7. ASSESSMENT OF GROUNDWATER EFFECTS

7.1 INTRODUCTION

This Chapter assesses the potential effects of the Project on groundwater quantity and quality. Pre-mining baseline hydrogeological conditions at the Project site are characterized based on data collected from 2009 up to May of 2014. This chapter summarizes the key results of the baseline investigations, and the details of the related baseline information and data can be found in *Murray River Coal Project Hydrogeology Baseline Report* (Appendix 7-A). The assessment of Project-related effects is based on the results of three-dimensional groundwater numerical modelling. Modelling exercises included calibration of the baseline model to pre-mining conditions and predictive simulations for potential effects. Among the Project activities, underground mine dewatering and seepage from the CCR piles (see Figures 7.1-1 and 7.1-2) are identified to be the key with potential effects to groundwater quantity and quality during Operation and Post Closure. Complete details of the modelling methodologies and results are presented in *Murray River Coal Project Groundwater Modeling Report* (Appendix 7-B).

7.2 REGULATORY AND POLICY FRAMEWORK

The guidelines and regulations that are applicable to hydrogeological baseline characterizations, groundwater quality sampling and evaluation, and numerical groundwater modeling for the purpose of the environmental impact assessment for the Project are outlined below.

The *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*, published by the BC Ministry of Environment (BC MOE, 2012a), describes the general requirements for hydrogeology baseline characterizations and groundwater quality study, as well as the requirements for groundwater related environmental impact assessment.

The *British Columbia Field Sampling Manual*, published by Water, Air and Climate Change Branch of the Ministry of Water, Land and Air Protection (BC WLAP, 2003) provides guidance for the procedure, protocol, equipment, and quality control for groundwater sampling.

The *British Columbia Ministry of Environment's Water Quality Guidelines for Freshwater Aquatic Life and for Raw Drinking Water Supply* (BC MOE, 2012b) set up the water quality standards (criteria) for various specific metals and chemical compounds to protect aquatic life and raw drinking water supply.

Health Canada's *Drinking Water Quality Guidelines* are established by the Federal-Provincial-Territorial Committee of Canada on Drinking Water based on current, published scientific research related to health effects, aesthetic effects, and operational considerations, and the guidelines set up the criteria (including microbiological parameters, chemical and physical parameters, and radiological parameters) to assess the suitability of water for drinking (Health Canada, 2012).

The *BC Ministry of Environment's Guidelines for Groundwater Modelling to Assess Impacts of Proposed Natural Resource Development Activities* (BC MOE, 2012c) provide general guidance based on the accepted "best practice" for the methodologies and procedures of numerical groundwater flow and transport modeling undertaken to identify and assess the impacts of natural resources mining and development projects in British Columbia.

The *Canada Water Act* (1985), *BC Water Act* (1996), and *BC Water Protection Act* (1996) provide the comprehensive Canadian federal and BC provincial regulations for protection of the water resources supply and water quality management.

The aforementioned guidelines and regulations were followed in the hydrogeology baseline and numerical groundwater modeling studies for this Project.

7.3 REGIONAL OVERVIEW

This section provides an overview of the regional information related to groundwater.

7.3.1 Climate and Meteorology

Meteorological conditions in the Tumbler Ridge region are heavily influenced by the orographic shadow created by the Rocky Mountains, which are situated to the west and southwest of BC. In general, moist coastal air masses from the west release precipitation on the western side of the Rocky Mountains, resulting in drier conditions to the east. Mean annual precipitation at weather stations near the project site range from 450 to 800 mm.

Precipitation amounts are greatest during the summer months, when convective weather systems bring thunderstorms. The majority of precipitation from November to April occurs as snow and represents about 30 to 50% of the annual total precipitation.

Mean monthly temperatures in the region range from a high of 15°C in July to a low of -10°C in January. Temperatures are generally above freezing from April to October; however, freezing conditions may occur at any time of the year at higher elevations. Mid-winter thaws may also occur on occasion due to Chinook winds.

Additional information documenting climate and meteorology in the Tumbler Ridge Region and at the Project site may be found in *Murray River Coal Project Meteorology Baseline Report* (Appendix 6-C).

7.3.2 Hydrology

The proposed underground mine area of the Project is situated within the Twenty Creek and M20 Creek (also referred to as Camp Creek) catchments, which report westward to the Murray River. The proposed CCR site is situated within the catchments of M19, M19A and M17B creeks, which report eastward to the Murray River.

The Murray River flows northward, discharging into the Pine River 40 km downstream from the Village of Chetwynd, BC. Both the Murray and Pine rivers belong to the greater Peace River drainage system, which drains into the Slave and Mackenzie Rivers and onto the Arctic Ocean.

