwater head contours for the bedrock unit is provided in Figure 9.4-23.

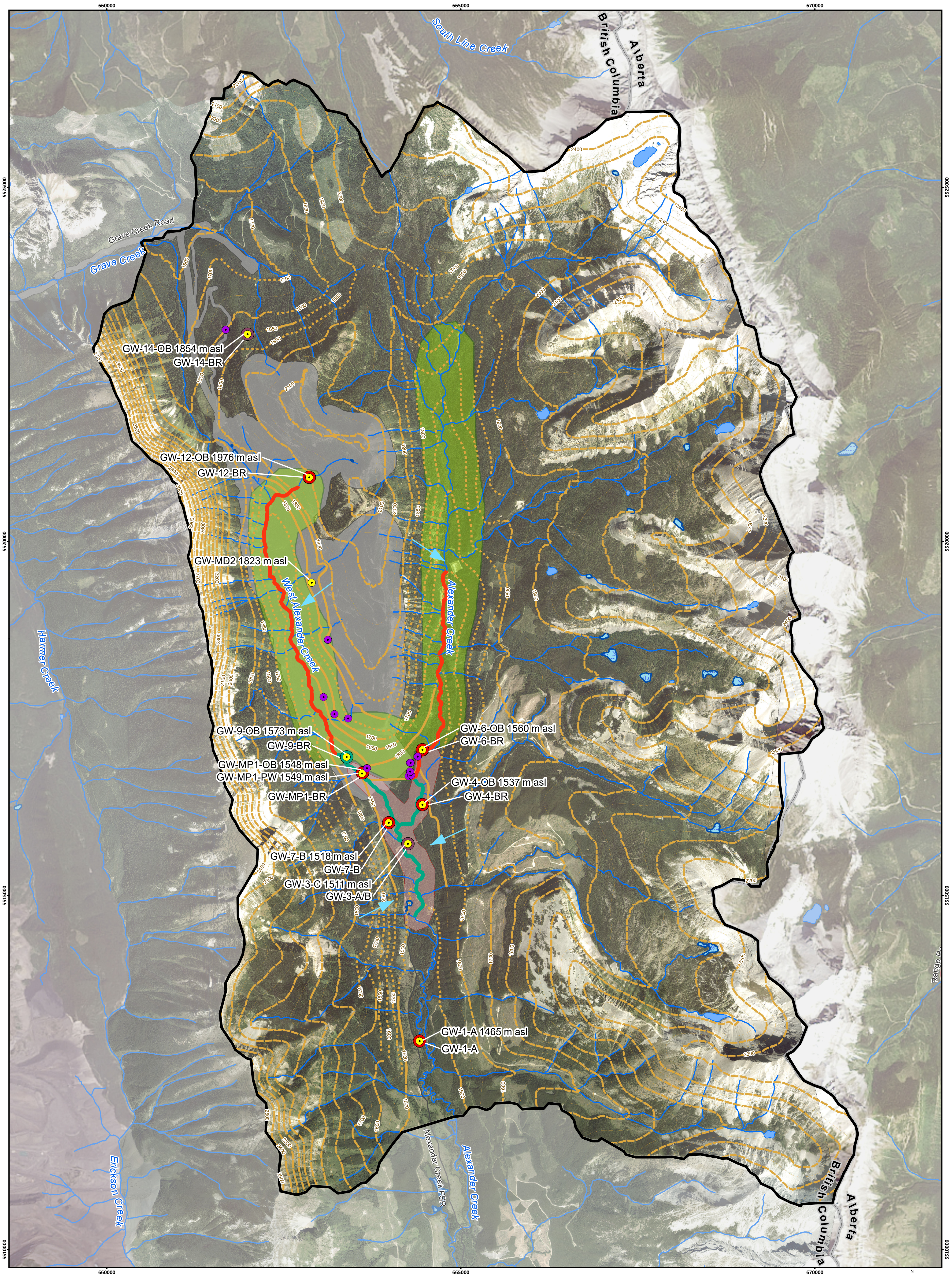
Hydraulic head mimics topography. A groundwater divide generally coincides with the topographic saddle between the West Alexander and Grave Creek drainages and is assumed to follow ridgelines away from that. Hydraulic conductivity data indicates higher values in fluvial and weathered bedrock units as compared to till and competent bedrock. This is comparable to observations at other projects in this region.

At a large scale, groundwater flow will move from high elevation recharge areas to low elevation discharge areas via the most permeable pathways. These flow paths can occur at multiple scales, such as the local, intermediate and regional groundwater systems as defined by Toth (1963). Using the West Alexander Creek valley as an example at the Project, local flow paths represent recharge in the area of the open pits that moves through relatively thin colluvial or fluvial overburden and discharges in West Alexander Creek somewhere directly downhill. This water has a relatively short travel time and characteristics more representative of recharge than deep groundwater (e.g., lower TDS). Intermediate flow paths are occurring in weathered bedrock to moderate depths and still discharging to valley bottoms generally within the Groundwater LSA. Regional flow paths represent water that is infiltrating deep into relatively more competent bedrock, travelling for significantly longer periods of time, and not discharging until well down gradient of the Project. Till or glaciolacustrine units can confine water into these flow paths, transforming from one flow path to another (e.g., an intermediate flow path to a more regional one).

For example, recharge entering weathered bedrock in the vicinity of the Project may become confined by glaciolacustrine units as it enters the Alexander Creek valley and cannot return to surface until some location well down-gradient.

Most groundwater flow is inferred to occur through local or intermediate pathways and discharges close to site. Monitoring wells in valley bottoms (GW-9-OB and GW-9-BR) show upwards vertical gradients from near surface overburden materials supporting the concept of a discharge zone in the valley bottom, or baseflow to West Alexander Creek. This is supported by the results of the flow accretion survey.

On the northern side of the Project in the Grave Creek catchment, wells GW-14-BR and GW-14-OB typically indicate downwards gradients, reflective of a groundwater recharge area. Upwards gradients in October 2018 and October 2019 suggest these gradients can reverse, perhaps related to autumn rains, but it is unclear why this is not also apparent during freshet. The area is considered a groundwater recharge zone. Further downgradient of the Project, downward vertical gradients (GW7-A, GW7-B, GW1-A and GW1-B) indicate recharge of the groundwater from West Alexander Creek.



Crown Mountain Coking Coal Project

Figure 9.4-22
Interpreted Current Conditions - Potentiometric Surface Shallow Aquifer

LEGEND

● Seepage Point

● Local Groundwater Monitoring Location

Gradient

● Downward

● Upward

● Variable

Creek Nature

🟥 Gaining Reach

🟩 Losing Reach

Shallow Aquifer Contours (50 m)

— Measured

┅ Inferred

– – Modelled

↙ Flow Direction

Recharge Zones

🟩 Groundwater Discharge Zone

🟥 Groundwater Recharge Zone

▭ Groundwater Local Study Area

▨ Project Footprint

— Local/Resource Road

— Watercourse

🟦 Waterbody

▨ Wetland

▭ British Columbia/Alberta Border

0 1 2
Kilometres
Scale 1:50,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Water level contours were interpreted from groundwater level readings (Sept 2018 - Aug 2020). Creek nature is an interpretation from flow survey conducted by Swiftwater Consulting in 2018. Recharge and discharge zones correspond to a study area scale interpretation and may have variations locally.
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).

Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231

Status: FINAL

Date: 2021-06-09

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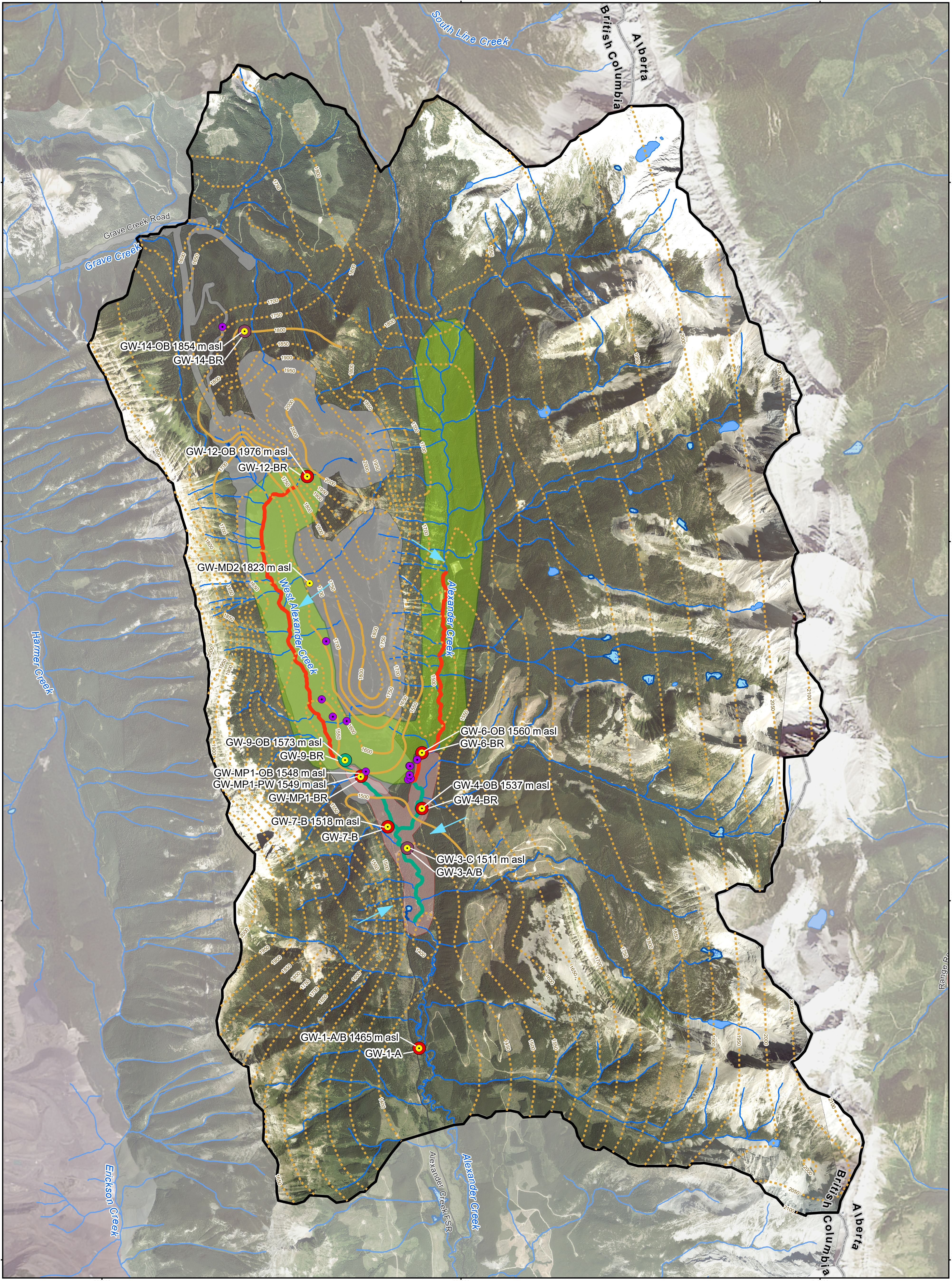

0 1 2
Kilometres

N W E S

Crown Mountain Coking Coal Project

Figure 9.4-23
Interpreted Potentiometric Surface Bedrock Aquifer

LEGEND

- ● Seepage Point
- ● Local Groundwater Monitoring Location

Gradient

- 🔴 Downward
- 🟢 Upward
- ● Variable

Creek Nature

- ▬ Gaining Reach
- ▬ Losing Reach

Bedrock Contours (50 m)

- ▬ Measured
- ┄ Inferred
- ↙ Flow Direction

Recharge Zones

- 🟩 Groundwater Discharge Zone
- 🟥 Groundwater Recharge Zone
- ☐ Groundwater Local Study Area

- ▨ Project Footprint
- ― Local/Resource Road
- ― Watercourse
- 🟦 Waterbody
- ▨ Wetland
- ☐ British Columbia/Alberta Border

Scale 1:50,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Water level contours were interpreted from groundwater level readings (Sept 2018 - Aug 2020). Creek nature is an interpretation from flow survey conducted by Swiftwater Consulting in 2018.
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NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 2021-06-09

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9.4.3.5.4 Groundwater Numerical Modelling Results

A numerical model was constructed based on the conceptual model and calibrated for baseline, pre-mining water levels, and creek baseflow estimates. The final calibrated model reproduced the regional hydrogeological system reasonably well, with a normalized root mean squared error (NRMSE) of 0.3% and simulated baseflows within 80% to 120% to those calculated from local streamflow measurements (except for point SW 7.1 on East Alexander Creek, which shows a sudden drastic increase in observed flow, which is approximately 3 times greater than that modeled).

The sensitivity analyses showed low sensitivity to K (horizontal to vertical) anisotropy and bedding planes. However, it has medium to high sensitivity to recharge (~ 80 millimetres per year [mm/yr] in average) and decreasing bedrock K with depth. These parameters also have a high impact on model calibration, but the conditions used for calibration of the model are considered reasonable; thus, there remains confidence in the model predictive results within the uncertainty range.

Particle tracking from the MRSF and Main Sediment Pond locations show that the vast majority of groundwater flow is towards the creeks and dewatered mine pits; however, a small number of particles indicate potential flow to East Alexander Creek if there is mine rock deposition to the east of the groundwater divide.

A comparison of model predictive scenario seepage results with and without faults shows a low sensitivity to faults. This is likely due to the orientation of the narrow width of the faults (assumed to be 1 m), the orientation of the faults aligning with local bedding, and the relatively minimal extension of the faults south/down-gradient of South Pit.

While specific results are calculated during the modelling process, there always remains a degree of uncertainty associated with these estimates. Quantification of the uncertainty may be a laborious and expensive process. A range of estimates was used to quantify the uncertainty; however, these ranges should not be viewed as definitive.

Modelling results indicate that:

- The mass water balance (Table 9.4-14) for the model area indicates that the vast majority of recharge from rainfall (10 to 15% of the mean annual precipitation, which corresponds to an average of about 80 mm/yr) flows into the local creeks; however, a very small percentage (0.1%) flows southwards below Alexander Creek, and there are sections of losing streams (with flow from streams to groundwater) within the model area;
- The groundwater fluxes through North Pit, East Pit, and South Pit are 317 m^3/d, 147 m^3/d, and 965 m^3/d, respectively. The East Pit is the smallest and situated near the top of the ridge, hence why it has a lower groundwater flux. Although the groundwater flux through the South Pit is highest, it is not considered extremely high. This is also due to it being on a ridge and thus only capturing local recharge water. In addition, groundwater is quite deep (> 50 m bgs) over a large area of South Pit;
- The total horizontal groundwater fluxes within the top 50 m at defined locations along the West Alexander Creek, East Alexander Creek, and Alexander Creek valleys are 215 m^3/d, 796 m^3/d, and 1,001 m^3/d, respectively; and

- Modelled water levels in the cross-section of East Alexander Creek show intersection with topography at a location on the west bank where springs have been observed, and a water level below the base of the creek, consistent with observations and the conceptual model that it is a losing stream in this area.

Table 9.4-14: Model Mass Water Balance (Baseline)

Model Mass Balance (16s)	Inputs (m^3/d)	Outputs (m^3/d)
Recharge	25,417	-
Baseflow (GW to SW)	-	25,710
Flow from Aquifer (out of model boundary)	-	33
Losing Streams (SW to GW)	326	-
Total	25,743	25,743

GW – Groundwater
SW – Surface water

Baseline baseflow conditions are presented in Table 9.4-15. Further details regarding modelling results including fluid rate budget and forward streamlines in Lower Alexander Creek are provided in Appendix 9-A.

Table 9.4-15: Mass Balance: Baseline Groundwater Baseflow Yield by Watershed

Mass Balance	Inflow (m^3/d)	Outflow (m^3/d)
West Alexander Creek Baseflow	74	3,280
Upper Alexander Creek Baseflow	63	10,368
Alexander Creek Baseflow*	189	9,169
Alexander Creek Cumulative Change**	326	22,817

Notes:
* Alexander Creek below confluence of Upper and West Alexander Creek.
** Includes West Alexander Creek, Upper Alexander Creek and Alexander Creek below confluence.

9.4.3.6 Groundwater and Surface Water Interactions

Baseline groundwater data discussed in Section 9.4.3 and baseline surface water quality data presented in Chapter 11 and Appendix 11-B were reviewed to understand potential interactions. Details on this review, including cross plots and Piper diagrams of key parameters, are provided in Appendix 9-D.

In general, within the Alexander Creek catchment, water quality from wells completed in bedrock (generally deeper) tend to plot differently than surface water, with higher SO_4/Cl, higher Na/K, lower HCO_3/CO_3, and lower Ca/Mg than wells completed in overburden (generally shallower) and in surface water. Water quality from most wells completed in overburden tend to plot similarly to surface water; however, water quality from wells completed in overburden can also plot between water quality from bedrock wells and surface water. Characterizations of key areas with the Alexander Creek catchment are described in the following subsections.

9.4.3.6.1 West Alexander Creek

Stations used in the characterization of West Alexander Creek included WA1 for surface water and both shallow and deep wells at the GW-12, CM-13-25, GW-09, GW-MP1, GW-MD2, and GW-07 locations. Samples from overburden groundwater wells tend to have concentrations of constituents of interest (COIs) relatively similar to surface water; concentrations can vary higher or lower than average surface water. COI concentrations in deeper bedrock groundwater can also be similar, though differences can be observed at GW-09-BR.

The cross plots of parameter ratios for the GW-09 well cluster and surface water station WA1 (Appendix 9-D) illustrate a similarity between surface water and overburden, and the relatively larger difference between surface water and deeper bedrock water quality. The GW-09 cluster is located between the downstream toe of the proposed Mine Rock Storage Facility and Main Sediment Pond. Mg/Ca, SO_4/HCO_3, and K/Na cross plots show clear groupings for surface water, overburden groundwater, and bedrock groundwater, with bedrock groundwater having distinctly different ratios to surface water with overburden groundwater much more similar to surface water. F/NO_3-N ratios show a different pattern than other ratios, but with similar groupings and surface water tending to be more similar to overburden groundwater than bedrock groundwater. The different patterns are a result of low NO_3-N concentrations in bedrock groundwater.

Despite some differences, on average, surface water and most overburden groundwater are generally similar. Deeper groundwater can be distinct, typically with relatively higher parameter concentrations than surface water, but not always. Surface water is interpreted to be distinctly different than bedrock waters, while overburden groundwater is generally similar to surface water.

9.4.3.6.2 Alexander Creek

Stations used to characterize the reaches of Alexander Creek upstream of the confluence with West Alexander Creek included A4 and A5 for surface water and both shallow and deep wells at the GW-06 and GW-04 locations. Water characteristics are similar to West Alexander Creek, except that the differences between bedrock groundwater versus overburden groundwater and surface water are more distinct. Both timeseries plots and cross plots for the GW-06 and GW-04 wells show distinct differences in sulphate and sodium between the bedrock waters compared to surface water, and cross plots show bedrock groundwaters grouping significantly different than surface water or overburden water. On average, surface water and most overburden groundwater are generally similar, but different than deeper groundwater.

Stations used to characterize the reaches of Alexander Creek downstream of the confluence with West Alexander Creek included A3 and A3(B) for surface water and both shallow and deep wells at the GW-03 and GW-01 locations. Looking at cross plots, water characteristics at the GW-01 cluster (southernmost groundwater wells along Alexander Creek) are generally similar to West Alexander Creek and Alexander Creek upstream of the confluence with West Alexander Creek. Water characteristics at GW-03 (located near the confluence of West Alexander and Alexander Creeks) are somewhat different than other areas, with generally more similarities between different waters. In particular, surface water shows similarities to the relatively shallow GW-03-B and -A wells (K-Na and F-NO_3), including similarity to some deeper groundwater samples, with the exception that the differences between bedrock groundwater versus overburden ground and surface water are more distinct. Most COIs show concentrations generally similar to surface water. Water quality data suggest that the area of the West Alexander and Alexander Creek confluence may reflect more mixing of shallow and deep water and therefore have greater similarity to surface water.

9.4.3.6.3 Seasonality and Inter-Annual Variability

In West Alexander Creek, seasonal trends in groundwater data can be seen for some parameters, but not all. At wells CM-13-25, GW-MP1-BR, GW-MP1-OB, and GW-MP1-PW, sulphate can be lower during May and June but the number of samples during this period of year is relatively limited, and it is not possible to tell if this is consistent across the entire West Alexander Creek area. Parameters such as sodium may also show seasonal variation in some wells similar to WA1, but again are not strong or consistent trends. Seasonal trends in groundwater are not strong in the monitoring stations upstream or downstream of the West Alexander Creek and Alexander Creek confluence.

Qualitatively, at the scale of the monitoring network, seasonal differences in groundwater-surface water interaction may occur locally based on observed water quality trends. Different relationships may be observed at the very local scale (e.g., the hyporheic zone immediately under creeks), but this level of detail cannot be assessed with the current monitoring network. In general, the relative magnitude of interaction related to water quality is assumed to be more important in lower flow periods when groundwater flows and surface water flows are relatively more similar compared to higher flow periods when surface water flows are relatively much more significant than groundwater flows.

9.5 Project Effects Assessment

9.5.1 Thresholds for Determining Significance of Residual Effects

For the purpose of this assessment, a significant adverse residual environmental effect of the Project on groundwater is defined as follows:

- For groundwater quantity:
    - Greater than 10% change in flows relative to baseline conditions (Locke and Paul 2011; Beecher et al 2016); or
    - Reduction in the quantity of groundwater recoverable from an aquifer on a sustainable basis such that it no longer meets present or future needs of current users or land owners; or
    - Reduction in groundwater discharge and consequent adverse effects to baseflow to a stream, preventing current users from meeting present and future needs on a sustainable basis.
    - Absolute changes to groundwater levels greater than 1 m relative to baseline conditions.
- For groundwater quality:
    - Exceedance of a guideline value (except an exceedance related to baseline concentrations). Significance thresholds for groundwater quality consider the EVWQP WQT (for the four Order constituents), the B.C. WQG DW and the B.C. CSR Schedule 3.2 DW Standards over a given season; or
    - An increase of greater than 10% from the mean of baseline conditions over a given season (KNC, 2020); or
    - For constituents that have been demonstrated to exceed these criteria during the baseline assessment (e.g., lithium and cobalt), an increase of greater than 10% from the 95th percentile of baseline concentrations over a given season.

9.5.2 Project Effects

Project activities during Construction and Pre-Production, Operations, Reclamation and Closure, and Post-Closure stages could affect groundwater quantity and quality. Potential adverse effects to shallow groundwater aquifers may contribute to surface water systems in groundwater discharge zones along West Alexander Creek within the Project footprint and may travel further in deep groundwater. Discharge of deeper groundwater does not appear to be important close to the Project due to the presence of the glaciolacustrine confining unit but could occur further down-gradient in the Alexander Creek valley.

This assessment focuses only on planned activities within the designed scope of the Project. Potential effects related to unplanned events (e.g., spills, equipment malfunctions, accidents) are presented in Chapter 21. Key Project activities that are expected to interact with groundwater, with the potential for adverse effects, are presented in an interaction matrix in Table 9.5-1 below. Additional details relating to specific Project activities are discussed in Chapter 3.

Table 9.5-1: Project-Groundwater Interaction Matrix and Ranking

Project Phase	Project Component	Description of Activities	Groundwater	
			Quantity	Quality
Construction and Pre-Production	Transportation	Use of Highway 43, Line Creek Mine Road, Valley Road, and Grave Creek Road by highway transport trucks, light duty vehicles, and crew busses to transport personnel, materials, and consumable items	I	I
	Logging of Merchantable Timber	Merchantable timber will be logged from the infrastructure and pre-production development footprint	I	I
	Clearing and Grubbing	After the merchantable timber has been removed, the remaining vegetation will be cleared and grubbed from the infrastructure and pre-production development footprint	I	I
	Stockpiling Wood Waste	Wood waste will be stockpiled on site and used for reclamation as a source of coarse woody debris	I	I
	Quarry for Construction Materials	Excavation of road bed materials from the North Pit footprint for use on Grave Creek Road	I	II
	Water Management or Water Management Structures	Water management structures to support initial construction activities will be built prior to soil being salvaged from the run of mine (ROM) and plant site	I	I
		Interim Sediment Pond will be built prior to the soil removal and stockpiling from the pit access road and initial phase of the North Pit	II	I
		Grave Creek Reservoir will be constructed to act as a back-up source of process water	II	II
	Soil Salvage	Soil will be salvaged from the footprint of the infrastructure	I	I

Project Phase	Project Component	Description of Activities	Groundwater	
			Quantity	Quality
	Road Upgrading and Construction	Branch C Road will be widened and upgraded to facilitate construction and mine traffic to plant site area	I	I
		Grave Creek Road will be widened to facilitate the clean coal haul	I	I
		A new road will be constructed off the Valley Road to access the rail loadout for construction and operation	I	I
	Linear Infrastructure	Installation of the powerline	I	I
		Installation of the natural gas line	I	I
	Overland Conveyor	Clearing, grubbing, and construction of overland conveyor from the plant site to Grave Creek Road	I	I
	Coal Handling Process Plant Construction	Excavating and pouring of foundation	I	I
		Transportation of materials and personnel to site	I	I
		Constructing of the Coal Handling Process Plant (CHPP)	I	I
		Commissioning of the CHPP	I	I
	Workshop / Mine Dry Construction	Excavating and pouring of foundations	I	I
		Transportation of materials to site	I	I
		Construction of workshop / mine dry	I	I
		Equipment wash bay and heavy equipment parking	I	I
		Administration, first aid, and mine dry building	I	I
		Diesel tank farm	I	I
		Warehouse	I	I
		Potable water system	I	I
		Septic system	I	I
		Water supply pipelines from Grave Creek and West Alexander Creek	I	I
		Commissioning of the facilities	I	I
	Explosives Factory Construction	Construction of the explosives factory	I	I
	Rail Loadout Construction	Excavation and preparation of the rail bed	I	I
		Excavation and preparation of foundation stockpiling and coal handling systems	I	I
		Transportation of materials and personnel to site	I	I
		Construction of rail loadout	I	I
		Connection to the CP Fording Sub-line	I	I
		Commissioning of the rail loadout	I	I
	Labour	Hiring of personnel for the mine, CHPP operations, administration, and coal haul	I	I

Project Phase	Project Component	Description of Activities	Groundwater	
			Quantity	Quality
		Training of personnel	I	I
	Construction Waste Materials	Collection and transfer to a recycling facility or other approved facility	I	I
Operations	Transportation	Use of Highway 43, Line Creek Mine Road, Valley Road, and Grave Creek Road by highway transport trucks, light duty vehicles, and crew busses to transport personnel, materials, and consumable items	I	I
	Explosives Factory	Ammonium nitrate / emulsion storage facilities which have the ability to load explosive agents into delivery trucks	I	II
		Wash facility to decontaminate the bulk explosive delivery trucks	I	II
		Storage of explosives (detonators and boosters)	I	II
	Fuel Storage	Receiving bulk fuel deliveries	I	II
		On-site storage of fuel	I	II
		Dispensing fuel	I	II
		Transferring fuel to on-site delivery trucks	I	II
	Mine Roads Development	Building roads from material sourced on-site	I	I
	Mining	Progressive clearing	I	I
		Removal of unconsolidated material	I	I
		Loading, hauling, and stockpiling of soil	I	I
		Drilling and loading of blastholes	I	II
		Detonating the explosives	II	II
		Loading, hauling, and dumping of mine rock	III	III
		Loading, hauling, and stockpiling of coal	I	II
	Site Water Requirements	Using contact water as the primary process make-up water from Interim Sediment Pond (Year 1 to 5)	II	II
		Using contact water as the primary process make-up water from the North Pit (Year 5 to 15)	II	I
		Backup reservoir in Grave Creek as a secondary source of process make-up water	II	II
	Coal Processing	Run of mine coal sizing	I	I
		Washing coal	I	II
		Mechanical and thermal drying of coal	I	I
		Coal reject disposal (part of loading, hauling, and dumping of mine rock activities)	I	III
		Conveying clean coal	I	I

Project Phase	Project Component	Description of Activities	Groundwater	
			Quantity	Quality
	Sewage Treatment	Sewage will be treated by a septic system constructed at the plant site which will support the administration, mine dry, and CHPP facilities	I	I
	Main Sediment Pond	Construction of Main Sediment Pond in Year 4	II	II
		Management of the Main Sediment Pond discharge	II	III
	Reclamation	Reclaiming available areas as soon as possible to achieve reclamation objectives	I	I
Reclamation and Closure	Transportation	Use of Highway 43, Line Creek Mine Road, Valley Road, and Grave Creek Road by highway transport trucks, light duty vehicles, and crew busses to transport personnel, materials, and consumable items	I	I
	Dismantling Infrastructure and Buildings	Dismantling of the CHPP, maintenance facilities, administration, and other facilities	I	I
		Dismantling, salvaging, collecting, and transferring materials to a recycling facility or other approved facility	I	I
	Removal of Linear Infrastructure	Removal of the powerline	I	I
		Removal of the natural gas line	I	I
	Reclamation	Reclaiming available areas as soon as possible to achieve reclamation objectives	II	I
	Monitoring	Reclamation monitoring	I	I
		Geotechnical monitoring	I	I
		Aquatic effects monitoring	I	I
	Water Management	Management of the Main Sediment Pond discharge	II	III
Post-Closure	Water Management	Decommissioning the Main Sediment Pond once water quality objectives have been met	II	II
	Road Use	Branch C Road will remain as a permanent access road for future commercial and recreational use	I	I
	Rail Line	The rail line will remain as a permanent feature	I	I
	Monitoring	Reclamation monitoring	I	I
		Geotechnical monitoring	I	I
		Aquatic effects monitoring	I	I

Notes (after EAO, 2013):
I = No or negligible effect (positive or adverse) is anticipated; not carried forward in the assessment
II = Potential adverse effects requiring additional mitigation or substantive positive effects are expected; carried forward in the assessment
III = Key interaction resulting in potential significant adverse effect or significant concern; carried forward in the assessment

As shown, among the proposed Project activities, those associated with activities within the pits and stockpiling of mine rock and coal rejects, and on-site water management are identified as key interactions resulting in potential adverse effects to groundwater quantity and quality during mine Construction and

Pre-Production, Operations, Reclamation and Closure, and Post-Closure stages. In general, the Project has the potential to affect groundwater quantity through:

- Construction of the Interim Sediment Pond, Main Sediment Pond, and Grave Creek Reservoir;
- Detonating explosives, development of pits by removal of rock mass, and dewatering of pits;
- Loading, hauling, and dumping of mine rock at the MRSF, and physical changes to site drainage;
- Use of contact water as primary process makeup water from the Interim Sediment Pond (Year 1 to 5), from the North Pit (Year 5 to 15), and use of Grave Creek Reservoir as a secondary source of process make-up water;
- Managing the Main Sediment Pond discharge to West Alexander Creek during operation through to decommissioning; and
- Reclamation and filling of pits to spill point levels and re-equilibration of the groundwater flow system, but not to the same state as baseline conditions.

The Project has the potential to affect groundwater quality through: Groundwater quality effects which are anticipated from the Project include:

- Infiltration of surface water (i.e., non-contact water runoff) to groundwater during excavation of construction materials from small quarry for the construction of Grave Creek Road, and construction of Grave Creek Reservoir, Sediment Ponds, and other areas during site clearing, construction, soil movement/salvage, maintenance, and reclamation activities;
- Contact water runoff and infiltration to groundwater from mine disturbed areas and infrastructure (herein referred to as “mine site drainage”);
- Nitrogen loading from explosives handling, loading, washing and detonation, resulting in potential leaching of explosive residues;
- Routine use of hydrocarbon fuels on site, fuel handling, dispensing and transferring;
- Disposal of mine rock and coal rejects, and infiltration of seepage water to groundwater;
- Use of contact water from the Interim Sedimentation Pond or Grave Creek Reservoir, and potential for infiltration of contact water to groundwater;
- Washing and stockpiling of coal carry the potential for seepage and metal leaching (i.e., sulphate and selenium) and infiltration of wash/seepage water to groundwater; and
- Managing the Main Sediment Pond discharge to West Alexander Creek including surface water-groundwater interactions and potential seepage/leakage from pond to groundwater during operation through to decommissioning.

Potential effects on groundwater quantity and quality as a result of the Project that are carried forward in the discussion of potential effects are summarized below in Table 9.5-2.

Table 9.5-2: Potential Effects on Groundwater Quantity and Quality

Potential Effect	Rationale for Selection of Environmental Effect
Groundwater Quantity	
Changes in groundwater quantity from construction of the Interim Sediment Pond, Main Sediment Pond, and Grave Creek Reservoir	Alteration of local groundwater levels and flow patterns such as water table mounding or drawdown, or changes to flow direction or hydraulic gradients (within ~100 m radius). Significant effects are not expected

Potential Effect	Rationale for Selection of Environmental Effect
	within Grave Creek catchment, since key mine components represent less than 1% of its total area.
Changes in groundwater quantity from detonating explosives, mining process and dewatering of pits	Alteration to local groundwater conditions due to modification of surface topography by removal of rock mass. As the open pits are mined, drawdown will extend outwards, redirecting groundwater flows towards pits altering runoff patterns / groundwater recharge and reducing groundwater discharge to creek valley bottoms.
Changes to groundwater quantity through altered drainage patterns and groundwater-surface water interaction associated with loading, hauling and dumping of mine rock at the MRSF	The MRSF will affect recharge rates but are not expected to significantly change groundwater flow paths as mine rock piles typically have higher conductivities than natural ground. During operations, infiltration through the dumps is assumed to be double natural recharge (from slow release of storage) and will carry load that can enter the groundwater system. Modelling indicates that flows starting at dumps typically discharge to West Alexander Creek locally, with limited down gradient migration. Runoff directed around the MRSF will ultimately still report to the same catchment drainages, as will water infiltrating through these dumps. Groundwater flow quantities may change, but overall flow directions will likely remain similar to baseline conditions.
Changes to groundwater quantity due to use of water for use as primary process make-up water from the Interim Sediment Pond (Year 1 to 5) and from the North Pit (Year 5 to 15. Grave Creek Reservoir may be used as a secondary source of process make-up water	Water table drawdown and other local changes to groundwater flow patterns (flow direction, hydraulic gradient) are anticipated in the immediate vicinity of the ponds and pits. Potential reduction to baseflows in Alexander Creek catchment is most significant in West Alexander Creek, but cumulative reduction in Alexander Creek is <10%. The North Pit will be flooded (at least partially), and limited impact on groundwater flow directions or quantity is anticipated. Significant effects are not expected within Grave Creek catchment since key mine components represent less than 1% of its total area.
Changes to groundwater quantity associated with surface water-groundwater interactions during discharge of effluent from the Interim Sediment Pond and Main Sediment Pond during operation and decommissioning	Potential effects are related to interactions between surface water and groundwater during discharge of mine effluent to West Alexander Creek. Modelling indicates that water flowing from the ponds will mainly flow through groundwater below the losing portion of Alexander Creek, before forming baseflow further south, within the Groundwater LSA.
Changes to water table elevation in the local vicinity of the pits following reclamation and filling of pits to spill point levels	Filling of pits to spill point levels and re-equilibration of the groundwater flow system will occur as the pits are completed, which will occur through the operational phase and into closure. Local water levels in the vicinity of the pits will be altered from baseline conditions due to altered surface topography and rock mass removal. Reclamation of mine rock dumps may reduce infiltration to a degree and further modify groundwater recharge within their footprints.

Potential Effect	Rationale for Selection of Environmental Effect
Groundwater Quality	
Changes in groundwater quality due to infiltration of non-contact surface water runoff to groundwater during construction, site clearing, and maintenance and reclamation activities	Erosion and sedimentation during site clearing, construction, maintenance, and reclamation activities could result in elevated levels of total suspended solids (TSS) and turbidity in nearby watercourses. Due to the potential for surface water-groundwater interaction through surface water infiltration to groundwater, these factors have the potential to affect local groundwater quality.
Changes in groundwater quality due to infiltration of contact water (i.e., surface water and mine site drainage) to groundwater	Contact water runoff and infiltration to groundwater from mine disturbed areas and infrastructure (herein referred to as “mine site drainage”), may increase sediment load and metal leaching potential, and result in elevated concentrations of TSS, turbidity, and other substances (e.g., petroleum hydrocarbon products, coal dust). The Groundwater LSA includes both gaining and losing reaches within watercourses. Changes to surface water quality via seepage from mine disturbed areas could result in potential changes to groundwater quality. Open pit development will require blasting, where residues contain nitrogen compounds that can remain on the surface, including on mine rock and excavated rock. As a result, mine site drainage released to the receiving environment may contain elevated levels of nitrogen compounds. During active mining of the pits, it will be necessary to dewater each pit through the use of drainage ditches, berms, sumps, and pumps. Water from Mine dewatering activities released to the receiving environment may contain elevated concentrations of suspended solids or other parameters such as metals and nutrients. Changes to groundwater quantity (such as in the local vicinity of the pits due to dewatering) can affect local groundwater flow rates and redox conditions, which can affect metal loading in groundwater from natural materials.
Routine use of hydrocarbon fuels on site, fuel handling, dispensing and transferring	The storage and transport of petroleum hydrocarbon products (e.g., gasoline, diesel, lubricants, hydraulic fluids, and solvents), as well as fueling and maintenance of machinery, heavy equipment, and vehicles, have the potential affect water quality at local drainages and nearby watercourses, thereby affecting groundwater through infiltration.
Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects	Disposal of mine rock and coal rejects through seepage and metal leaching/acid rock drainage (ML/ARD) and infiltration to groundwater, resulting in increased metal loading (i.e., selenium and nitrate) from pit walls and the MRSF within their footprints. Impacted groundwater will discharge to ground surface relatively close to the MRSF. The rejects and mine rock have generally low ARD potential due to an overall low sulphur content combined with excess neutralization potential. Modelling indicates that load does not generally travel far from sources,

Potential Effect	Rationale for Selection of Environmental Effect
	given a 100 year model run. Load transported to any appreciable distance results in groundwater remaining within guidelines.
Changes in groundwater quality from runoff of water during washing coal and stockpiling of coal	Washing of coal may result in potential increased sediment load and metal leaching. Stockpiling of coal also carries the potential for seepage and metal leaching (i.e., sulphate and selenium) from stockpiles.
Changes in groundwater quality due management and discharge of sediment pond water to West Alexander Creek via infiltration to groundwater	Sediment pond discharge to the receiving environment through surface water-groundwater interactions and potential seepage/leakage from pond to groundwater. Discharge from the sediment ponds has the potential to contain elevated concentrations of TSS, selenium, nitrate, and other parameters that will be released to the receiving environment. Ponds will be lined, thereby minimizing potential interactions.

9.5.2.1 Discussion of Potential Effects

The potential effects identified in Table 9.5-2 are discussed in the context of each Project phase (Construction and Pre-Production, Operations, Reclamation and Closure, and Post-Closure) in the following subsections.

The following Construction and Pre-Production phase activities will have minimal or no interaction with groundwater; transportation of construction materials, logging, clearing and grubbing, stockpiling of wood waste, soil salvage, road and facilities construction and presence of personnel on site.

During the Operations phase, no interaction is expected from any continued construction activities, drilling of blast holes and removal of unconsolidated materials such as soil. Coal processing activities such as run of mine coal sizing, drying, and conveying, and sewage treatment activities are also not anticipated to materially affect groundwater quality or quantity.

Reclamation and Closure and Post-Closure activities phases are not expected to result in substantive interaction with groundwater, with the exception of decommissioning of open pits and sediment ponds (discussed in the following section). All of the Project activities ranked as Level I in Table 9.5-1 are not anticipated to result in adverse effects, and have not been considered further in this effects assessment.

9.5.2.1.1 Construction and Pre-Production

During Construction and Pre-Production, construction of a new access roads and site infrastructure will require quarrying and excavation of construction materials. Overburden stripping, quarrying of rock, site preparation, and dust generation is expected to result in increased sediment load if not mitigated. This may slightly increase organic loading, which can shift groundwater redox conditions to more reducing conditions and affect some metal loadings for redox sensitive constituents that are naturally occurring in the groundwater environment. Dewatering for quarry construction is not expected. As the proposed quarry and road footprints are anticipated to be relatively small, these effects are anticipated to be highly localized and for the duration of quarrying and construction activities only. Where feasible, surface water diversions will be constructed to divert clean runoff from undisturbed areas north of the Grave Creek /

West Alexander Creek drainage divide. Sediment control during construction will be implemented as a mitigation to minimize introduction of suspended solids to the groundwater system.

The construction of the Interim Sediment Pond and Grave Creek Reservoir may affect water levels on a local scale due to temporary damming and flooding, which may influence the local shallow water table. Some local mounding of the local shallow water table is anticipated to affect groundwater flow rates which may result in a temporary change in groundwater redox conditions and metal loadings in the immediate vicinity of the reservoir. These effects are anticipated to be highly localized and not extend beyond the local vicinity (~ 100 m radius). Effects related to the construction of the Grave Creek Reservoir on the groundwater system due to Project infrastructure in the Grave Creek valley bottom (i.e., the Explosive Storage Facility, Grave Creek Water Reservoir, and Rail Loadout) are also not expected to have any significant effect on the groundwater system, since key mine components represent less than 1% of its total area.

Construction activities may introduce sediment to nearby watercourses, which may affect groundwater quality and quantity through groundwater-surface water interactions; however, these can be easily mitigated by best management practices to reduce erosion and minimize sediment introduction to watercourses. The potential environmental effects (including cumulative environmental effects) of these activities on groundwater during the Construction phase will not be significant and are not discussed further.

9.5.2.1.2 Operations

During site operation, some localized erosion and sedimentation is expected from routine operational activities including:

- Continued site construction including mine road development and Main Sediment Pond;
- Blasting and removal of unconsolidated materials from the pits;
- Loading, hauling, and stockpiling of soil, mine rock and coal rejects; and
- Reclamation activities.