Figure 7.1-1

Underground Mine Blocks and Coarse Coal Rejects (CCR) Site Footprints

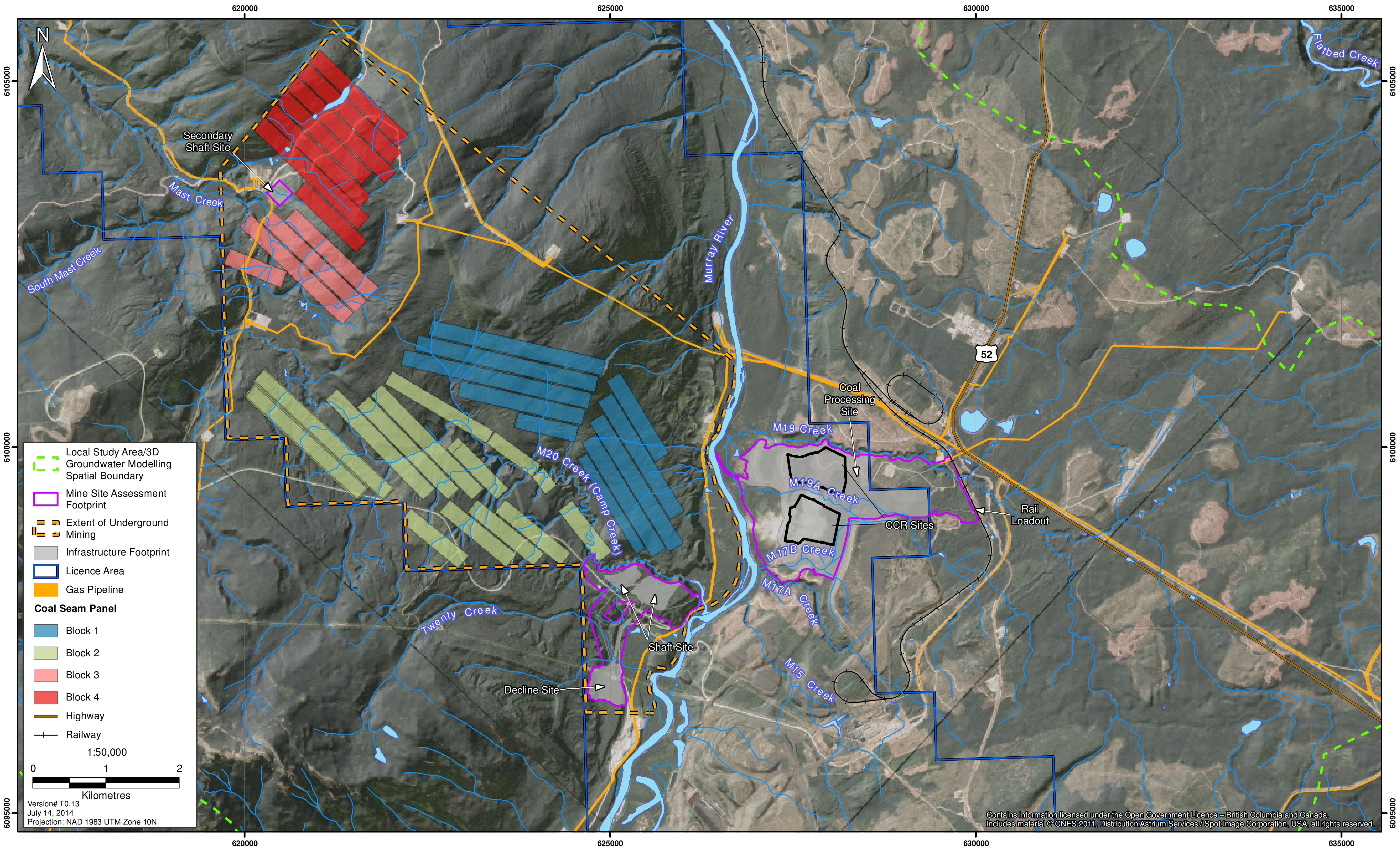

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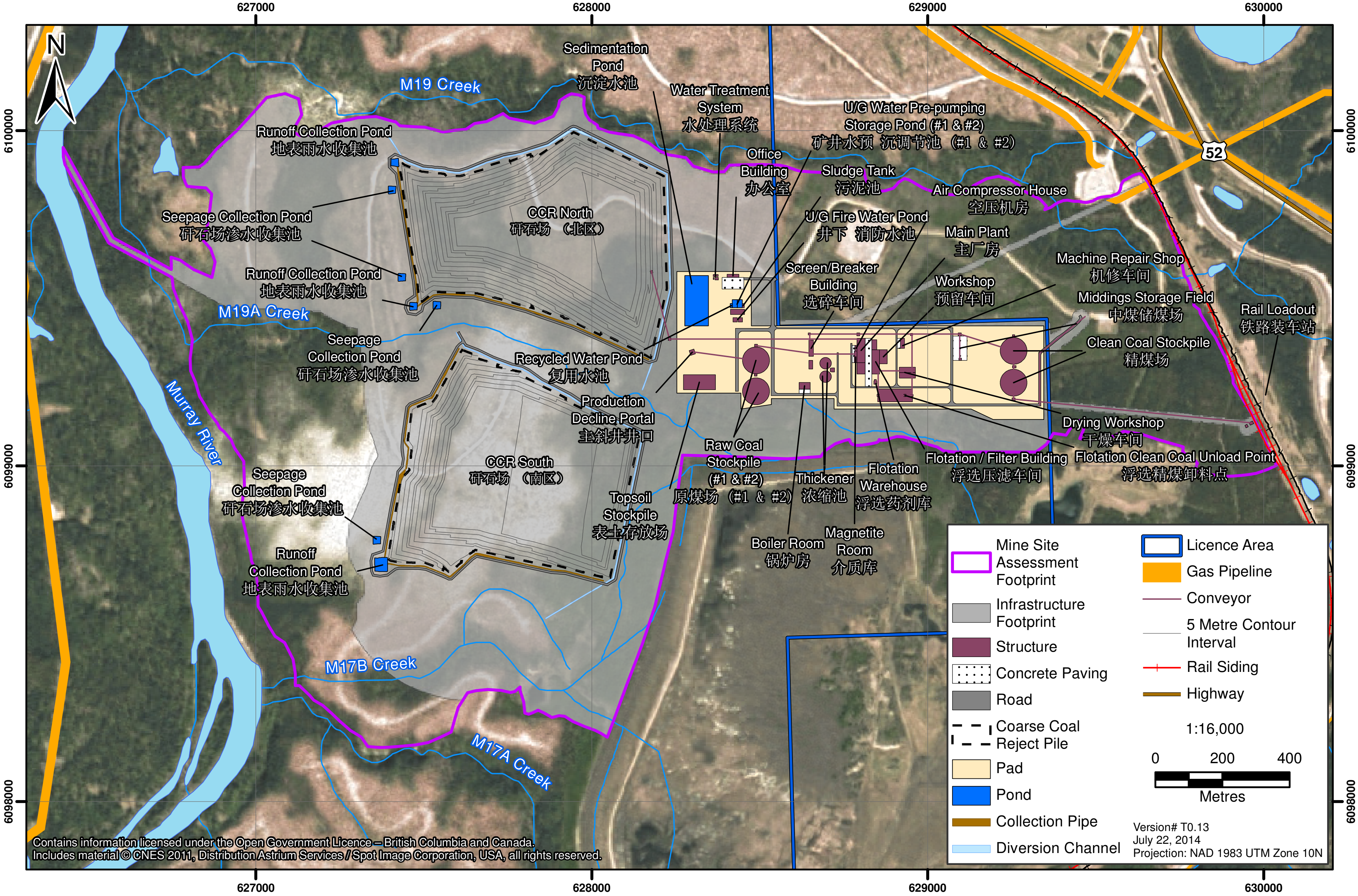
Figure 7.1-2

Coarse Coal Rejects (CCR) Site Layout in Detail



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Streams generally peak during spring freshet (April), with high flow rates continuing into mid-summer, as sustained by convective rainfall events. Moderate flow rates are generally observed from late summer to mid-fall. Low flows occur from mid-fall through early spring, as sustained by groundwater discharge.

Additional information documenting the hydrology in the regional study area and at the Project site may be found in *Murray River Coal Project Hydrology Baseline Report* (Appendix 8-A).

7.3.3 Geology

7.3.3.1 Unconsolidated Sediments

The unconsolidated sediments at the Project site and in the region are dominated by glacial deposits with lesser amounts of fluvials, colluvials and organics. Morainal sediments consist of well-compacted, non-stratified mixtures of sand, silt, and clay, with a heterogeneous mixture of sub-rounded to angular coarse fragments. Glaciofluvial materials are found along the slopes of the Murray River valley, consisting of stratified sands and silts with frequent rounded to sub-rounded coarse fragments. Fluvial deposits dominate the flood plains of the Murray River valley, consisting largely of well-sorted, stratified sands and gravels, and sometimes containing considerable fractions of silt and clay. Colluvial materials are found along moderate to steep slopes, consisting of poorly sorted, heterogeneous materials. Organic materials are found in wet lowlands, consisting of poorly to moderately decomposed peat.