As discussed in the previous section, effects on groundwater associated with construction activities will be mitigated by best management practices to reduce erosion and minimize sediment introduction to watercourses. Construction-related effects are not anticipated to be significant and are not discussed further.

Pit Development, Blasting and Dewatering

The development of the North, South, and East Pits will require blasting requiring the storage of fixed emulsion and ammonium nitrate (ANFO) on-site in a designated explosives factory. Explosives storage and handling and decontamination of bulk explosive delivery trucks at the explosives factory have the potential to result in elevated concentrations of nitrogen compounds in mine site drainage if engineered controls are not in place. Loading of blast holes with explosives in the pits also has the potential to result in elevated concentrations of these compounds in the mine site drainage, and excavated material can include blasting residues that contain nitrogen compounds that remain on the surface. There is limited information on the prediction of nitrogen compounds in mine site drainages resulting from blasting activities; however, Ferguson and Leask (1988) found that 0.2% of explosives remain as residues and are lost to runoff in dry conditions and between 2% and 5% in wetter conditions.

Blasting activities will occur primarily during the Operations phase and will cease at the end of mine life, with no additional potential for nitrogen loading from blasting anticipated during the Reclamation and Closure and Post-Closure phases of the Project. The key interactions during the mine Operations phase are expected to result from dust generation due to blasting of open pits and dewatering. Surface mining is proposed in the open pits using conventional open pit, truck/shovel/excavator mining methods at a nominal production rate of 3.7 million run of mine (ROM) tonnes/year.

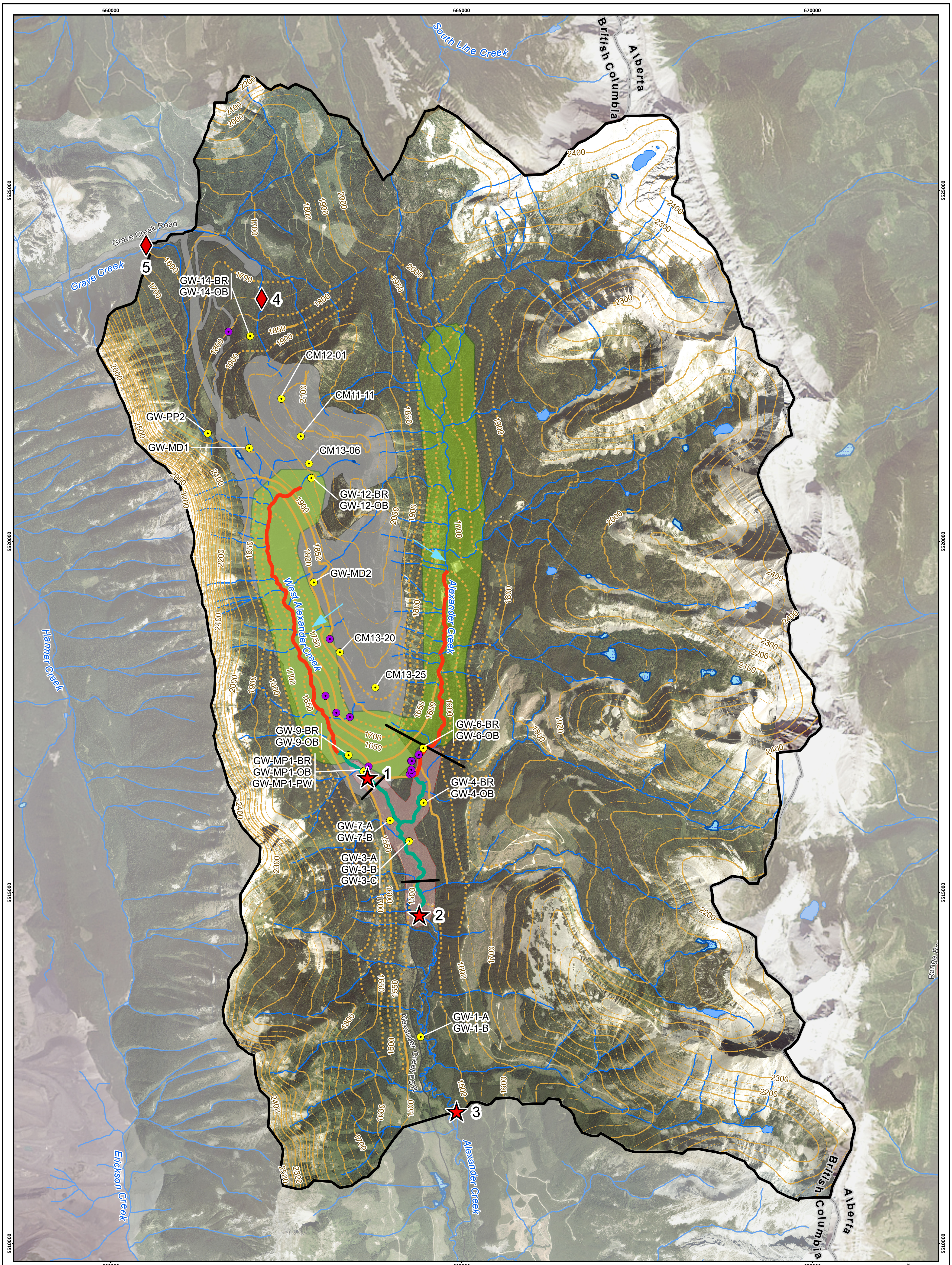
Each of the pits will be developed sequentially, starting with the North Pit. The East Pit will be mined after North Pit is substantially completed, which allows time for the access to be developed to the top of the East Pit. The East Pit is mined through from Year 4 to Year 6. Mining operations will be moved to the southern end of the South Pit. Once the East Pit is complete and will then be backfilled in conjunction with North Pit. The South Pit will be mined in four phases which will allow for earlier backfilling of the mined out South Pit phases.

The North Pit has been identified as the primary source for process water upon completion. Increased water levels due to precipitation and infiltration caused by development of the site are expected to be offset by the use of water; the effects on groundwater quality and quantity are anticipated to be minimal. Use of water from Grave Creek is a secondary source and expected to be minor. If water usage results in significant drawdown of the reservoir, water levels will be affected on a local scale. Contact water used in dust suppression in the pits and in coal washing will be managed and diverted to sedimentation ponds prior to discharge to West Alexander Creek during Operations.

Dewatering induced by pit excavations will affect groundwater flow patterns, to the greatest extent in the immediate vicinity of the pits, and to a lesser degree in other portions of the Groundwater LSA, with reduced effects with increasing distance from dewatering sites. Dewatering rates estimated with the model for end-of-mining (EOM) are 169 and 559 m^3/d for the North Pit and South Pit, corresponding to <1% and 2.2 % of the recharge, respectively.

Pit dewatering flows from the South Pit will be discharged into the Main Sediment Pond intake system and return to creek flow, reducing effects due to changes to the groundwater system in the West Alexander catchment. In the Grave Creek catchment, after year five, pit dewatering flows from the North Pit will be used as process makeup water; after end of mining flows will return to the natural drainage.

At EOM, groundwater flow rates and pit dewatering requirements are not anticipated to be particularly large and will not need dedicated pit perimeter dewatering systems, though actual conditions may be found to require localized systems. As the pits are located on a ridgetop, dewatering effects do not extend significant distances from the pits, though it is possible the ridgetop itself is drained to a large extent. As the open pits are expanded, drawdown will extend outwards, redirecting groundwater flows towards pits and reducing groundwater discharge to creek valley bottoms. During mining, open pits will act as hydraulic sinks and the combination of pit development itself and dewatering will reduce groundwater quantity flowing towards valley bottoms. Potential changes to groundwater flow within creek valley bottoms, at locations shown on Figure 9.5-1, are summarized in Table 9.5-3 below.



Crown Mountain Coking Coal Project

Figure 9.5-1
Flow Cross-Sections and Groundwater Quality Control Points

LEGEND

— Flow Cross-Section
● Seepage Point
● Local Groundwater Monitoring Location

GW Quality Control Points

★ Alexander Creek
♦ Grave Creek

Creek Nature

— Gaining Reach
— Losing Reach

Shallow Aquifer Contours (50 m)

— Measured
…… Inferred
— Modelled

→ Flow Direction

Recharge Zones

🟩 Groundwater Discharge Zone
🟥 Groundwater Recharge Zone
☐ Groundwater Local Study Area
■ Project Footprint

— Local/Resource Road
— Watercourse
■ Waterbody
▨ Wetland
▭ British Columbia/Alberta Border

Scale 1:50,000

Map Drawing Information:
Data Provided By NWP Coal Canada Ltd, Dillon Consulting Limited, Province of British Columbia GeoBC Open Data, Government of Alberta Open Data, Natural Resource Canada. Water level contours were interpreted from groundwater level readings (Sept 2018 - Aug 2020). Creek nature is an interpretation from flow survey conducted by Swiftwater Consulting in 2018.
Imagery Provided By Landsat 8 (Aug 2018), and GeoBC Ortho Imagery (Aug 2016).
Map Created By: MZS
Map Checked By: JFC
Map Coordinate System: NAD 1983 UTM Zone 11N

NWP Coal Canada Ltd

Project: 12-6231
Status: FINAL
Date: 2021-06-09

Table 9.5-3: Potential Effects on Horizontal Groundwater Quantity (Flux) in Valley Bottoms

GW Flux Cross-Section	Baseline (m^3/d)	EOM (most likely) % change from baseline	EOM (uncertainty range) % change from baseline	LTC (most likely) % change from baseline	LTC (uncertainty range) % change from baseline
West Alexander Creek	215	-17%	-25% to -9%	-0.12	-18% to -6%
Upper Alexander Creek (above the confluence)	796	-9%	-14% to -4%	-0.04	-9% to 0%
Alexander Creek (below the confluence)	1001	-4%	-7% to -1%	-0.03	-6% to 0%

Note:
Negative values correspond to decrease in flow
EOM – End of Mining
LTC – Long-Term Closure

Changes to groundwater flow within the shallower aquifer will occur, with decreases in groundwater flow estimated to be most significant in West Alexander Creek at EOM, on the order of 20% lower than baseline. This equates to a decrease on the order of 40 m^3/d (< 1 L/s), which is likely not substantive. Changes to horizontal groundwater flow in the Alexander Creek above the confluence of West Alexander Creek and Alexander Creek, and below this confluence, are estimated to be even less than West Alexander Creek. Impacts to groundwater baseflow are estimated to be most significant for the EOM period. Changes to baseflow are expected to be most significant in West Alexander Creek, with a maximum estimated reduction of 30% with respect to current conditions. This is due primarily to pit dewatering reducing groundwater flow from the pit areas. Groundwater baseflow for Upper Alexander Creek could reduce by up to 5%. Below the confluence of West Alexander Creek and Alexander Creek, baseflow to Alexander Creek could decrease by a cumulative percentage of 7%. After being discharged to the Main Sediment Pond, dewatering flows from the North Pit will be discharged to the creek, reflecting a maximum contribution of 169 m^3/d or a 5% of the West Alexander Creek baseflow.

Impacts to groundwater baseflow are reduced during the long-term closure (LTC) period, as pits fill with water to their spill points and the groundwater system re-equilibrates. Impacts to groundwater baseflow to West Alexander Creek reduce to only 20% lower than baseline; baseflow to Upper Alexander Creek recovers slightly to 4% lower than baseline, and the cumulative change below the confluence is approximately 5% lower than baseline. Impacts at LTC will be mitigated to a large degree by surface flows, and pit decant being redirected back to West Alexander Creek. Changes in baseflow at Grave Creek are predicted to correspond to a maximum reduction of 4% with respect to baseline conditions.

Numerical modelling estimates that potential effects to groundwater quantity resulting from pit dewatering will be greatest during the Operations stage at EOM, with the largest relative effect in the West Alexander Creek valley. Effects are predicted to mostly occur close to the Project footprint. No significant changes are expected to groundwater flow direction to the north of the proposed mining area and to the south of the confluence between Upper Alexander and West Alexander Creeks. Potential changes to baseflow are summarized in Table 9.5-4 as percentage change from the baseline.

Table 9.5-4: Potential Effects on Groundwater – Expected Changes to Baseflows

Mass Balance	Pre-Mining	EOM	LTC
	Groundwater Discharge (m^3/d)	% Change from Baseline[a]	% Change from Baseline[a]
West Alexander Creek Baseflow	3,280	-30%	-21%
Upper Alexander Creek Baseflow	10,368	-5%	-4%
Baseflow below confluence of Upper Alexander Creek and West Alexander Creek[b]	9,169	-2%	-1%
Alexander Creek Cumulative Change[c]	22,817	-7%	-5%
Grave Creek (Upper) Baseflow	2,893	-4%	-2%
Flow from Aquifer (out from model boundary/LSA)	33	0%	0%

Notes:

(a) A negative value represents a reduction with respect to baseflow

(b) Upper Alexander Creek below confluence with West Alexander Creek to model/LSA boundary

(c) Includes West Alexander Creek, Upper Alexander Creek and Alexander Creek below confluence

No change to groundwater quantity through the bedrock is predicted to occur as a result of the Project. This is due to the generally low conductivity of bedrock units and consequently limited area of effect due to pits being located on elevated ridges. There are no mapped aquifers within the Project footprint or Groundwater LSA based on a search of the B.C. Water Resources Atlas (ENV, 2021). Uncertainty exists with the range of inflow to pits and change in valley bottom groundwater flow (or baseflow) due to limited understanding of material hydraulic properties and groundwater recharge, but in general, effects are not expected to be substantive by Alexander Creek or within the upper Grave Creek catchment. Effects on groundwater quantity should decrease with increasing downstream distance in the Alexander Creek and Grave Creek valleys as the catchment area gets larger and surface water flow rates (thus potentially groundwater recharge) generally increase. Effects on groundwater baseflow contribution to surface water are not expected to be substantive, if measurable, at the confluence of Alexander Creek with Michel Creek, nor at Grave Creek where it intersects Harmer Creek.

Estimated change in groundwater elevation at monitoring wells for the End of Mining and Long Term Closure time periods is listed in Table 9.5-5. Changes are estimated based on difference between modeled baseline and future time period scenario.

Table 9.5-5: Potential Effects on Groundwater – Expected Changes to Groundwater Elevations

Well ID	Baseline	EOM		LTC	
	GW Elevation (masl)	GW Elevation (masl)	Change in Water Level from Baseline (m)	GW Elevation (masl)	Change in Water Level from Baseline (m)
CM11-11	2,068	1,978	-90.0	1,975	-93.0
CM12-01	2,069	1,978	-91.1	1,975	-94.0
CM13-06	2,022	1,978	-44.1	1,975	-47.0
CM13-20	1,843	1,671	-171.7	1,671	-171.7
CM13-25	1,860	1,671	-189.4	1,671	-189.4
GW12-BR	1,992	1,978	-13.9	1,975	-16.8

Well ID	Baseline	EOM		LTC	
	GW Elevation (masl)	GW Elevation (masl)	Change in Water Level from Baseline (m)	GW Elevation (masl)	Change in Water Level from Baseline (m)
GW12-OB	1,992	1,978	-14.2	1,975	-17.1
GW14-BR	1,843	1,842	-1.3	1,843	-0.5
GW14-OB	1,844	1,842	-1.3	1,843	-0.5
GW1-A	1,464	1,468	+3.7	1,464	0.0
GW1-B	1,464	1,468	+3.8	1,464	0.0
GW3-A	1,512	1,512	-0.8	1,512	-0.2
GW3-B	1,512	1,512	-0.9	1,512	-0.2
GW3-C	1,512	1,512	-0.9	1,512	-0.2
GW4-BR	1,518	1,517	-0.2	1,517	-0.5
GW4-OB	1,518	1,518	-0.1	1,517	-0.6
GW6-BR	1,539	1,540	+1.6	1,536	-2.7
GW6-OB	1,539	1,538	-1.1	1,536	-2.8
GW7-A	1,516	1,515	-0.2	1,515	-0.4
GW7-B	1,516	1,516	-0.1	1,515	-0.4
GW9-BR	1,586	1,595	+9.3	1,586	+0.2
GW9-OB	1,582	1,595	+13.2	1,582	+0.2
GW-MD1	1,910	1,913	+2.7	1,909	-1.1
GW-MD2	1,818	1,796	-22.7	1,751	-67.4
GW-MP1-BR	1,530	1,525	-5.5	1,530	-0.6
GW-MP1-OB	1,521	1,525	+3.6	1,521	-0.5
GW-MP1-PW	1,524	1,526	+2.4	1,523	-0.5
GW-PP2	1,867	1,867	-0.6	1,867	-0.4

By End of Mining, changes to groundwater levels greater than 1 m, either as increases or decreases, are expected to happen at monitoring wells located within the project footprint. Decreases in water level are most significant near the open pits or at higher elevations. Increase in water levels are estimated for numerous locations down gradient of the mine rock dumps as a result of a more continuous release of water over the year from the dumps themselves.

MRSF, Seepage and Mine Site Drainage

Acid-base accounting for the Project indicate a generally low potential for ARD mine rock due to an overall low sulphur content combined with excess neutralization potential. Isolated potentially ARD generating strata and/or samples have been identified, but the sulphur content is only marginally above 0.1% at 0.12%. The host formation of the target coal seams, the Mist Mountain Formation (MMF) was found to have a sulphide sulphur content of 0.12%, and is classified as generally non-Potentially Acid Generating (non-PAG), where the presence of excess neutralization potential within host and mine rock provides offset acid potential (SRK, 2019). Average data for the Morrissey Formation (MF) indicated that interburden and near seam material is classified as uncertain or Potentially Acid Generating (PAG). This is consistent with expectations for this material and for results at other sites in the Elk Valley (Teck Resources Limited, 2014). The MMF in the Project footprint has comparable low ARD potential to MMF elsewhere in the Elk Valley. It is classified as non-PAG with some isolated zones of PAG material which are generally associated with near seam material and represent a small volume of waste. Coal rejects are not expected to be acid generating based on the presence of low levels of carbonate minerals which appear to provide sufficient buffering of low levels of acidity, and the disposal configuration, which are designed to limit oxidation. The overall conclusion is that ARD potential for mine rock is low, and is supported by the lack of acid drainage throughout the Elk Valley, despite the long history of coal mining in the area and significant amount of monitoring that has taken place over the past 40 years or so.

Trace element characterization for the Project indicates similar potential for leaching from mine rock compared to other sites in the Elk Valley, with the primary constituent of concern being selenium. Other elements were elevated in the mine rock, such as antimony, barium, molybdenum, copper, nickel, zinc, nickel, cobalt, arsenic, mercury, and cadmium. However, geochemical results did not indicate any significant upward trends in release rates for these constituents. Villeneuve et al. (2017) indicates that, in addition to sulphate (associated with the oxidation of pyrite), cadmium, chloride, and nitrate can also be present at elevated concentrations. However, they are typically of short-term concern and are associated with initial flushing of solutes. Recent geochemical studies have also identified arsenic and iron in Elk Valley dump solutes and showed that these solutes are associated with the oxidation of primary sulfides (Biswas et al., 2017; Essilfie-Dughan et al., 2017). As such, arsenic and iron have been included as potential constituents of concern.

Seepage from the MRSF is anticipated to affect groundwater quality within and immediately downstream of their footprints only. Potential effects on groundwater quantity due to the development of the MRSF in the West Alexander Creek valley may change groundwater recharge within the dump footprint, but since the area under the dump is a groundwater discharge zone, any effects should be more pronounced in terms of changes to surface water flow. Groundwater discharge will not be directly affected by the dump; discharge slopes on the east side of West Alexander Creek and to the valley bottom would be expected to continue and move as flow along the base of the dump. Groundwater quality may also be affected during pit dewatering due to anticipated increased groundwater flow rates towards the drawdown area and may have a local effect on the geochemical conditions. Potential seepage and metal leaching (i.e., sulphate and selenium) from pit walls are anticipated due to blasting, rock handling and increased dust generation and may locally affect groundwater seeping from the pit during Operations. Weathering and leaching processes in pit walls are anticipated to be comparable to mine rock; however, on a smaller scale due to the much lower amount of exposed rock surface area. In addition, there is a higher likelihood that carbon dioxide will not accumulate to the same degree in pores and water along pit walls than within the MRSF.

As the mine develops during the Operations phase, changes to groundwater-surface water interactions are expected to occur within creeks and drainages within the Project footprint, where both gaining (i.e., groundwater is entering the system and contributing to baseflow) and losing (i.e., surface water from watercourses goes sub-surface, resulting in reduced baseflow) reaches have been identified. Where possible, non-contact water runoff will be directed away from the mine disturbed areas by means of small catchment sumps and drainage ditches, and routed to the natural catchments draining watercourses. Due to localized challenges such as geotechnical stability and avalanche risks, channel construction is not feasible in all areas of the site such as the upper western slopes of West Alexander Creek above the main mine rock storage facility. As a result, it is expected that water management structures will intercept both surface runoff from undisturbed areas, as well as from mine disturbed areas at these locations.

The majority of impacted groundwater associated with the MRSF is estimated to discharge to ground surface relatively close to the MRSF. The seasonal distribution of flows may be altered somewhat by attenuation of flow through the dumps, and diversion of runoff around the dumps and back into creeks within gaining reaches should reduce impacts on creek flow rates. Impacted groundwater remaining in the groundwater system will flow downgradient towards the Alexander Creek valley, mixing with non-contact waters from other parts of the catchment. Contact groundwater remaining at depth will move slowly downgradient and remain at depth. Mitigation measures for the MRSF, coal processing, washing and stockpiling are discussed in Section 9.5.3.

Sediment Ponds

Two sediment ponds are proposed for managing the combined runoff of contact water from the mine footprint and non-contact water from the upper western slopes of West Alexander Creek as mine development advances. These ponds will be placed downstream of the MRSF and will be developed through the mine life to accommodate the advancing mine rock placement and provide a means to collect and temporarily retain mine affected water to meet Technical Guidance 7 Environmental Management Act requirements (B.C. MOE, 2015). Initially, the Interim Sediment Pond will capture seepage and runoff from the mine rock piles. During Year 4 of Operations, the Main Sediment Pond will be built downstream of the ultimate mine rock storage facility footprint. In addition, the grading and site drainage around the coal handling process plant, maintenance/office complex, and ROM pad will be designed such that runoff from these areas will also drain to the West Alexander Creek catchment. During Year 5, the Interim Sediment Pond will be decommissioned. This infrastructure includes haul roads, the plant and warehouse/shop site, and coal transfer and stockpile areas.

Seepage of contact water from the Interim Sediment Pond could locally infiltrate into the shallow groundwater system but is expected to return to surface flowing along the base of the MRSF in the West Alexander catchment. Flow accretion data and the groundwater numerical model estimate that the area under the MRSF will be a groundwater discharge zone, with any pond leakage mixing with seepage from the dump and reporting to the Main Sediment Pond. Over the long term, seepage from the MRSF will be more significant than pond leakage. Model simulations assuming the sediment pond as a source (for example, from leakage) suggest contact water could travel as far as 2,500 m downstream of the pond, and much further than seepage from the MRSF. Lining of the sediment pond will reduce the potential for any impact, so these estimates are conservative. A percentage of discharge from the Main Sediment Pond could infiltrate into the groundwater system, but is expected to remain shallow due to the presence of a fine grained confining unit at depth in the valley bottom, and discharge back to Alexander Creek within 3,000 m of pond discharge. Water quality predictions estimate no substantial change to concentrations for Grave Creek; groundwater seepage and impacts to groundwater quality are not expected to be substantive at any appreciable distance from the area of the North Pit.

Use of Hydrocarbon Fuels

Operation of mobile mining equipment, fuelling activities, and the storage and transport of petroleum hydrocarbon products (e.g., gasoline, diesel, lubricants, hydraulic fluids, and solvents) present potential risk to groundwater quality on a local scale. While unplanned events such as spills are discussed in Chapter 21, measures related to the proactive mitigation and prevention of spills during routine mine site activities have been discussed in Section 9.5.3.

Fuel storage on-site will include a diesel filling station for heavy mine equipment with four 45,000 L tanks (double-walled) and two fueling stations. The light vehicle station comprises a single 7,000 L tank and a single fueling station. Both stations will be located on the southern edge of the main shop pad area. Small amounts of hydrocarbons released from other Project activities, such as operation and refuelling of mobile mining equipment, will be captured by mine site drainage infrastructure throughout the site.

Potential effects from hydrocarbon release may occur during Construction and Pre-Production, Operations, and Reclamation and Closure, with the significant majority of fuel usage occurring during the Operations phase. No effects are anticipated during Post-Closure as the fueling stations, and all heavy equipment and vehicles will be removed from the site prior to final decommissioning.

9.5.2.1.3 Reclamation and Closure

During Reclamation and Closure, pit development activities will cease; however, some localized erosion and sedimentation may occur from the decommissioning of mine site infrastructure and reclamation of remaining disturbed areas. Project activities associated with pit development during the Operations stage are anticipated to affect local groundwater quality within the Project footprint during the course of Operations into Post-Closure, with reducing concentrations of constituents of concern in groundwater over time. The Main Sediment Pond and associated sediment control structures will remain in place until final closure of the site to manage the potential movement of sediment into the receiving environment.

MRSF, Seepage, and Mine Site Drainage

At decommissioning, the MRSF will have been developed to its maximum extents. Seepage from the MRSF will continue to follow the same trajectories as during the Operations phase, and groundwater flow quantities may change, but overall flow directions will likely remain similar to baseline conditions. Mitigation measures including the design of the MRSF, and decommissioning elements such as re-vegetation and sloping to reduce infiltration, which will result in reduced oxygen availability, are further discussed in Section 9.5.3.

Decommissioning of the Pits

During the Reclamation and Closure phase, dewatering of pits will cease and filling to spill point levels as a function of the altered topography will occur. The groundwater system within the Project footprint will be allowed to re-equilibrate to the surrounding groundwater system, but not to the same state as baseline conditions. The pits will form small pit lakes, or saturated rock fills, and groundwater levels close to these saturated zones will adjust and ultimately stabilize to a new equilibrium water level. Seepage from saturated zones in pits will follow groundwater flow paths within the re-equilibrated flow system, with shallow flow paths mostly reporting to the West Alexander Creek valley bottom under the MRSF. Some seepage will occur from the south end of the South Pit and could move in a southerly direction towards Alexander Creek; flow would be completely within bedrock, and flow rates would be anticipated to be relatively low. Potential effects to cumulative groundwater quantity are not expected to be substantive. Potential effects to groundwater quality are expected to be less substantive than effects related to MRSF seepage.

Sediment Ponds

Management of the Main Sediment Pond discharge, including associated sediment control structures, will remain in place during Post-Closure until all water quality objectives have been met. The Main Sediment Pond will then be decommissioned to re-establish flows in West Alexander Creek, and will require the removal of sediment from the dam structure, constructing additional spillways, and breaching the main dam. Sediment removed from the pond will be placed in the mine rock storage facility for disposal. Under this scenario, groundwater flow quantity, which is a small percentage of total flow at the Project, is not estimated to have a substantive effect on total flow quantity. Surface flows are routed back to receiving streams, and groundwater will combine with this flow. Infiltration of pond discharge into the groundwater system could occur but is expected to discharge back into Alexander Creek within 3,000 m of the pond discharge. The combination of mixing with other groundwater inputs and any natural attenuation would further reduce effects of groundwater discharging back to surface water.

9.5.2.1.4 Post-Closure

Effects on groundwater baseflow quantity during the Post-Closure phase are reduced as compared to prior phases, as the groundwater system re-equilibrates, with no significant changes in flow directions and hydraulic gradients anticipated. Long-term closure pit water levels will reach a maximum elevation corresponding to decant points: 1,978, 2,049, and 1,671 m asl for North Pit, East Pit, and South Pit, respectively. Reclamation activities are conservatively assumed to have no interaction with the groundwater system and are not discussed further.

9.5.2.2 Transboundary Effects

The Project is located approximately 5 km west from the Alberta border and 85 km north from the Montana border in the United States of America. As discussed in Chapter 1, Section 1.3.3, the nearest federal lands to the proposed Project are the ?aq'am First Nation Bummer's Flat 1 Reserve (approximately 69 km southwest), Stoney Nakoda Edan Valley 216 Reserve (approximately 70 km northeast), Tobacco Plains 2 (approximately 80 south), Piikani Nation Peigan Timber Limit 147B (approximately 52 km east in Alberta), and Parcels 73 and 82 of the Dominion Coal Blocks (approximately 20 and 40 km southwest, respectively). Federal land is not required to facilitate the Project and the Project does not overlap with any federal land.

Due to their distance from the Project and associated Project activities and components that may affect groundwater quantity and quality, and based on the groundwater catchment divides indicated by regional topography and watercourses, potential groundwater effects arising from the Project are not expected to occur in either the bordering province of Alberta, the bordering State of Montana, or on federal lands. As such, transboundary effects on groundwater quantity or quality arising from the Project are not expected to occur in either province or state or on federal lands.

9.5.3 Mitigation Measures

The mitigation measures proposed for groundwater quality and quantity are based on available best management practices, provincial and federal guidance documents, mitigation measures conducted and accepted for similar projects, and professional judgement. The identification and selection of technically and economically feasible mitigation measures followed the mitigation hierarchy approach outlined by the provincial Environmental Mitigation Policy and related Environmental Mitigation Procedures (British

Columbia Ministry of Environment (B.C. MOE, 2014b; 2014c). For the purposes of this assessment, mitigation measures are defined to include Project design features, procedures, or practices that will reduce or eliminate Project-related effects to groundwater. Where mitigation measures are considered to be highly effective, potential Project effects to groundwater quantity and quality are not identified as residual effects.

9.5.3.1 Groundwater Quantity

The following subsections describe mitigation strategies for the following potential Project effects on groundwater quantity from:

- Changes in groundwater quantity from the construction of the Interim Sediment Pond, Main Sediment Pond and Grave Creek Reservoir;
- Changes in groundwater quantity from pit development, blasting, mining and dewatering;
- Changes to groundwater quantity through altered drainage patterns and groundwater-surface water interactions associated with loading, hauling and dumping of mine rock and coal rejects at the MRSF;
- Changes to groundwater quantity due to use of water as primary process make-up water from the Interim Sediment Pond (Year 1 to 5) and from the North Pit (Year 5 to 15), with Grave Creek Reservoir used as a secondary source of process make-up water;
- Changes to groundwater quantity associated with surface water-groundwater interactions during discharge of effluent from the Interim Sediment Pond and Main Sediment Pond during Operations and Reclamation and Closure; and
- Changes to water table elevation in the local vicinity of the pits by filling to spill point levels during the Reclamation and Closure phase.

In general, mitigation measures for groundwater quantity are not considered to be required during Operations as groundwater flows are not expected to be impacted substantively beyond the immediate vicinity of the Project footprint. The implementation of impermeable liners at the Interim and Main Sediment Pond and the Grave Creek Reservoir will dampen any local interactions with groundwater, including changes to local groundwater levels and gradients. The implementation of pond liners is further discussed in the following section as they related to mitigation of effects to groundwater quality.

During active mining of the pits during the Operations phase, it will be necessary to dewater each pit through the use of drainage ditches, berms, sumps and pumps. Water collected and pumped out of the North and East Pits will be collected through internal ditches and directed to the Interim Sediment Pond up to Year 4. Following construction of the Main Sediment Pond, all water will be routed around the MRSF and to the Main Sediment Pond, including water originating from the South Pit. Pit dewatering will be coordinated to meet overall water quality objectives, within groundwater monitoring occurring throughout the life of the Project into Post-Closure. After mining has ceased, each pit will be backfilled in accordance with the designs with mine rock, which will ultimately negate the need for pumping infrastructure. Pits will be allowed to fill to their spill point levels and re-equilibrate with the surrounding local groundwater environment. Once the pits are full, and equilibrium has been achieved, there should be no further interaction between the Project and groundwater quantity.

9.5.3.2 Groundwater Quality

The following subsections describe mitigation strategies for the following potential Project effects on groundwater quantity from:

- Changes in groundwater quality due to infiltration of non-contact surface water runoff to groundwater;
- Changes in groundwater quality due to infiltration of contact water (i.e., surface water and mine site drainage) to groundwater;
- Potential release of explosive residues (i.e., nitrogen forms) and hydrocarbon fuels to the environment;
- Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects at the MRSF;
- Changes in groundwater quality from runoff of water during washing coal and stockpiling of coal; and
- Changes in groundwater quality via infiltration to groundwater due management and discharge of sediment pond water to West Alexander Creek.

9.5.3.2.1 Mitigation Measures for Changes in Groundwater Quality due to Infiltration of Non-Contact Surface Water Runoff to Groundwater

The primary measure to mitigate changes in surface water quality, thereby mitigating associated effects in groundwater quality from non-contact water runoff, is to reduce the potential for erosion and the transportation of material in surface runoff to the West Alexander Creek, Alexander Creek, Grave Creek, and Elk River drainages. This is done through the implementation of the Erosion and Sediment Control Plan (ESCP; Chapter 33, Section 33.4.1.4). Specific mitigation measures, as organized by mitigation hierarchy level, include:

1. Avoid:
    - Earthmoving activities throughout the life of mine will be scheduled to limit durations of exposed soils and to avoid such activities during wet and/or windy seasons, where possible;
    - Sediment loading in runoff will be reduced by the application of standard industry practices (e.g., benching, erosion blankets, silt fencing) to intercept sediment before it reaches the receiving environment; and
    - Regular inspections will be conducted to confirm drainage, erosion, and sediment control measures are effective and functioning properly, which will allow for timely repairs and adjustments as required.
2. Minimize:
    - NWP's site strategy for surface water (detailed in the Site Water Management Plan [SWMP] in Chapter 33, Section 33.4.1.8) includes limiting the mine disturbance footprint and avoiding affecting additional drainages beyond West Alexander and Grave Creeks;
    - Further to the north of the Grave Creek-West Alexander Creek drainage divide, runoff will be directed to small catchment sumps prior to release or managed with localized erosion mitigation measures for small isolated areas of disturbance (e.g., minor road cuts); and
    - Surface water that cannot be diverted is captured in sediment ponds prior to release into the West Alexander Creek drainage.
3. Restore On-Site:

- Progressive reclamation and revegetation will occur throughout the mine life to minimize erosion potential and reduce the Project footprint, minimizing the potential for runoff effects to surface water.

No residual effects from non-contact water runoff are predicted on groundwater quality through the implementation of the ESCP and the SWMP. The SWMP will include a groundwater quality monitoring program including measurement of groundwater levels and collection of groundwater sampled at select groundwater monitoring wells on a seasonal basis. In addition, the SWMP will include a Trigger Action Reponses Plan (TARP) detailing trigger thresholds for ground quality and quantity. Groundwater monitoring data will be used to update the groundwater model (if necessary), and validate the efficiency of the proposed mitigation measures.

9.5.3.2.2 Mitigation Measures for Changes in Groundwater Quality Due To Infiltration of Mine Contact Water (i.e., Surface Water and Mine Site Drainage) to Groundwater

The primary measure to mitigate potential effects to groundwater quality from other constituents contained in mine site drainage will be to direct all contact water to the Interim and Main Sediment Ponds for settling to remove suspended solids and allow the testing of water quality prior to discharge into West Alexander Creek as detailed in the SWMP. In addition, effects from mine site drainage will be minimized through limiting the mine disturbance footprint and avoiding affecting additional drainages beyond West Alexander and Grave creeks.

Based on scientific studies and wider knowledge of the geochemistry of Elk Valley coal mines, it is evident that ARD is typically of low concern. However, these studies have all identified metal leaching, specifically relating to the release of selenium, of principal concern. Selenium concentrations in rocks within the Project footprint shows concentrations varying from 0.80 to 2.2 milligrams per kilogram (mg/kg) on average, with lower concentrations in sandstones and higher concentrations in mudstones. These results are very similar to academic studies in the Elk Valley. From the groundwater quality predictions, none of the groundwater control points are expected to have selenium concentrations above the B.C. Drinking Water Guidelines within 100 years following the start of pre-production.

After mining has ceased, each pit will be backfilled with mine rock, which will ultimately negate the need for pumping infrastructure. Research shows that selenium and nitrate are effectively reduced in mildly sub-oxic saturated zones once open pits are backfilled and saturated with groundwater inflow (Kirk et al., 2017), minimizing the potential for effects to surface water and groundwater quality. Residual effects from pit dewatering and infiltration of mine contact water to groundwater are anticipated to be in concentrations less than guidelines. Any residual effects will be addressed through the implementation of the SWMP, and monitoring and adaptive management will be used to validate the efficiency of the proposed mitigation measures.

9.5.3.3 Mitigation Measures for Changes in Groundwater Quality from Surface Water – Groundwater Interactions at Sedimentation Ponds

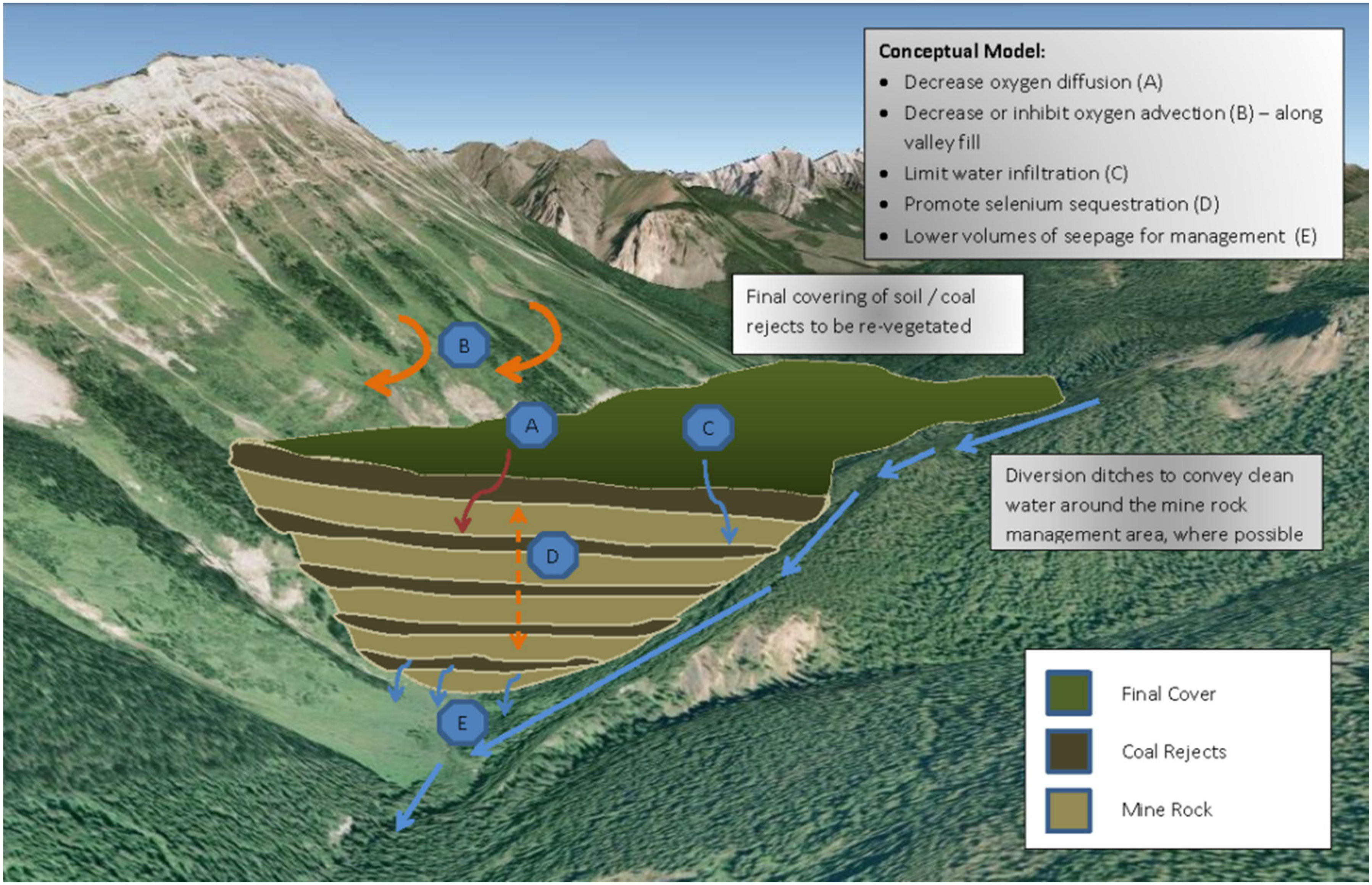
Groundwater infiltration/seepage from ponds into the ground has the potential to adversely affect groundwater quality; however, effects are expected to be effectively mitigated using impermeable liners to prevent losses. The sediment ponds are sized according to B.C. Ministry of Environment Technical Guidance 7 Environmental Management Act requirements (B.C. MOE, 2015), to settle particles having a diameter of 5 to 10 microns or greater during conveyance of runoff resulting from the 10-year, 24-hour storm event. They also include riprap spillway structures and containment berms to contain and convey the 200-year, 24-hour storm and maintain adequate freeboard. Avoidance measures include the diversion of clean, non-contact water away from the sediment ponds and other Project infrastructure, where possible, to reduce the burden on the sediment ponds. Water treatment will lower contaminants of potential concern to either below the provincial and/or CCME water quality guidelines, or to within natural variability of the baseline concentrations in the receiving environment. Restorative measures include progressive reclamation and revegetation throughout mine life to reduce the Project footprint, minimizing the potential for surface runoff from mine disturbed areas. The Main Sediment Pond will be decommissioned Post-Closure once effluent quality objectives have been met.

Increased sediment loads and metal loadings are anticipated in sedimentation pond water. Final seepage and pond effluent will be discharged directly to West Alexander Creek. Groundwater quality is assumed to be the same quality as in the sediment pond and, with significantly lower flow rates, will constitute a significantly lower chemical load. Effects on groundwater quantity should decrease with increasing downstream distance in the Alexander Creek valley as the catchment area gets larger and surface water flow rates (thus potentially groundwater recharge) generally increase.

Impacts at the confluence of Alexander Creek with Michel Creek are not expected to be substantive, if measurable. Concentrations in the sediment ponds would be below guidelines for most of the year, except during winter months. Water from the Main Sediment Pond is assumed to be discharged back to Alexander Creek. Under this scenario, groundwater flow, which is a small percentage of total flow at the project, has no material effect on the system; surface flows are routed back to receiving streams and groundwater will simply combine with this flow. Discharge of this water into creeks, should it occur in groundwater discharge areas downstream of the sediment ponds, is assumed to not materially worsen surface water quality. These groundwater flow paths would be long (10s to 100s of years) and the combination of mixing with other groundwater inputs and any natural attenuation would further reduce risk of impact from these waters, if they discharged to surface water. Simulations assuming the sediment ponds as a source (for example, from leakage) suggest mine contact water could travel as far as 2,500 m downstream of the pond, and much further than seepage from the MRSF. Lining of the sediment ponds will reduce the potential for any impact, so these estimates are considered conservative. Groundwater and surface water monitoring and adaptive management will be used to validate the goals and water management strategies detailed in the SWMP.

9.5.3.3.1 Mitigation Measures for Changes in Groundwater Quality from Loading, Hauling and Disposal of Mine Rock and Coal Rejects

Potential adverse effects to groundwater quality from metal leaching are addressed through a layered mine rock design, as an in situ mitigation strategy for selenium leaching. The approach to mine rock management for Crown Mountain is based on a layering of coal rejects and mine rock (Figure 9.5-2). The reject layers will act as sub-oxic environments where oxygen, nitrate and selenate will be reduced to water, nitrogen gas and selenite, or elemental selenium, respectively. The layers also act to disrupt large-scale gas convection thereby restricting oxidation of the mine rock. Oxidation will continue on the edges of the facility but is modelled to be restricted internally. The aim of the layered approach to mine rock management at Crown Mountain is to mitigate against the oxidation of pyrite and prevent the release of selenium and nitrate in the long term. Excess neutralizing potential will also lead to attenuation of elements such as cadmium, zinc and copper by reaction with iron oxides under basic weathering conditions.



Conceptual Model:

- Decrease oxygen diffusion (A)
- Decrease or inhibit oxygen advection (B) – along valley fill
- Limit water infiltration (C)
- Promote selenium sequestration (D)
- Lower volumes of seepage for management (E)

Final covering of soil / coal rejects to be re-vegetated

Diversion ditches to convey clean water around the mine rock management area, where possible

Source: NWP Coal Canada Ltd (https://www.nwpcoal.com/environmental)

Figure 9.5-2: Layered Approach to Mine Rock Management

Mitigation measures to minimize ML/ARD are described in the Site Water Management Plan (Chapter 33, Section 33.4.1.8) and include the placement of mine rock outside of the pits will blend potentially acid generating (PAG) and non-PAG materials such that the resulting mixture performs as non-PAG. Mine rock will initially be placed outside of the valley-floor area of West Alexander Creek, located between the North Pit and East Pit footprints.

The MRSF will require ongoing maintenance to maintain roads, berms, and water management/ sediment control features. The North Pit and East Pit will be suitable for placement of mine rock because the mine rock will be contained inside the pit walls. Water accumulating inside the pits will saturate the lower portions of the mine rock fill, limiting oxidation and subsequent selenium release. Selenium concentrations in groundwater and outflows from saturated backfills are much lower than observed for comparable mine rock in conventional ex-pit mine rock at several operating mines.

Restorative measures include the progressive reclamation of available MRSF areas to be integrated into the overall mine schedule and soil handling plan in order to achieve reclamation objectives after the mine rock has been placed to final grade and re-sloped. Monitoring and adaptive management will be used to validate the efficiency of the proposed ML/ARD mitigation measures through the implementation of the ML/ARD Plan, and the SWMP.

Mitigation to collect groundwater from the dumps is not considered necessary at this time. If the MRSF does not perform as expected, and groundwater mitigation is deemed appropriate, the West Alexander Creek valley represents an ideal location for a conventional collection or cut-off system. The valley is relatively narrow, overburden is shallow and groundwater flows are low, on the order of 2 to 3 L/s. Deeper flow, in bedrock, is estimated to be a minor component in the overall groundwater flow system. Effects on groundwater quantity should decrease with increasing downstream distance in the Alexander Creek valley as the catchment area gets larger and surface water flow rates (thus potentially groundwater recharge) generally increase. Impacts at the confluence of Alexander Creek with Michel Creek are not expected to be significant, if measurable. Water quality predictions estimate no significant change to concentrations for Grave Creek; groundwater seepage and impacts to groundwater quality is not expected to be significant at any appreciable distance from the area of the North Pit.

9.5.3.3.2 Mitigation Measures for Changes in Groundwater Quality from Runoff of Water during Washing Coal and Stockpiling of Coal

Generally, handling, run of mine sizing, and general processing of coal product will be conducted within designated areas on controlled surfaces or indoors. Coal stockpiling and processing is contained within a building with concrete floor and containment, where process water enters via an interior sump and is recycled within the plant. Wash water is recirculated and reused throughout the process, which is a closed circuit with the exception of dryer by-products, clean coal product and plant rejects. No residual effects are expected due to processing and stockpiling of coal product with these mitigation measures in place.

9.5.3.3.3 Mitigation Measures for Storage and Handling of Hydrocarbon Fuels

Fuelling activities and bulk fuel storage will occur in designated areas only. Fuel storage and fuelling stations will be located on the southern edge of the main shop pad area, and service fluid tanks will be located adjacent to the maintenance shop on a bermed secondary containment pad. Vehicle washing and routine maintenance activities will also occur in a lined facility or equivalent. Mitigation measures to minimize hydrocarbon releases to surface water are described in the Spill Prevention, Control, and Countermeasures Plan (Chapter 33, Section 33.4.1.10) and include, as organized by mitigation hierarchy level:

- Avoid:
    - Designation of appropriate locations where mobile equipment will be refueled, lubricated, and serviced with appropriate containment measures.
    - All fuels will be delivered to site by a licensed contractor.
- Minimize:
    - Implementing procedures for handling and storing fueling and fuel transfer;
    - Developing, implementing, and documenting regularly scheduled site inspections, which include fueling locations and shops;
    - Inspecting vehicles and equipment regularly for leaks and document their condition;
    - Developing, implementing and documenting a preventative maintenance program for all vehicles and equipment on site; and
    - Placement of spill kits at high risk locations (i.e., in areas with the highest risk activities).

Residual effects from hydrocarbons are not predicted on groundwater quality through the implementation of the Spill Prevention, Control, and Countermeasures Plan, and monitoring and adaptive management will be used to validate the efficiency of the proposed mitigation measures.

9.5.3.3.4 Mitigation Measures for Nitrogen Loading from Explosives Use

The location of the explosives factory has been selected based on requirements in the Natural Resources Canada (NRCan) Guidelines for Bulk Explosives Facilities Minimum Requirements G05-01 (2014), National Standard of Canada Explosives – Quantity Distances, document number CAN/BNQ 2910-510, 2015, and the Health, Safety and Reclamation Code for Mines in British Columbia (British Columbia Ministry of Energy, Mines and Low Carbon Innovation, 2021). This facility will be located approximately 1.4 km from the active mining area in the northeast portion of the Project footprint on a separate access off the Grave Creek Road. Construction and maintenance of the facilities will be the responsibility of the selected licenced blasting contractor, in addition to the environmental, health, and safety requirements for the operation of the explosives factory. All water used in the decontamination of the bulk explosive delivery trucks and other equipment will be collected from the explosives factory wash bay and stored in a secure holding tank, and disposed off-site by the blasting contractor at an approved facility.

Mitigation measures to minimize nitrogen loading to surface water and groundwater during blasting activities are described in the Site Water Management Plan (Chapter 33, Section 33.4.1.8) and include, as organized by mitigation hierarchy level:

1. Avoid:
    - Blasting activities will be limited to within the North, East, and South Pits, avoiding additional nitrogen loading to other areas of the site; and
    - Look to use non-nitrate explosives as they become commercially available.
2. Minimize:
    - Lining all blastholes to keep the ANFO dry;
    - Minimizing the use of emulsion bulk explosives;
    - Optimizing the blasthole size and pattern design;
    - Limiting the sleep time of a loaded pattern to one week; and

- Training of employees to limit spillage of explosive agents on the blast pattern.

In addition, the proposed layered mine rock design is intended to reduce nitrate leaching from blasting residues on the mine rock. With the mitigation measures outlined in the Site Water Management Plan (Chapter 33, Section 33.4.1.8) in place, a direct residual effect to groundwater quality as a result of nitrogen loading from blasting activities is not anticipated.

9.5.3.4 Summary of Mitigation Measures for Groundwater Quality

The key mitigation measures proposed to mitigate potential effects on groundwater quantity and quality are summarized in Table 9.5-6. This table also identifies the anticipated residual effects that will be carried forward in the characterization of residual effects, significance, and likelihood and confidence.

These proposed mitigation measures are generally accepted, understood, and proven to effectively reduce environmental effects related to surface water and groundwater quality. Given that the impacts to groundwater quality and quantity cannot be completely avoided, the overall effectiveness of the proposed mitigation to address changes from the development of pits, blasting and dewatering, altered drainage patterns, water table elevation, infiltration of mine contact water, loading, hauling and disposal of mine rock and coal rejects, and the management and discharge of sediment pond water are rated as moderate. Where mitigation measures do not or may not mitigate all effects or if there is a low level of confidence in their effectiveness, the effect was carried forward for further analysis of residual effects.

Mitigation measures that are expected to completely mitigate potential effects with a high level of confidence based on their proven effectiveness elsewhere were classified as having no expected residual effects.

The effectiveness of the proposed mitigation measures will be addressed through the Site Water Management Plan (Chapter 33, Section 33.4.1.8). If monitoring indicates that the effectiveness of mitigation measures is lower than predicted, further mitigation may be required as per adaptive management strategies outlined in the Site Water Management Plan.

9.5.4 Characterization of Residual Effects, Significance, Likelihood and Confidence

Based on the evaluation of potential Project effects on groundwater quantity, potential residual effects that may remain after implementation of proposed mitigation measures include:

- Changes in groundwater quantity from development of pits by blasting and dewatering;
- Changes to groundwater quantity through altered drainage patterns and groundwater-surface water interactions associated with loading, hauling and dumping of mine rock at the MRSF; and
- Changes to water table elevation in the local vicinity of the pits during Reclamation and Closure and filling of pits to spill point levels.

Table 9.5-6: Proposed Mitigation Measures for Groundwater Quantity and Quality

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Groundwater Quantity					
Changes in groundwater quantity from Construction and Operation of Interim Sediment Pond, Main Sediment Pond and Grave Creek Reservoir	Installation of impermeable liners in the Interim and Main Sediment Ponds.	Impermeable geomembrane liners are proven to be effective in preventing interaction with groundwater. However, the potential for seepage of contaminated groundwater to surface water downstream of the sediment ponds remains. Alteration to local groundwater conditions due to development of the Grave Creek Reservoir.	Construction and Pre-Production, and Operations	High	No
Changes in groundwater quantity from development of pits, blasting and dewatering	During active mining, dewatering will be carried out using drainage ditches, berms, sumps and pumps to sedimentation ponds. Pit dewatering will be coordinated to meet overall water quality objectives. Groundwater monitoring.	Standard industry practices for dewatering are proven to be effective at reducing impacts in the receiving environment.	Operations	Moderate	Yes
Changes to groundwater quantity through altered drainage patterns and groundwater-surface water interaction associated with loading, hauling and dumping of mine rock at the MRSF	Engineered layering of coal rejects and mine rock at the MRSF, and progressive reclamation by re-vegetation and re-sloping. Groundwater monitoring.	Engineered MRSF designed to increase infiltration. Water recharging groundwater from infiltration through the dumps is assumed to be double natural recharge (from slow release of storage), and will be conveyed around the MRSF to sedimentation pond. Reclamation activities limit exposure time of seepage water.	Construction and Pre-Production, Operations, and Reclamation and Closure	Moderate	Yes

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Changes to groundwater quantity due to use of water as primary process make-up water from the Interim Sediment Pond (Year 1 to 5) and from the North Pit (Year 5 to 15. Grave Creek Reservoir may be used as a secondary source of process make-up water	Groundwater and surface water monitoring.	Increased infiltration is expected to be offset by the use of water at the Site, effects on groundwater quantity are anticipated to be minimal. Increased water within North Pit from precipitation is expected to be offset by the use of water at the Site, effects on groundwater quality are anticipated to be minimal. Use of water from Grave Creek is a secondary source and expected to be minor.	Operations	High	No
Changes to groundwater quantity associated with surface water-groundwater interactions during discharge of effluent from the Interim Sediment Pond and Main Sediment Pond during operation and reclamation and closure	Installation of impermeable liners in the Interim and Main Sediment Ponds.	Liners will minimize interaction of pond water with groundwater and minimize effect on local water levels. Pond water will be released to West Alexander Creek.	Operations	High	No
Changes to water table elevation in the local vicinity of the pits during reclamation and filling of pits to spill point levels	Groundwater monitoring.	Collection and management of groundwater flow into the pits during Operations. Flooding of pits to spill point during Reclamation and Closure and revegetation of decommissioned areas.	Reclamation and Closure and Post-Closure	Moderate	Yes

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Groundwater Quality					
Changes in groundwater quality due to infiltration of non-contact surface water runoff to groundwater	Limit erosion and contain sediment through the application of standard industry practices. Conduct regular inspections to confirm control measures are effective and functioning properly. Divert clean runoff around mine disturbed areas, where possible. Capture clean surface water that cannot be diverted in sediment ponds prior to release. Limit the mine disturbance footprint through Project design and progressive reclamation. Groundwater and surface water monitoring.	Erosion and sediment control measures (e.g., silt fencing) are standard industry practices and proven to be effective. Regular inspection of erosion and sediment control measures allows for timely repairs and adjustments as required. Minimizing the Project footprint minimizes potential erosion and sedimentation effects to surface water.	Construction and Pre-Production, Operations, and Reclamation and Closure	High	No
Changes in groundwater quality due to infiltration of mine contact water (i.e., surface water and mine site drainage) to groundwater	Limit the mine disturbance footprint through Project design and progressive reclamation. Control mine site drainage through the layered MRSF design and diversion ditches to sedimentation ponds. Ponds are equipped with impermeable liners. Groundwater and surface water monitoring.	Minimizing the Project footprint, particularly area of exposed soils, minimizes potential wind erosion and dust generation. Liners will minimize interaction of pond water with groundwater and minimize effects of seepage/leakage of pond water to groundwater.	Construction and Pre-Production, Operations, and Reclamation and Closure	Moderate	Yes

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Routine use of hydrocarbon fuels on site, fuel handling, dispensing and transferring	Restricting the storage and transfer of fuel will be restricted to certain areas. Implementing procedures for handling and storing fueling and fuel transfer. Conducting regular site and vehicle inspections. Preventative maintenance for all vehicles and equipment on site.	Standard industry practices for handling, storing, and transferring fuel are proven to be effective at reducing the release of hydrocarbons to the receiving environment. Regular inspections of the site, vehicles, and equipment allows for timely repairs and adjustments as required.	Construction and Pre-Production, Operations, and Reclamation and Closure	High	No
Potential release of explosive residues (i.e., nitrogen forms) to the environment	Following provincial and federal requirements for the storing and handling of explosives. Collection and disposal of decontamination water off site. Lining all blast holes to keep the ANFO dry. Minimizing the use of emulsion bulk explosives. Optimizing the blast hole size and pattern design. Limiting the sleep time of a loaded pattern to one week. Training of employees to limit spillage of explosive agents on the blast pattern.	Standard industry practices are proven to be effective to reduce the potential for nitrogen loading from explosives use. However, some nitrogenous residues are likely to remain on mine rock after blasting that is placed in the mine rock storage facilities.	Construction and Pre-Production and Operations	High	No

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects	Divert clean runoff around mine disturbed areas, where possible. Capture clean surface water that cannot be diverted in sediment ponds prior to release. Conduct regular inspections to confirm control measures are effective and functioning properly. Engineered layering of the MRSF. Saturated backfill of mine rock with high selenium levels in the East and North Pits. Progressive reclamation of the mine rock storage facilities. Groundwater and surface water monitoring.	The mine rock placement outside of the pits will blend PAG and non-PAG materials such that the resulting mixture performs as non-PAG. The reject layers will act as sub-oxic environments where oxygen, nitrate and selenite will be reduced in a few years. The proposed design will be evaluated during the first few years of operations to determine if successful by monitoring for evidence of decreasing oxygen levels and water chemistry indicators of nitrate and selenium removal such as stable isotopes. Selenium removal from contact waters has not been demonstrated directly, but selenium concentrations from saturated backfills are much lower than observed for conventional ex-pit mine rock at several operating mines. Progressive reclamation will limit exposure time of the mine rock storage facility.	Construction and Pre-Production, Operations, Reclamation and Closure, and Post-Closure	Moderate	Yes
Changes in groundwater quality from runoff of water during washing coal and stockpiling of coal	Generally, handling of coal product is on controlled surfaces or indoors.	Coal processing, including hauling, run of mine sizing, stockpiling and loading are conducted in designated areas on controlled surfaces or indoors to prevent infiltration of water to ground.	Operations	High	No

Potential Effect	Mitigation Measure(s)	Rationale	Applicable Project Phase(s)	Effectiveness	Residual Effect
Changes in groundwater quality due management and discharge of sediment pond water to West Alexander Creek via infiltration to groundwater	Diverting clean, non-contact water away from the sediment ponds, where possible. Appropriate sizing of sediment ponds and installation of impermeable liner to minimize seepage losses and convey runoff during storm events. Treating water prior to discharge as required in order to meet effluent standards. Limit the mine disturbance footprint through Project design and progressive reclamation. Groundwater and surface water monitoring and adaptive management.	Appropriately sized sediment ponds are proven to be effective to settle particles. Minimizing the Project footprint reduces the amount of surface runoff from mine disturbed areas, reducing the burden on the sediment ponds. However, the potential for discharge of water containing elevated concentrations of TSS, selenium, nitrate, or other parameters exists should other upstream mitigation methods (e.g., mine rock management) not operate as intended. Liner to mitigate effects leakage and seepage of pond water to groundwater. Pond water is expected to meet effluent standards and B.C. WQG Aquatic Life guidelines prior to discharge to West Alexander Creek.	Operations, Reclamation and Closure, and Post-Closure	Moderate	Yes

Potential Project effects on groundwater quality that present potential residual effects include:

- Changes in groundwater quality due to infiltration of mine contact water (i.e., seepage and mine site drainage) to groundwater;
- Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects at the MRSF; and
- Changes in groundwater quality due management and discharge of sediment pond water to West Alexander Creek via infiltration to groundwater.

9.5.4.1 Groundwater Quantity and Quality Assessment Methods

Potential Impacts from Project were assessed using the 3D groundwater numerical model described in Section 9.4.2.7. The model was calibrated to current conditions for water level and flow, then was used to assess potential future conditions for the following scenarios:

- End of Mining (EOM): when Project footprint, open pits and dewatering, and MRSF have been developed to their maximum extents; and
- Long Term Closure (LTC): when Project footprint is at its maximum, but open pits have been flooded to decant levels. Reclamation activities are assumed to have no additional impact on the groundwater system.

The baseline model was presented in Section 9.4.3. Potential effects on the Project on groundwater quantity due to the North, East and South open pits, the MRSF (external and internal) and the lined sediment pond were assessed by comparing results of the EOM and LTC predictive models to the baseline model. Groundwater flow was quantified across cross-sectional areas to 50 m depth in the West Alexander and Alexander Creek valleys, as well as groundwater discharge to West Alexander, Upper Alexander, Alexander and Grave creeks. Cross-section locations and creek reaches used for each assessment are shown on Figure 9.5-1. Results of the groundwater quantity modelling have been discussed throughout the previous section, with further details on the modelling approach and methodology provided in Appendix B of the Groundwater Technical Report (SRK, 2021a), in Appendix 9-A.

9.5.4.1.1 Predictive Groundwater Modelling – Groundwater Quality

The numerical model was used to inform groundwater pathways and the magnitude of change to groundwater quality that could occur. The baseline numerical model was modified and run in a conservative transport mode to estimate migration of water from source locations through the groundwater system and mixing of this water with other groundwater entering the system from non-contact sources. Details on the base model can be found in Appendix B of SRK (2021a), provided in Appendix 9-A. The transport model assumed a fixed source concentration of 100 mg/L, longitudinal dispersivity of 100 m and an average value of 10 m for transverse dispersivity. The predictive transport model was run transiently for 100 years starting at the first year of operation. Control points in the groundwater numerical model were used to extract breakthrough concentrations of the modelled contaminant plume. Processing of these data to convert to estimate actual concentrations and results are described further in this section.

An important part of the Project design is the engineered mine rock dump that will be constructed to reduce nitrate and selenium concentrations in water seeping from the dump. Water quality predictions (SRK 2021b) estimate that if the dump functions as designed, selenium and nitrate concentrations in Grave and Alexander creeks would be below the proposed Coal Mining Effluent Regulations (CMER) or B.C. Aquatic Life guidelines (chronic). Concentrations in the sediment pond would be below guidelines for most of the years, except during winter months (SRK, 2021b). Water from the sedimentation pond is assumed to be discharged back to Alexander Creek. Assessment of potential effects directly from this system are presented in Appendix B of SRK (2021b), provided in Appendix 9-A.

Particle tracking from the Main Sediment Pond within the groundwater numerical model shows that the streamlines starting at this facility remain shallow within the first 30 m from ground surface. Results from the groundwater model are not directly incorporated into the surface water quality prediction model. The water quality prediction model assumes that total catchment yield for all affected catchments reports to surface water each year. This catchment yield is effectively annual runoff, which itself includes groundwater that is contributing to runoff (baseflow). The transport groundwater model estimates future groundwater quality in both shallow and deep flow paths but the groundwater loading to surface water will already be incorporated in the surface water quality model, thus is not added again. This approach is conservative in terms of potential effects on surface water quality. The transport groundwater model is used to estimate potential effects on groundwater quality only.

9.5.4.1.2 Groundwater Quality Predictive Methods

Potential effects on groundwater quality were assessed for all parameters included in the surface water quality model, except for ammonium (NH_4). Ammonium was not included in the baseline groundwater quality surveys. However, ammonia was always included, and the laboratories have only reported this analyte because acid was used to preserve the samples. When samples are preserved in this way, any ammonium will be converted to ammonia. Results for specific parameters are presented in the following sections, including those in the Elk Valley Water Quality Plan (EVWQP) and parameters known to be elevated in the Elk Valley or common parameters of concern at Elk Valley coal mines. These parameters are listed in Table 9.5-7. Results for the full parameter list (43 parameters) are included in Appendix 9-E.

Table 9.5-7: Key Constituents of Concern

Key Constituent of Concern	Constituent Selection Rationale
Cadmium	Included as an Order Constituent in the EVWQP, which provides specific Water Quality Target (WQT) values for use within the Elk Valley (Teck Resources Limited, 2014).
Nitrate	
Sulfate	
Selenium	
Arsenic	Naturally and regionally elevated in the Elk Valley (Biswas et al., 2017; Essilfie-Dughan et al., 2017).
Iron	
Lithium	
Nickel	
Cobalt	Locally presenting exceedances for baseline conditions (SRK, 2021c).
Sodium	
Manganese	
Phosphorus	

Estimates of groundwater quality were assessed for five groundwater control (prediction) points to determine Project effects. These five locations are within the LSA but downstream of all the facilities in the Alexander Creek and Grave Creek catchments and include boundaries of the LSA. Table 9.5-8 summarizes locations and objectives. Control point locations are shown on Figure 9.5-1.

Table 9.5-8: Control Points Selected for Groundwater Quality Effects Assessment

Catchment	Control Point Number	Location
Alexander Creek	1	Sedimentation Pond
	2	Podrasky Cabin
	3	Alexander Creek at LSA Boundary
Grave Creek	4	North Pit Drainage at Property Boundary
	5	Grave Creek at LSA Boundary

Control points 1, 2, and 3 are within the Alexander Creek catchment. Control point 1 is located immediately downgradient the MRSF in the West Alexander Creek catchment at the location of the Main Sediment Pond. Control point 2 is in the Alexander Creek catchment, at the location of a cabin approximately 2,000 m downstream the sediment pond. Control point 3 is within the Alexander Creek catchment at the boundary of the Groundwater LSA and the property boundary.

Control points 4 and 5 are within the Grave Creek catchment. Control point 4 is at the property boundary down gradient of the North Pit. Control point 5 is at the intersection of Grave Creek and the Groundwater LSA boundary.

Estimated groundwater quality at control points was calculated by scaling normalized breakthrough results (C'/C_0) from the conservative transport model to source terms for a given source (SRK, 2021a) and baseline groundwater quality using the following equation:

$$C = C_b + (\frac{C'}{C_0} \times C_s)$$

Where:

$C = modelled\ concentration$

$C_b = background\ concentration$

$C' = extracted\ concentration\ from\ the\ numerical\ model$

$C_0 = modelled\ source\ concentration$

$C_s = actual\ source\ term\ concentration$

This approach assumes conservative mass transport; no reactions were assumed (e.g., oxidation/reduction, parameter saturation or precipitation, attenuation, etc.). Baseline concentrations for each control point were chosen based on groundwater quality from the closest monitoring well. Average concentrations were used to represent baseline conditions for each control point, as summarized in Table 9.5-9 below.

Table 9.5-9: Baseline Concentrations of Key Constituents of Concern

Control Point		1	2	3	4	5
		Sedimentation Pond	Podrasky Cabin	Alexander Creek at LSA /Model Boundary	North Pit Creek at East Model Boundary	Grave Creek at West Model Boundary
HU		Overburden & Bedrock	Overburden	Overburden	Overburden & Bedrock	Overburden & Bedrock
Constituents of Concern		GW-MP1-PW & GW-MP1-OB & GW-MP1-BR	GW-3-A/GW-3-B/GW-3-C	GW-1-A & GW-1-B	GW-14-OB & GW-14-BR	GW-14-OB & GW-14-BR
Arsenic [As]	mg/L	0.0003	0.0003	0.0009	0.0004	0.0004
Iron [Fe]	mg/L	0.01	0.02	0.04	0.20	0.20
Cadmium [Cd]	mg/L	0.000006	0.000008	0.000006	0.000007	0.000007
Nitrate [NO$_3$]	mg/L	0.12	0.07	0.01	0.04	0.04
Sulfate [SO$_4$]	mg/L	13.9	19.8	25.8	33.1	33.1
Selenium [Se]	mg/L	0.0004	0.0010	0.0005	0.0005	0.0005
Lithium [Li]	mg/L	0.19	0.01	0.01	0.01	0.01
Sodium [Na]	mg/L	69.8	2.6	13.9	7.4	7.4
Cobalt [Co]	mg/L	0.0001	0.0001	0.0002	0.0002	0.0002
Nickel [Ni]	mg/L	0.0004	0.0003	0.0005	0.0007	0.0007
Manganese [Mn]	mg/L	0.01	0.11	0.08	0.05	0.05
Phosphorus [P]	mg/L	0.029	0.025	0.025	0.029	0.029

Two main contamination sources have been used for this assessment: MRSF for the control points in the Alexander Creek catchments, and the North Pit for control points in the Grave Creek catchment. Source term concentrations were extracted from the Water Quality Prediction Model (SRK, 2021b) and used the 95th percentile results. For the MRSF, it was assumed the engineered mine rock layering approach operates as intended with climate change.

MRSF seepage over time does not coincide precisely with prediction timeframes of the transport groundwater model. Seepage flow rates from the MRSF peak around Year 12 of Operations but source term concentrations are relatively low (SRK, 2021b). Source term concentrations are highest during the first two years of Operations, but seepage rates are low. Longer term (i.e., EOM), higher seepage rates and corresponding source terms were assumed for the groundwater modelling. Transport groundwater modelling results incorporating seepage water quality from this MRSF suggest that near surface seepage (in the overburden unit) would not extend beyond approximately 500 m down-gradient of the MRSF (to approximate area of sediment pond) within 100 years. Seepage in the deeper bedrock system could travel on the order of 1,000 m down-gradient of MRSF over the same period of time. Potential substantive effects on groundwater quality within 100 years are limited to areas between the MRSF and sediment pond.

Breakthrough data was extracted from the transport groundwater model at 10 different depths for each control point, from ground surface to a depth of 700 m. For the assessment, at each control point the breakthroughs at each depth were compared and the highest concentration values selected for assessment. Variation of breakthrough with depth is a function of distribution of flow within the overall groundwater flow system. Depths with highest concentrations were:

- Control point 1 (at Sediment Pond): 200 m depth;
- Control point 2 (at Podrasky Cabin): near surface depth;
- Control point 3 (Alexander Creek at LSA Boundary): 60 m depth;
- Control point 4 (North Pit Drainage at Property Boundary): 200 m depth; and
- Control point 5 (Grave Creek at LSA Boundary): 60 m depth.

Groundwater quality predictive results were compared to B.C. WQG for Drinking Water and Freshwater Aquatic Life (FWAL), B.C. CSR Schedule 3.2 DW Standards and EVWQP WQT. However, only DW guidelines were used for determination of significance as FWAL guidelines apply to surface water.

9.5.4.1.3 Groundwater – Surface Water Interactions and Water Quality Predictions

A summary of model assumptions for groundwater – surface water interactions, and consequent assumed characteristics of the relationship between groundwater and surface water quality, are presented below. Actual characteristics for these periods cannot be assessed as these reflect conditions that do not yet exist.

Surface water quality predictions assume that all water sourced from mining areas reports to surface water. No specific surface water – groundwater pathway is assumed. This is a conservative assumption from the perspective of chemical load in surface water (i.e., all chemical load reports to surface water).

Groundwater water quality predictions were based on a scaling source terms to breakthrough characteristics defined by the calibrated groundwater model (SRK, 2021a). For the scenarios reflecting active mining, boundary conditions for the sediment ponds and Alexander Creek downstream of the sediment ponds were defined to allow groundwater to discharge into surface water or for surface water to infiltrate to the groundwater system. Conservative mass transport was used to define breakthrough curves (C/Co trends) for a theoretical conservative constituent. Groundwater quality for this future scenario was then predicted by scaling the source term by the C/Co ratio at a number of different locations.

This approach to estimating future groundwater quality honoured the conceptual model and is generally considered to be conservative but cannot be assumed to provide definition of small scale variations along Alexander Creek. As with the surface water quality predictions, all load is assumed to be able to interact with groundwater and/or surface water, but actual water quality will be affected by geochemical performance of the layered Mine Rock Storage Facility and any reactions that can occur along groundwater or surface water pathways (e.g., redox reactions, mineral precipitation, adsorption, etc.).
While the models do not attempt (or are able) to simulate small scale surface water – groundwater interactions, the models are constructed in a manner which is expected to provide conservative estimates of potential water quality in the future.

9.5.4.1.4 Assumptions and Limitations

- Groundwater flow paths are assumed the same as for the calibrated baseline groundwater numerical model. Differences may occur locally due to variation in subsurface materials or characteristics and due to assumptions in areas with less information on ground conditions.

- Transport parameters are assumed based on literature values and could be different;
- Source terms assume the engineered MRSF layering is functioning as designed;
- Highest concentrations are assessed, regardless of depth;
- Available baseline groundwater quality data is representative for the Project;
- Travel time estimates are influenced by assumptions of porosity, which were selected conservatively based on literature values. Differences in porosity (effective porosity) at the small or large scale could increase or decrease travel time for water from a source to a control point or receptor; and
- Transport parameters (e.g., dispersivity) are assumed based on literature values and could be different. This can have the effect of increasing or decreasing concentrations at a given point in space or time. Assumed parameters were considered reasonable for this assessment and follow generally accepted practice.

Models have many assumptions and limitations. A comparison of predicted effects to observations should be conducted during the Operations phase and through Reclamation and Closure to evaluate the model performance and verify that predicted values such as recharge, infiltration, baseflow, surface water runoff, and quality are within an order of magnitude of observed effects.

9.5.4.2 Screening of Constituents of Potential Concern

Screening results for parameters listed in Table 9.5-9, are presented in Table 9.5-10. Results for the complete parameter list (43 parameters) are provided in Appendix 9-E.

Phosphorous and lithium are the only parameters identified in the baseline data to consistently exceed one or more applicable comparison criteria at the model control points. No measurable change in the concentrations of these constituents is predicted to occur at Year 17 or Year 101 following the onset of mine Operations at the model control points. A summary of the baseline and modelled exceedances of the B.C .WQG for DW, B.C. CSR DW standards and EVWQP WQT is presented in Appendix 9-A.

In general, there is no significant difference between predicted concentrations for 17 and 101 years from the onset of mine Operations, where typically, when a parameter is predicted to exceed a guideline value, the effect is predicted for both time frames. Except for the exceedances of the B.C. CSR DW standard for cobalt predicted to occur at control points located at the Main Sedimentation Pond and North Pit Creek at the Property Boundary, every other guideline/standard exceedance is attributed to elevated baseline concentrations. Concentrations of cobalt at downstream control points located at the boundary of the LSA (Control points 3 and 5) do not indicate a measurable change in the concentration of cobalt over time.

At the location of Podrasky Cabin, the only potential groundwater user within the LSA, no additional drinking water exceedances are predicted at 17 or 101 years. The baseline concentration of phosphorous modelled for this location exceeds the B.C. CSR DW standard; however, concentrations of phosphorous are not predicted to increase over time. Predicted concentrations of three key constituents (cadmium, cobalt and nickel) at the Podrasky Cabin are predicted to increase more than 10% from mean baseline conditions. However, concentrations are not predicted to exceed the standards/guidelines by 101 years from the beginning of the Operation phase. Predicted concentrations of these parameters are each more than an order of magnitude below the most stringent standard/guideline value. No measurable change to groundwater quality is predicted downstream of the Podrasky Cabin at Control point 5 positioned at the southern LSA boundary at either 17 or 101 years.

Table 9.5-10: Groundwater Quality Predictions for EOM and LTC

Catchment	Groundwater Quality Control Point	End of Operations (Year 17)									Long Term Closure (Year 101)								
		Parameter	Background Parameter Concentration	Source Term value	Estimated Contaminant Ratio	Estimated Parameter Concentration	Significance Threshold	B.C. DW Guideline	B.C. CSR DW Guideline	EV WQP	Parameter	Background Parameter Concentration	Source Term Value	Estimated Contaminant Ratio	Estimated Parameter Concentration	Significance Threshold	B.C. DW Guideline	B.C. CSR DW Guideline	EVWQP
			mg/L	mg/L	C/Co	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	C/Co	mg/L	mg/L	mg/L	mg/L	mg/L
West Alexander Creek	Control Point # 1: Sedimentation Pond / Background GW-MP1-BR & GW-MP1-PW & GW-MP1-OB	[As]	0.00032	0.00390	0.00253	0.00033	0.00035	0.01	0.01	-	[As]	0.00032	0.00390	0.04394	0.00049	0.00035	0.01	0.01	-
		[Cd]	0.0000059	0.0027000	0.0025346	0.0000128	0.0000065	0.005	0.005	0.00024	[Cd]	0.0000059	0.0027000	0.0439424	0.0001246	0.0000065	0.005	0.005	0.00024
		[Co]	0.000082	0.146980	0.002535	0.000455	0.000090	0.001	0.001	-	[Co]	0.000082	0.146980	0.043942	0.006541	0.000090	0.001	0.001	-
		[Fe]	0.008	0.042	0.003	0.008	0.009	0.3	6.5	-	[Fe]	0.008	0.042	0.044	0.010	0.009	0.3	6.5	-
		[Li]	0.1945	0.0000	0.0025	0.1945	0.2140	-	0.008	-	[Li]	0.1945	0.0000	0.0439	0.1945	0.2140	-	0.008	-
		[Mn]	0.01	0.27	0.00	0.01	0.01	0.12	1.5	-	[Mn]	0.01	0.27	0.04	0.02	0.01	0.12	1.5	-
		[Na]	69.77	0.00	0.00	69.77	76.74	-	200	-	[Na]	69.77	0.00	0.04	69.77	76.74	-	200	-
		[Ni]	0.00035	0.38000	0.00253	0.00131	0.00039	0.08	0.08	-	[Ni]	0.00035	0.38000	0.04394	0.01705	0.00039	0.08	0.08	-
		[NO$_3$]	0.121	0.500	0.003	0.122	0.133	45	10	3	[NO$_3$]	0.121	0.500	0.044	0.142	0.133	45	10	3
		[P]	0.029	0.000	0.003	0.029	0.032	0.01	-	-	[P]	0.029	0.000	0.044	0.029	0.032	0.01	-	-
		[Se]	0.00040	0.05781	0.00253	0.00055	0.00044	0.01	0.01	0.019	[Se]	0.00040	0.05781	0.04394	0.00294	0.00044	0.01	0.01	0.019
		[SO$_4$]	13.87	531.76	0.00	15.22	15.26	500	500	429	[SO$_4$]	13.87	531.76	0.04	37.24	15.26	500	500	429
	Control Point # 2: Podrasky Cabin/ Background GW-3-A & GW-3-B & GW-3-C	[As]	0.00028	0.00390	0.00000	0.00028	0.00030	0.01	0.01	-	[As]	0.00028	0.00390	0.00165	0.00028	0.00030	0.01	0.01	-
		[Cd]	0.0000076	0.0027000	0.0000000	0.0000076	0.0000084	0.005	0.005	0.00024	[Cd]	0.0000076	0.0027000	0.0016540	0.0000121	0.0000084	0.005	0.005	0.00024
		[Co]	0.000080	0.146980	0.000000	0.000080	0.000087	0.001	0.001	-	[Co]	0.000080	0.146980	0.001654	0.000323	0.000087	0.001	0.001	-
		[Fe]	0.015	0.042	0.000	0.015	0.017	0.3	6.5	-	[Fe]	0.015	0.042	0.002	0.015	0.017	0.3	6.5	-
		[Li]	0.0052	0.0000	0.0000	0.0052	0.0058	-	0.008	-	[Li]	0.0052	0.0000	0.0017	0.0052	0.0058	-	0.008	-
		[Mn]	0.11	0.27	0.00	0.11	0.12	0.12	1.5	-	[Mn]	0.11	0.27	0.00	0.11	0.12	0.12	1.5	-
		[Na]	2.64	0.00	0.00	2.64	2.90	-	200	-	[Na]	2.64	0.00	0.00	2.64	2.90	-	200	-
		[Ni]	0.00026	0.38000	0.00000	0.00026	0.00029	0.08	0.08	-	[Ni]	0.00026	0.38000	0.00165	0.00089	0.00029	0.08	0.08	-
		[NO$_3$]	0.072	0.500	0.000	0.072	0.080	45	10	3	[NO$_3$]	0.072	0.500	0.002	0.073	0.080	45	10	3
		[P]	0.025	0.000	0.000	0.025	0.028	0.01	-	-	[P]	0.025	0.000	0.002	0.025	0.028	0.01	-	-
		[Se]	0.00099	0.05781	0.00000	0.00099	0.00108	0.01	0.01	0.019	[Se]	0.00099	0.05781	0.00165	0.00108	0.00108	0.01	0.01	0.019
		[SO$_4$]	19.80	531.76	0.00	19.80	21.78	500	500	429	[SO$_4$]	19.80	531.76	0.00	20.68	21.78	500	500	429
	Control Point # 3: Alexander Creek at LSA Boundary / Background GW-1-A & GW-1-B	[As]	0.00093	0.00390	0.00000	0.00093	0.00102	0.01	0.01	-	[As]	0.00093	0.00390	0.00000	0.00093	0.00102	0.01	0.01	-
		[Cd]	0.0000055	0.0027000	0.0000000	0.0000055	0.0000061	0.005	0.005	0.00024	[Cd]	0.0000055	0.0027000	0.0000000	0.0000055	0.0000061	0.005	0.005	0.00024
		[Co]	0.000154	0.146980	0.000000	0.000154	0.000170	0.001	0.001	-	[Co]	0.000154	0.146980	0.000000	0.000154	0.000170	0.001	0.001	-
		[Fe]	0.040	0.042	0.000	0.040	0.044	0.3	6.5	-	[Fe]	0.040	0.042	0.000	0.040	0.044	0.3	6.5	-
		[Li]	0.0113	0.0000	0.0000	0.0113	0.0124	-	0.008	-	[Li]	0.0113	0.0000	0.0000	0.0113	0.0124	-	0.008	-
		[Mn]	0.08	0.27	0.00	0.08	0.09	0.12	1.5	-	[Mn]	0.08	0.27	0.00	0.08	0.09	0.12	1.5	-
		[Na]	13.88	0.00	0.00	13.88	15.26	-	200	-	[Na]	13.88	0.00	0.00	13.88	15.26	-	200	-
		[Ni]	0.00053	0.38000	0.00000	0.00053	0.00059	0.08	0.08	-	[Ni]	0.00053	0.38000	0.00000	0.00053	0.00059	0.08	0.08	-
		[NO$_3$]	0.011	0.500	0.000	0.011	0.012	45	10	3	[NO$_3$]	0.011	0.500	0.000	0.011	0.012	45	10	3
		[P]	0.025	0.000	0.000	0.025	0.028	0.01	-	-	[P]	0.025	0.000	0.000	0.025	0.028	0.01	-	-
		[Se]	0.00049	0.05781	0.00000	0.00049	0.00054	0.01	0.01	0.019	[Se]	0.00049	0.05781	0.00000	0.00049	0.00054	0.01	0.01	0.019
		[SO$_4$]	25.78	531.76	0.00	25.78	28.36	500	500	429	[SO$_4$]	25.78	531.76	0.00	25.78	28.36	500	500	429

Catchment	Groundwater Quality Control Point	End of Operations (Year 17)									Long Term Closure (Year 101)								
		Parameter	Background Parameter Concentration	Source Term value	Estimated Contaminant Ratio	Estimated Parameter Concentration	Significance Threshold	B.C. DW Guideline	B.C. CSR DW Guideline	EV WQP	Parameter	Background Parameter Concentration	Source Term Value	Estimated Contaminant Ratio	Estimated Parameter Concentration	Significance Threshold	B.C. DW Guideline	B.C. CSR DW Guideline	EVWQP
			mg/L	mg/L	C/Co	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	C/Co	mg/L	mg/L	mg/L	mg/L	mg/L
Grave Creek	Control Point # 4: North Pit Creek at Property Boundary / Background GW-14-OB & GW-14-BR	[As]	0.00039	0.00390	0.00655	0.00042	0.00043	0.01	0.01	-	[As]	0.00039	0.00390	0.06589	0.00065	0.00043	0.01	0.01	-
		[Cd]	0.00001	0.00270	0.00655	0.00002	0.00001	0.00500	0.00500	0.00024	[Cd]	0.00001	0.00270	0.06589	0.00019	0.00001	0.00500	0.00500	0.00024
		[Co]	0.000210	0.146980	0.006554	0.001173	0.000231	0.001	0.001	-	[Co]	0.000210	0.146980	0.065892	0.009894	0.000231	0.001	0.001	-
		[Fe]	0.205	0.042	0.007	0.205	0.225	0.3	6.5	-	[Fe]	0.205	0.042	0.066	0.207	0.225	0.3	6.5	-
		[Li]	0.0143	0.0000	0.0066	0.0143	0.0157	-	0.008	-	[Li]	0.0143	0.0000	0.0659	0.0143	0.0157	-	0.008	-
		[Mn]	0.05	0.27	0.01	0.06	0.06	0.12	1.5	-	[Mn]	0.05	0.27	0.07	0.07	0.06	0.12	1.5	-
		[Na]	7.42	0.00	0.01	7.42	8.16	-	200	-	[Na]	7.42	0.00	0.07	7.42	8.16	-	200	-
		[Ni]	0.00071	0.38000	0.00655	0.00320	0.00078	0.08	0.08	-	[Ni]	0.00071	0.38000	0.06589	0.02575	0.00078	0.08	0.08	-
		[NO$_3$]	0.044	0.500	0.007	0.047	0.048	45	10	3	[NO$_3$]	0.044	0.500	0.066	0.077	0.048	45	10	3
		[P]	0.029	0.000	0.007	0.029	0.032	0.01	-	-	[P]	0.029	0.000	0.066	0.029	0.032	0.01	-	-
		[Se]	0.00054	0.05781	0.00655	0.00092	0.00059	0.01	0.01	0.019	[Se]	0.00054	0.05781	0.06589	0.00435	0.00059	0.01	0.01	0.019
		[SO$_4$]	33.05	531.76	0.01	36.54	36.36	500	500	429	[SO$_4$]	33.05	531.76	0.07	68.09	36.36	500	500	429
	Control Point # 5: Grave Creek at LSA Boundary / Background GW-14-OB & GW-14-BR	[As]	0.00039	0.00390	0.00000	0.00039	0.00043	0.01	0.01	-	[As]	0.00039	0.00390	0.00007	0.00040	0.00043	0.01	0.01	-
		[Cd]	0.0000072	0.0027000	0.0000002	0.0000072	0.0000079	0.005	0.005	0.00024	[Cd]	0.0000072	0.0027000	0.0000710	0.0000073	0.0000079	0.005	0.005	0.00024
		[Co]	0.000210	0.146980	0.000000	0.000210	0.000231	0.001	0.001	-	[Co]	0.000210	0.146980	0.000071	0.000220	0.000231	0.001	0.001	-
		[Fe]	0.205	0.042	0.000	0.205	0.225	0.3	6.5	-	[Fe]	0.205	0.042	0.000	0.205	0.225	0.3	6.5	-
		[Li]	0.0143	0.0000	0.0000	0.0143	0.0157	-	0.008	-	[Li]	0.0143	0.0000	0.0001	0.0143	0.0157	-	0.008	-
		[Mn]	0.05	0.27	0.00	0.05	0.06	0.12	1.5	-	[Mn]	0.05	0.27	0.00	0.05	0.06	0.12	1.5	-
		[Na]	7.42	0.00	0.00	7.42	8.16	-	200	-	[Na]	7.42	0.00	0.00	7.42	8.16	-	200	-
		[Ni]	0.00071	0.38000	0.00000	0.00071	0.00078	0.08	0.08	-	[Ni]	0.00071	0.38000	0.00007	0.00073	0.00078	0.08	0.08	-
		[NO$_3$]	0.044	0.500	0.000	0.044	0.048	45	10	3	[NO$_3$]	0.044	0.500	0.000	0.044	0.048	45	10	3
		[P]	0.029	0.000	0.000	0.029	0.032	0.01	-	-	[P]	0.029	0.000	0.000	0.029	0.032	0.01	-	-
		[Se]	0.00054	0.05781	0.00000	0.00054	0.00059	0.01	0.01	0.019	[Se]	0.00054	0.05781	0.00007	0.00054	0.00059	0.01	0.01	0.019
		[SO$_4$]	33.05	531.76	0.00	33.05	36.36	500	500	429	[SO$_4$]	33.05	531.76	0.00	33.09	36.36	500	500	429

Notes:

1. Light blue cells represent concentrations above the B.C. Water Quality Guidelines for drinking water
2. Light green cells represent concentrations above the B.C. CSR drinking water standard
3. Bold values represent predictive concentrations with an increase greater than 10% from the mean baseline conditions (Column Significance Threshold)

Concentrations of constituents of concern (COCs) at the control points located at the Sedimentation Pond (Control point 1) and North Pit Creek at the Property Boundary (Control point 4) and are predicted to increase greater than 10% from the mean baseline conditions in the monitoring wells nearby at Year 17 and 101; however, these effects are considered local because they are not observed in the control points located downstream at the LSA boundary. No measurable change to groundwater quality is observed at the boundary of the LSA (Control points 3 and 5) 17 years following onset of mine Operations. A potential <5% change in the concentration of cobalt is possible at Control point 5 (Grave Creek at the LSA boundary) at 101 years following onset of mine Operations; however, the predicted cobalt concentration is an order of magnitude lower than the most stringent drinking water criteria. Potential changes to groundwater quality for constituents which are below the significance threshold (i.e., arsenic, cadmium, cobalt, nickel and sulphate) at this location at Year 101 are also at least one order of magnitude below the most stringent drinking water standard/guideline, and are approaching the limits of laboratory analytical precision. As such, these changes are not considered to materially affect groundwater quality at the LSA boundary, if even measurable at 101 years following onset of mine Operations. Therefore, no material adverse effects on groundwater quality are anticipated to occur beyond the boundary of the LSA as a result of the Project at EOM and LTC mine life phases. Any potential Project effects on groundwater quality are limited to the extent of the Groundwater LSA.

9.5.4.3 Characterization of Residual Effects

The assessment of residual effects on surface water quality involves the consideration and evaluation of specific effects assessment criteria based on the degree (i.e., 'level') of potential Project effects. Criteria used to characterize residual effects include duration, magnitude, Geographic extent, frequency, reversibility, and context.

9.5.4.3.1 Changes in Groundwater Quantity from Development of Pits by Blasting and Pit Dewatering

The residual effect to groundwater quantity from the development of pits by blasting, and dewatering is characterized as follows:

- Duration: Long-term, change to groundwater levels by water table drawdown will alter local groundwater flow patterns (flow direction, hydraulic gradient) during active pit development and dewatering.
- Magnitude: High, water table elevation changes will be readily observable in the immediate vicinity of the pits.
- Geographic Extent: Local, changes in flow direction during operation and dewatering of the pits will be limited at West Alexander Creek and Alexander Creek, and will mostly occur close to the Project footprint. No significant changes are expected to groundwater flow direction to the north of the proposed mined area and to the south of the confluence between Upper Alexander and West Alexander Creeks.
- Frequency: Continuous, effects on groundwater levels due to pit development and dewatering are anticipated to increase over the duration of mine development during Operations, however should reduce at Reclamation and Closure when pits are filled to decant levels.
- Reversibility: Irreversible, some degree of effects are irreversible due to permanent alteration of the topography thereby affecting local groundwater conditions. Following Reclamation and Closure, pit dewatering will cease, and pits will fill to their spill point levels, and re-equilibration of the groundwater flow system will occur, but not to the same state as baseline conditions. At

long-term closure, no significant changes in flow directions and hydraulic gradients are expected with respect the EOM configuration.
- Context: Neutral, groundwater levels in the immediate vicinity of pits will adjust and ultimately stabilize to a new equilibrium with the surrounding groundwater environment.

Determination of Significance

The residual effect of pit development and pit dewatering on groundwater quantity is considered not significant. Water levels in the pits will be managed through pit dewatering, where increased water levels due to precipitation and infiltration caused by development of the site are expected to be offset by the use of water; the effects on groundwater quality and quantity are anticipated to be minimal if measurable much beyond the Project footprint.

Effects on groundwater baseflow are estimated to be most substantive for the EOM period. Changes to baseflow are expected to be most significant in West Alexander Creek with a maximum estimated reduction of 30% with respect to current conditions. This is due primarily to pit dewatering reducing groundwater flow from the pit areas. Groundwater baseflow for Upper Alexander Creek could reduce by up to 5%. Below the confluence, baseflow to Alexander Creek could decrease by a cumulative percentage of 7%. Impacts to groundwater baseflow are reduced during the LTC period, as pits fill with water to their spill points and the groundwater system re-equilibrates. Impacts to groundwater baseflow to West Alexander Creek reduce to only 20% lower than baseline; baseflow to Upper Alexander recovers slightly to 4% lower than baseline, and the cumulative change below the confluence is approximately 5% lower than baseline. Impacts at LTC will be mitigated to a large degree by surface flows, and pit decant being redirected back to West Alexander Creek. Therefore, reduction in groundwater baseflows beyond 10% are not anticipated to occur beyond the bounds of the Groundwater LSA at Reclamation and Closure phase and is therefore not considered significant.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

Confidence considers the reliability of data and analytical methods used in the assessment of effects. The confidence in the characterization of the residual effect to groundwater quantity from the development and dewatering of pits is considered moderate, because, as described in the model assumptions and limitations, hydraulic modelling is based on a limited number of samples of a large mass of rock which are estimations of the changes in groundwater quantity that will be experienced by the Project. The model represents the regional hydrogeological system reasonably well, with predicted reductions in horizontal flux and baseflows to be below significance thresholds at the boundary of the Groundwater LSA. Models have many assumptions and limitations. Follow-up monitoring programs, including water level and groundwater quality monitoring, will be conducted to validate the predicted versus observed effects. Groundwater models could be updated to verify the effects predictions and effectiveness of mitigation, thereby improving the level of confidence of this prediction. Refer to Section 9.7 for more details.

9.5.4.3.2 Changes in Groundwater Quantity through altered Drainage Patterns and Groundwater – Surface Water Interaction associated with Loading, Hauling and Dumping of Mine Rock and Coal Rejects at the MRSF

The residual effect to groundwater quantity through altered drainage patterns and groundwater – surface water interaction through seepage from the MRSF is characterized as follows:

- Duration: Permanent, the MRSF will affect recharge rates but are not expected to significantly change groundwater flow paths as mine rock piles typically have higher conductivities than natural ground. During Operations, infiltration through the dumps is assumed to be double natural recharge (from slow release of storage) and will carry load that can enter the groundwater system. Reclamation of the MRSF including re-vegetation and re-sloping may reduce infiltration to a degree and further modify groundwater recharge within their footprints.
- Magnitude: Moderate, seepage from the MRSF will continue to follow the same trajectories as in Operations. Impacted groundwater will discharge to ground surface relatively close to the mine rock dump. Limited impacted groundwater remaining in the groundwater system will flow downgradient towards the Alexander Creek valley, mixing with non-contact waters from other parts of the catchment.
- Geographic Extent: Discrete, modelling indicates that groundwater flows starting at dumps typically discharge to West Alexander, with limited down gradient migration locally. Measurable effects are anticipated to remain within the bounds of the Project footprint.
- Frequency: Continuous, effects on recharge and infiltration will occur when development of the MRSF is initiated through the life of the Project.
- Reversibility: Reversible long-term, changes in groundwater – surface water interactions are anticipated to be potentially reversible over long temporal scales due to gradual re-equilibration of the water table and natural groundwater flows.
- Context: High, moderate changes to local baseflow contribution to West Alexander Creek can be accommodated by the natural surface water system.

Determination of Significance

The residual effect on groundwater quantity from the development of the MRSF and altered drainage patterns within the Project footprint is considered not significant. As water infiltrates through the MRSF, groundwater flow quantities may change within their footprints, but overall flow directions will likely remain similar to baseline conditions. Seepage from saturated zones in pits will follow groundwater flow paths within the re-equilibrated flow system, with shallow flow paths mostly reporting to the West Alexander Creek valley bottom under the MRSF. Some seepage will occur from the south end of the South Pit and could move in a southerly direction towards Alexander Creek; flow would be completely within bedrock and flow rates would be anticipated to be relatively low.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

Confidence considers the reliability of data and analytical methods used in the assessment of effects. The confidence in the characterization of the residual effect to surface water quality from the disposal of mine rock and coal rejects is considered moderate, because, as described in the model assumptions and limitations, inputs to the model are based on a limited number of samples of a large mass of rock that will ultimately produce the impacted runoff and seepage flows, but they are only estimations of the water quantity that will be experienced by the Project. A follow-up program consisting of groundwater level and quality monitoring at seven peripheral locations will be implemented to verify the effects predictions and effectiveness of mitigation, thereby improving the level of confidence of this prediction. Results will be compared with surface water monitoring results. Refer to Section 9.7 for more details.

9.5.4.3.3 Changes to Water Table Elevation in the Local Vicinity of the Pits during Reclamation and Filling of Pits to Spill Point Levels

The residual effect to groundwater quantity by decommissioning of the pits by filling to spill point levels and re-equilibration to the local water table elevation is characterized as follows:

- Duration: Permanent, re-equilibrium of the water level in the flooded pits to the local groundwater table elevation will permanently change the groundwater regime (hydraulic gradients, flow rates) in the immediate vicinity of the pits.
- Magnitude: High, water table elevation and flow rate changes will be readily observable in the immediate vicinity of the pits.
- Geographic Extent: Local, changes to groundwater levels upon re-equilibrium are anticipated in the immediate vicinity of the pits are not anticipated to extend downstream of the confluence of West Alexander Creek and Alexander Creek. Measurable effects are anticipated to be limited to the bounds of the Groundwater LSA.
- Frequency: Continuous, groundwater levels are anticipated to ultimately achieve equilibrium with the surrounding groundwater environment once pit dewatering has ceased.
- Reversibility: Irreversible, some degree of effects are irreversible due to permanent alteration of the topography by mining, therefore re-equilibration of the groundwater flow system to the surrounding conditions will occur, but not to the same state as baseline conditions.
- Context: Neutral, groundwater levels in the immediate vicinity of pits ultimately stabilize to a new equilibrium with the surrounding groundwater environment.

Determination of Significance

The residual effect of pit decommissioning and filling of pits to spill point levels is considered not significant. During the Operations and Reclamation and Closure phases, dewatering of pits (pit dependent) will cease, at which time groundwater levels in the immediate vicinity of pits will adjust and ultimately stabilize to a new equilibrium with the surrounding groundwater environment. Long-term closure pit water levels will reach a maximum elevation corresponding to decant points: 1,978, 2,049, and 1,671 m asl for North Pit, East Pit, and South Pit, respectively. Effects on groundwater baseflow quantity during the Post-Closure phase are reduced as compared to prior phases, as the groundwater system re-equilibrates, with no significant changes in flow directions and hydraulic gradients anticipated.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

Confidence considers the reliability of data and analytical methods used in the assessment of effects. The confidence in the characterization of the residual effect to groundwater quantity from the development and dewatering of pits is considered moderate, because, as described in the model assumptions, hydraulic modelling and are based on a limited number of samples of a large mass of rock which are estimations of the changes in groundwater quantity that will be experienced by the Project. A follow-up program consisting of groundwater level and quality monitoring at seven peripheral locations will be implemented to verify the effects predictions and effectiveness of mitigation, thereby improving the level of confidence of this prediction.

9.5.4.3.4 Changes to Groundwater Quality Due To Infiltration of Contact Water (i.e., Surface Water and Mine Site Drainage) to Groundwater

The residual effect to groundwater quality due to infiltration of contact water (i.e., surface water and mine site drainage) to groundwater on-site is characterized as follows:

- Duration: Permanent, surface water which infiltrates to the groundwater system are subject to long-term flow paths up to 100s of years.
- Magnitude: Low, the majority of potentially impacted surface water and groundwater will be captured by the sediment ponds. Impacted groundwater remaining in the groundwater system will move slowly downgradient at depth and mix with non-contact waters from other parts of the catchment. The combination of mixing with other groundwater inputs and natural attenuation would further reduce potential risk of impact from these waters, if discharged to the surface, and is therefore unlikely to result in any measurable effect compared to baseline levels beyond the Project footprint.
- Geographic Extent: Local, groundwater modelling suggests that near surface seepage in the overburden unit would not extend beyond approximately 500 m down-gradient of the mine rock storage facility (to the approximate location of the Main Sediment Pond) within 100 years. Seepage in the deeper bedrock system could travel on the order of 1,000 m down-gradient of the mine rock storage facility over the same time period (SRK, 2021a) and would therefore be contained within the LSA.
- Frequency: Continuous, groundwater – surface water interactions occur continuously over time, however are expected to decrease following decommissioning of the site during Reclamation and Closure.
- Reversibility: Reversible long-term, changes in groundwater – surface water interactions are anticipated to be potentially reversible over long temporal scales due to natural attenuation and gradual re-equilibration of the water table and natural groundwater flows.
- Context: High, groundwater quality is anticipated to be highly resilient to potential changes in surface water quality through groundwater – surface water interactions because impacted groundwater is anticipated to move down-gradient over a long timescale that will allow for natural attenuation and mixing with other, non-contact groundwater inputs.

Determination of Significance

The residual effect on groundwater quality from groundwater – surface water interactions is considered not significant. The majority of potentially impacted surface water and groundwater generated through contact water will be captured by the water management infrastructure and contained within the Interim or Main Sediment Pond prior to discharge to the receiving environment once quality objectives are met. The potentially impacted groundwater remaining in the groundwater system will move slowly down-gradient at depth and mix with non-contact waters from other parts of the catchment. The combination of mixing with other groundwater inputs and natural attenuation would further reduce potential risk of impact from these waters, if they discharged to the surface or accessed for use as drinking water. Therefore, any effects are unlikely to result in a definable effect above baseline conditions beyond the Project footprint.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

The confidence in the characterization of the residual effect to groundwater through groundwater – surface water interactions is considered moderate, because, as described in the model assumptions and limitations, the model is based on a series of expected and conservative assumptions developed to be representative of the water and chemical mass conditions observed at the current, undeveloped site or conditions expected during future development of the Project. The water and load balance by necessity include the simplification of a number of complex natural phenomena, including, but not limited to: climate, runoff, snow melt, ice formation, infiltration, and seepage attenuation. The model uses physical models that are only representations of the processes, calibrated to observed baseline data where possible, but many of these processes do not exist in the current, undeveloped conditions and future behavior cannot be predicted with precision. Models have many assumptions and limitations. A follow-up program to validate the predicted versus observed effects, or update of the models will be implemented to verify the effects predictions and effectiveness of mitigation. Based on the groundwater monitoring data, the model may be updated if necessary based, thereby improving the level of confidence of this prediction.

9.5.4.3.5 Changes in Groundwater Quality from Loading, Hauling and Disposal of Mine Rock and Coal Rejects and MRSF

The residual effect to groundwater quality resulting from loading, hauling and disposal of mine rock and coal rejects is characterized as follows:

- Duration: Permanent, the potential for metal leaching from the mine rock storage facilities will persist beyond the 34 year temporal boundary for the Project.
- Magnitude: High, concentrations of constituents of concern are predicted to be no worse than those in surface water due to seepage from the MRSF, however may result in changes to contact water quality downstream within the Groundwater LSA, beyond the expected natural range of variation.
- Geographic Extent: Local, seepage from the MRSF that infiltrates to groundwater is not anticipated to affect groundwater quality beyond threshold levels beyond 500 m to 1,000 m beyond the Project footprint, and measurable effects in groundwater are not anticipated at the Groundwater LSA boundary.
- Frequency: Continuous, the potential for metal leaching occurs continuously once the mine rock storage facilities are established.
- Reversibility: Reversible, groundwater quality changes resulting from seepage and metal leaching from the MRSF is anticipated to improve in the very long term since depletion of constituents occurs. However, effects on groundwater quality are conservatively assumed to be irreversible given the timeframe and anticipated duration of measurable effects on groundwater quality.
- Context: Neutral, seepage water which infiltrates to groundwater from the MRSF is anticipated to move down-gradient over a long timescale. Concentrations of constituents in groundwater are predicted to be below the applicable guidelines at the boundary of the LSA.

Determination of Significance

The residual effect on groundwater quality from the disposal of mine rock and coal rejects is considered not significant. The magnitude of the residual effect of the mine rock piles on groundwater quality in the

Alexander Creek catchment is anticipated to be measurable in close proximity to the MRSF within the Project footprint. However, because of the implementation of mitigation measures, including the layered mine rock design and diversion to sedimentation ponds, effects are anticipated to reduce to below significance threshold levels within the Groundwater LSA. Similar potential local effects apply to seepage from the North Pit in the Grave Creek catchment but should be low magnitude. These effects will occur during Operations, Reclamation and Closure, and through Post-Closure, with reduced metal leaching input to the groundwater system, by limited oxygen availability within the MRSF over time.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

The confidence in the characterization of the residual effect to groundwater quality from the disposal of mine rock and coal rejects is considered moderate, because, as described in the model assumptions and limitations, water quality inputs to the model were developed from geochemical and hydraulic modelling and are based on a limited number of samples of a large mass of rock that will ultimate produce the impacted runoff and seepage flows. The model explores the possible range of water quality expected in the Project through the use of both average and upper case water quality inputs, but they are only estimations of the water quality that will be experienced by the Project. If the MRSF does not perform as expected, and groundwater mitigation is deemed appropriate, the West Alexander Creek valley represents an ideal location for a conventional collection or cut-off system. The valley is relatively narrow, overburden is shallow and groundwater flows are low, on the order of 2 to 3 L/s. Deeper flow, in bedrock, is estimated to be minor. A follow-up program consisting of groundwater level and quality monitoring at seven peripheral locations will be implemented to verify the effects predictions and effectiveness of mitigation, thereby improving the confidence of the predictions. Additional mitigation measures may be evaluated based on the groundwater monitoring data and the requirements of the SWMP.

9.5.4.3.6 Changes in Groundwater Quality due to Management and Discharge of Sediment Pond Water to West Alexander Creek via Infiltration to Groundwater

The residual effect to groundwater quality resulting from discharge of sediment pond water to West Alexander Creek via infiltration to groundwater is characterized as follows:

- Duration: Long-term, changes to surface water quality in West Alexander Creek and Alexander Creek are anticipated to be detectable from Operations through Post-Closure.
- Magnitude: Moderate, although B.C. WQG exceedances of some constituents of concern (i.e., cadmium, cobalt, and selenium) are predicted to occur in surface water quality in West Alexander Creek and in Alexander Creek upstream of Highway 3, these effects are not considered for groundwater quality since the West Alexander Creek valley bottom has been mapped as a groundwater discharge zone with upward hydraulic gradients.
- Geographic Extent: Local, measurable effects to groundwater quality within the Project footprint are anticipated as a result of discharge of pond water to West Alexander Creek, however shallow groundwater seepage from the sediment ponds is expected to return to Alexander Creek and measurable effects on groundwater quality at the Groundwater LSA boundary are not anticipated.
- Frequency: Regular, should they occur, groundwater quality guideline exceedances within the Project footprint are not anticipated to occur year round for most parameters. Concentrations are generally expected to be highest in the winter during low-flow conditions.

- Reversibility: Reversible long-term, the changes to groundwater quality as a result of sediment pond discharge are anticipated to be potentially reversible over long temporal scales. Concentrations of constituents in groundwater are predicted to be below the applicable guidelines at the boundary of the LSA.
- Context: Neutral, the groundwater receiving environments in the area down-gradient of the Project footprint is mapped as a groundwater discharge zone, where the majority of shallow groundwater is expected to contribute to West Alexander Creek as surface water. This surface water system is dynamic and naturally experiences a wide range of flow and water chemistry conditions. Impacted groundwater contributing to West Alexander Creek is anticipated to be of no worse quality than the surface water flowing through the Creek, and thus, is not anticipated to materially affect water quality.

Determination of Significance

The residual effect on groundwater quality from the sediment pond discharge is considered not significant. Particle tracking from the pond locations show that the vast majority of groundwater flow is towards the West Alexander Creek and is not anticipated to be worse than surface water quality, with significantly lower flow rates and a significantly lower chemical load. Discharge of this groundwater into creeks, should it occur in groundwater discharge areas downstream of the sedimentation pond, is assumed to not materially worsen surface water quality. These groundwater flow paths would be long (10’s to 100’s of years), and concentrations of constituents are anticipated to be below the applicable guidelines at the boundaries of the LSA. These factors further reduce the risk of impacts if groundwater is discharged to surface water downstream of the Project footprint. Water quality in the Interim and Main Sediment Ponds will be monitored and managed to confirm it meets all permitting conditions.

Likelihood and Confidence

Effects that are determined to be not significant do not require a characterization of likelihood.

The confidence in the characterization of the residual effect to groundwater quality from sediment pond discharge is considered moderate. As stated previously, a follow-up program consisting of groundwater level and quality monitoring at seven peripheral locations will be implemented to verify the effects predictions and effectiveness of mitigation, thereby improving the level of confidence of this prediction. Additional mitigation measures and adaptive management will be evaluated over the life of the Project, and will be implemented if necessary.

9.5.4.4 Summary of Residual Effects Assessment

Residual effects and the selected mitigation measures, characterization criteria, likelihood, significance determination, and confidence are summarized in Table 9.5-11 below.

For all effects assessed, in consideration of the above and with the application of mitigation measures and best practices to avoid, minimize, or reduce environmental effects, the residual environmental effects of all activities associated with the Project, during all Project phases, on groundwater quality and groundwater quantity are rated not significant, with a moderate level of confidence. A follow-up program described in Section 9.7 below to verify the effects predictions and the effectiveness of mitigation will improve the confidence in this prediction.

Table 9.5-11: Characterization of Residual Effects on Groundwater Quantity and Quality – Significance Determination Matrix

Residual Effect	Project Phase(s)	Mitigation Measures	Summary of Residual Effects Characterization	Significance (Significant, Not Significant)	Confidence (High, Moderate, Low)
Groundwater Quantity					
Changes in groundwater quantity from pit development, blasting and dewatering	Operations	During active mining, dewatering will be carried out using drainage ditches, berms, sumps and pumps to sedimentation ponds. Pit dewatering will be coordinated to meet overall water quality objectives. Groundwater and surface water monitoring.	Duration: Long-term Magnitude: High Geographic Extent: Local Frequency: Continuous Reversibility: Irreversible Context: Neutral	Not Significant	Moderate
Changes to groundwater quantity through altered drainage patterns and groundwater – surface water interactions associated with loading, hauling and dumping of mine rock and coal rejects at the MRSF	Construction and Pre-Production, Operations, Reclamation and Closure	Engineered layering of coal rejects and mine rock at the MRSF, and progressive reclamation by re-vegetation and re-sloping. Groundwater monitoring.	Duration: Permanent Magnitude: Moderate Geographic Extent: Discrete Frequency: Continuous Reversibility: Reversible Long-term Context: High	Not Significant	Moderate
Changes to water table elevation in the local vicinity of the pits during reclamation and filling of pits to spill point levels	Reclamation and Closure and Post-Closure	Groundwater monitoring.	Duration: Permanent Magnitude: High Geographic Extent: Local Frequency: Continuous Reversibility: Irreversible Context: Neutral	Not Significant	Moderate

Residual Effect	Project Phase(s)	Mitigation Measures	Summary of Residual Effects Characterization	Significance (Significant, Not Significant)	Confidence (High, Moderate, Low)
Groundwater Quality					
Changes in groundwater quality due to infiltration of contact water (i.e., surface water and mine site drainage) to groundwater	Construction and Pre-Production, Operations, and Reclamation and Closure	Limit the mine disturbance footprint through Project design and progressive reclamation. Control mine site drainage through layered MRSF design and diversion ditches to sedimentation ponds. Ponds are equipped with impermeable liners.	Duration: Permanent Magnitude: Low Geographic Extent: Local Frequency: Continuous Reversibility: Reversible Long-Term Context: High	Not Significant	Moderate
Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects at the MRSF	Construction and Pre-Production, Operation, and Reclamation and Closure, Post-Closure	Divert clean runoff around mine disturbed areas, where possible. Capture clean surface water that cannot be diverted in sediment ponds prior to release. Conduct regular inspections to confirm control measures are effective and functioning properly. Engineered layering of the MRSF. Progressive reclamation of the mine rock storage facilities.	Duration: Permanent Magnitude: High Geographic Extent: Local Frequency: Continuous Reversibility: Irreversible Context: Neutral	Not Significant	Moderate
Changes in groundwater quality due management and discharge of sediment pond water to West Alexander Creek via infiltration to groundwater	Operation, Reclamation and Closure, and Post-Closure	Diverting clean, non-contact water away from the sediment ponds; where possible. Appropriate sizing of sediment ponds and installation of impermeable liner to minimize seepage losses and convey runoff during storm events. Treating water prior to discharge as required in order to meet effluent standards. Limit the mine disturbance footprint through Project design and progressive reclamation. Monitoring and adaptive management.	Duration: Long-Term Magnitude: Moderate Geographic Extent: Local Frequency: Regular Reversibility: Reversible, Long-Term Context: Neutral	Not Significant	Moderate

9.6 Cumulative Effects Assessment

Cumulative environmental effects are the result of Project residual environmental effects interacting with the effects of other past, present, and reasonably foreseeable future projects or activities to produce a combined/overlapping effect. The objective of the cumulative effects assessment is to consider overlapping effects for all residual adverse effects, not only those predicted to be significant (EAO, 2013). The assessment of cumulative effects on the groundwater quantity and quality VC requires that:

- The Project results in a residual adverse environmental effect on the groundwater quantity and quality VC;
- A residual Project effect interacts cumulatively with effects from other projects or activities (i.e., an effect of the Project overlaps spatially and temporally with those of other projects or activities that have been or will be carried out);
- The other projects or activities have been or will be carried out and are not hypothetical; and
- The cumulative effect is likely to occur.

Further information regarding the cumulative effects assessment methodology is provided in Chapter 5, Section 5.3.5.4.

9.6.1 Overview of Residual Effects

Based on the characterization of residual effects on groundwater quantity, those Project effects that may remain after implementation of proposed mitigation measures were characterized as not significant. These potential residual not significant effects on groundwater quantity include:

- Changes in groundwater quantity from development of pits by blasting and dewatering;
- Changes to groundwater quantity through altered drainage patterns and groundwater-surface water interactions associated with loading, hauling and dumping of mine rock at the MRSF; and
- Changes to water table elevation in the local vicinity of the pits during Reclamation and Closure and filling of pits to spill point levels.

Potential Project effects on groundwater quality that present potential residual but not significant effects include:

- Changes in groundwater quality due to infiltration of mine contact water (i.e., seepage and mine site drainage) to groundwater;
- Changes in groundwater quality from loading, hauling and disposal of mine rock and coal rejects at the MRSF; and
- Changes in groundwater quality due management and discharge of sediment pond water to West Alexander Creek via infiltration to groundwater.

9.6.2 Assessment Boundaries

The spatial boundary of the cumulative effects assessment is the Groundwater RSA used for the groundwater quantity and quality effects assessment is shown on Figure 9.2-1. The Groundwater RSA boundaries constrain the hydrogeologically relevant areas to the Project footprint, based on the groundwater catchment divides indicated by regional topography and watercourses. The Project is in close proximity to other metallurgical coal mines in the Elk Valley and Crowsnest coal fields, including

Teck's Elkview Operations (8 km southwest) and Line Creek Operations (12 km north); however, these are both located outside of the Groundwater LSA for the Project. The Groundwater RSA boundary for the groundwater cumulative effects assessment is limited to the south by Michel Creek; to the west by the Elk River; and to the north by Grave Creek, and includes portions of the Line Creek Operations, Elk View Operations, and other groundwater users such as supply wells.

Due to their distance from the Project and associated Project activities and components that may affect groundwater quantity and quality, and based on the groundwater catchment divides indicated by regional topography and watercourses, potential cumulative groundwater effects arising from the Project are not expected to occur in either the bordering province of Alberta, the bordering State of Montana, or on federal lands. As such, transboundary cumulative effects on groundwater quantity or quality arising from the Project are not expected to occur in either province or state or on federal lands and the Groundwater RSA does not include transboundary lands.

Temporal, administrative, and technical boundaries for the cumulative effects assessment are equivalent to those used in the characterization of residual Project Effects (refer to Section 9.5.4).

9.6.3 Identifying Past, Present, and Reasonably Foreseeable Projects and/or Activities

Potential changes to groundwater quantity are predicted to occur in the form of baseflow (groundwater contributing to surface water) and not in the form of groundwater flowing through bedrock. Potential changes to baseflow at the boundary of the LSA are predicted to occur in the range of a 5% reduction at Alexander Creek (below the confluence of West Alexander Creek and Upper Alexander Creek), and a 2% reduction at Grave Creek. These reductions are considered not significant because they generally remain within the range of normal variation of groundwater quantity from one year to another or are within typical estimation error and are confined to the limits of the LSA. Once groundwater enters a surface watercourse as baseflow, it is considered part of the surface water system. As such, because the change in groundwater quantity at the boundary of the LSA is not significant, and because there are no overlapping effects of other past, present, or reasonably foreseeable future projects or activities within the LSA itself, potential cumulative effects on groundwater quantity resulting from groundwater contributing to surface water as baseflow have been considered in Chapter 10. Since no measurable change to groundwater quantity is anticipated for groundwater flowing through bedrock (thus representing no residual effect), and no mapped aquifers have been identified within the Project footprint or Groundwater LSA, further cumulative effects assessment for groundwater quantity is not required.

The effects of past and present projects or activities on groundwater quality are encompassed in the existing (baseline) conditions for groundwater quality described in Section 9.5 above. In addition, no reasonably foreseeable future projects or activities that are expected to have an adverse effect on groundwater quality have been identified within the Groundwater LSA beyond the existing (baseline) conditions described in Section 9.4. Since any residual effects on groundwater quality (if measurable at 101 years from beginning of the mine Operations phase) due to the Project are limited to the extent of the Groundwater LSA, no spatial or temporal overlap of the Project effects on groundwater quality with those of other reasonably foreseeable future projects or activities is anticipated. Given that there is no anticipated spatial and temporal overlap between any potential effects on groundwater quality associated with the Project and those of other past, present, and reasonably foreseeable future projects or activities, it follows that cumulative effects are not likely to occur, and a cumulative effects assessment for groundwater quality is not warranted.

As such, in consideration of the above, the residual cumulative effects of the Project in combination with those of other past, present, and reasonably foreseeable future projects or activities on groundwater (including groundwater quantity and groundwater quality) during all phases of the Project are rated not significant, with a moderate level of confidence.

9.7 Follow-up Strategy

For any residual effects due to the Project assessed, in consideration of applied mitigation measures and best practices to avoid, minimize, or reduce environmental effects, the residual environmental effects of activities associated with the Project, during each of the Project phases, on groundwater quality and groundwater quantity were rated not significant, with a moderate level of confidence. As described previously in Section 9.6, further cumulative effects assessment for groundwater quantity and quality is not warranted. However, a follow-up program is required when the level of confidence in the Project effects assessment is less than high, either to verify the effects predictions or to verify the effectiveness of mitigation measures, as required by the Canadian Environmental Assessment Act (2012).

The proposed follow-up program for groundwater is outlined in the SWMP (Chapter 33, Section 33.4.1.8), and includes the following components:

1. Groundwater monitoring program including measurement of groundwater levels and groundwater sampling for laboratory analysis on a seasonal basis (three times annually in summer, winter and spring) through mine Construction and Pre-Production, Operations, Reclamation and Closure, and Post-Closure. Monitoring wells to be included in the monitoring program are GW-9 and GW-7 (West Alexander Creek catchment), GW-4 (Upper Alexander Creek catchment), GW-3 and GW-1 (Lower Alexander Creek catchment), GW-14 (Grave Creek catchment), and GW-PP2 (background). Monitoring wells GW-9 and GW-7 will be used for early detection of elevated concentrations of COCs in groundwater with the Alexander Creek catchment, since they are located immediately downstream of mine infrastructure and are upstream of peripheral monitoring wells. GW-14, located within the Grave Creek catchment, will act as a sentinel monitoring well for groundwater flowing to the north from the Project footprint. Groundwater monitoring data will enable verification of the accuracy of the predicted Project effects at each potentially affected catchment. Comparison to the existing model and periodic model updates (if necessary) will be conducted to improve the level of confidence in the predicted Project effects. Groundwater quality monitoring data will be used in conjunction with other water quality monitoring to confirm geochemical predictions. Groundwater monitoring would cease following Post-Closure (at Year 34).
2. Development of a Trigger Action Response Plan (TARP) including trigger values for COCs in groundwater monitoring results. Trigger values that are lower than the applicable significance thresholds for groundwater quantity (assessed using groundwater level measurements) and groundwater quality (groundwater sampling analytical results) will be established, and will be selected to confirm regulatory compliance for the duration of the Project. The TARP will define response actions, such as the evaluation of existing mitigation measures and evaluation of potential additional measures, such as effluent treatment during Operations and pond discharge.

3. Maintenance of the monitoring well network including adjustments in the future if monitoring wells are destroyed or added, or in the event that mine plans change. The Elk Valley Water Quality Plan (EVWQP) is designed to manage the cumulative effects of coal mining on water quality within the Elk Valley (Teck Resources Limited, 2014). The plan was developed by Teck in response to a Ministerial Order issued in April 2013 under the Environmental Management Act 2003 (EMA). The Project will adhere to the Water Quality Targets provided in the EVWQP to mitigate potential cumulative effects on groundwater caused by the Project at the boundary of the Groundwater LSA. Best Achievable Control Technology (BACT) contingency measures and adaptive management strategies will be included in the SWMP.

9.8 Summary and Conclusions

The Crown Mountain Coking Coal Project (the Project) is predicted to result in a residual effect on groundwater quantity in the form of reduced baseflow (groundwater) contribution to surface watercourses at the boundary of the LSA. Based on the characterization of residual effects on groundwater quantity, potential local effects are associated with mine pit development and dewatering, altered mine site drainage patterns and groundwater-surface water interaction, and water table elevation changes in the local vicinity of the pits during filling of pits to spill point levels at the Reclamation and Closure phase.

At their maximum extent, the predicted effects on groundwater quantity are in the range of a 5% reduction of baseflow at Alexander Creek (below the confluence of West Alexander Creek and Upper Alexander Creek), and a 2% reduction of baseflow at Grave Creek. These effects are predicted to be limited to the extent of the Groundwater LSA, and are predicted to be not significant with a moderate level of confidence that will be improved through a follow-up program. In terms of cumulative effects on groundwater quantity, the assessment of effects associated with baseflow contribution to surface water is considered under the surface water quantity assessment provided in Chapter 10. Since no measurable change to groundwater quantity is anticipated for groundwater flowing through bedrock, and no mapped aquifers have been identified within the Project footprint or Groundwater LSA, further cumulative effects assessment for groundwater quantity is not required, and the residual cumulative effects of the Project in combination with those of other past, present, and reasonably foreseeable future projects or activities on groundwater quantity during all phases of the Project are rated not significant, with a high level of confidence.

The Project is predicted to result in a residual effect to groundwater quality marked by increased concentrations of some Constituents of Concern (COCs) in groundwater within the Project footprint. These changes are attributed to infiltration of mine contact water and the Mine Rock Storage Facility (MRSF) from mine site drainage and seepage to groundwater, and groundwater-surface water interaction associated with discharge of sediment pond water to West Alexander Creek. Residual effects on groundwater quality (if measurable at 101 years from beginning of the mine Operations phase) due to the Project are predicted to be not significant with a moderate level of confidence and will be limited to the extent of the Groundwater LSA. A follow-up program for groundwater quality will improve the confidence of this prediction. In terms of cumulative effects on groundwater quality, since no past, present, or reasonably foreseeable projects or activities, which are expected to have an adverse effect on groundwater quality, have been identified within the Groundwater LSA, no spatial or temporal overlap of the Project effects with those of other past, present, or reasonably foreseeable future projects or activities is predicted. As such, cumulative effects are not likely to occur, and a cumulative effects assessment for groundwater quality is not warranted, and the residual cumulative effects of the Project in combination with those of other past, present, and reasonably foreseeable future projects or activities on groundwater quality during all phases of the Project are rated not significant, with a high level of confidence.

The implementation of a Project-specific follow-up program to verify the effects predictions and the effectiveness of mitigation measures will improve the moderate level of confidence assigned to the prediction of residual effects on groundwater quantity and quality. The follow-up program includes the implementation of the Site Water Management Plan (SWMP; Chapter 33, Section 33.4.1.8), including seasonal groundwater monitoring, groundwater level measurement and sampling and development of a Trigger Action Response Plan (TARP). Monitoring results will be compared to baseline data and modelled predictions to support the evaluation and improvement of the model, and inform the development of adaptive management measures, should they be required.

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