Additional information documenting the unconsolidated sediments in the regional study area and at the Project site may be found in *Murray River Coal Project Terrain and Soils Baseline Report* (Appendix 10-A).

7.3.3.2 Bedrock Geology

The proposed mine site of the Project is located within the Peace River Coalfield (PRC) in the eastern foothills of the Canadian Rocky Mountains, in the transition area between the more faulted and tightly folded areas in the west to the less structurally complex areas in the east (Norwest 2010). The western margin of the foothills belt is usually classified as the easternmost major thrust fault that emplaced Paleozoic strata over Mesozoic strata. The eastern margin of the foothills is a series of en echelon thrust faults that separate the foothills from the gently dipping strata of the Alberta Plateau (Holland 1976, Norwest 2010). The Foothills Belt is characterized by folded and faulted Mesozoic sediments. The deformation within the Foothills Belt is variable – mostly decreasing in complexity toward the eastern margin. Deformation within the Rocky Mountains involves complicated folding and faulting. Regional axes for folding and faulting trend northwest, dipping to the southeast. In the Foothills Belt, dips tend to be 20° or less with local folds and undulations significantly modifying this value.

The regional bedrock geology and stratigraphy of the PRC is provided in Figures 7.3-1 and 7.3-2**.** Descriptions of the bedrock formations are provided below (Johnson 1985).

Figure 7.3-1

Regional Bedrock Geology of Northeast British Columbia

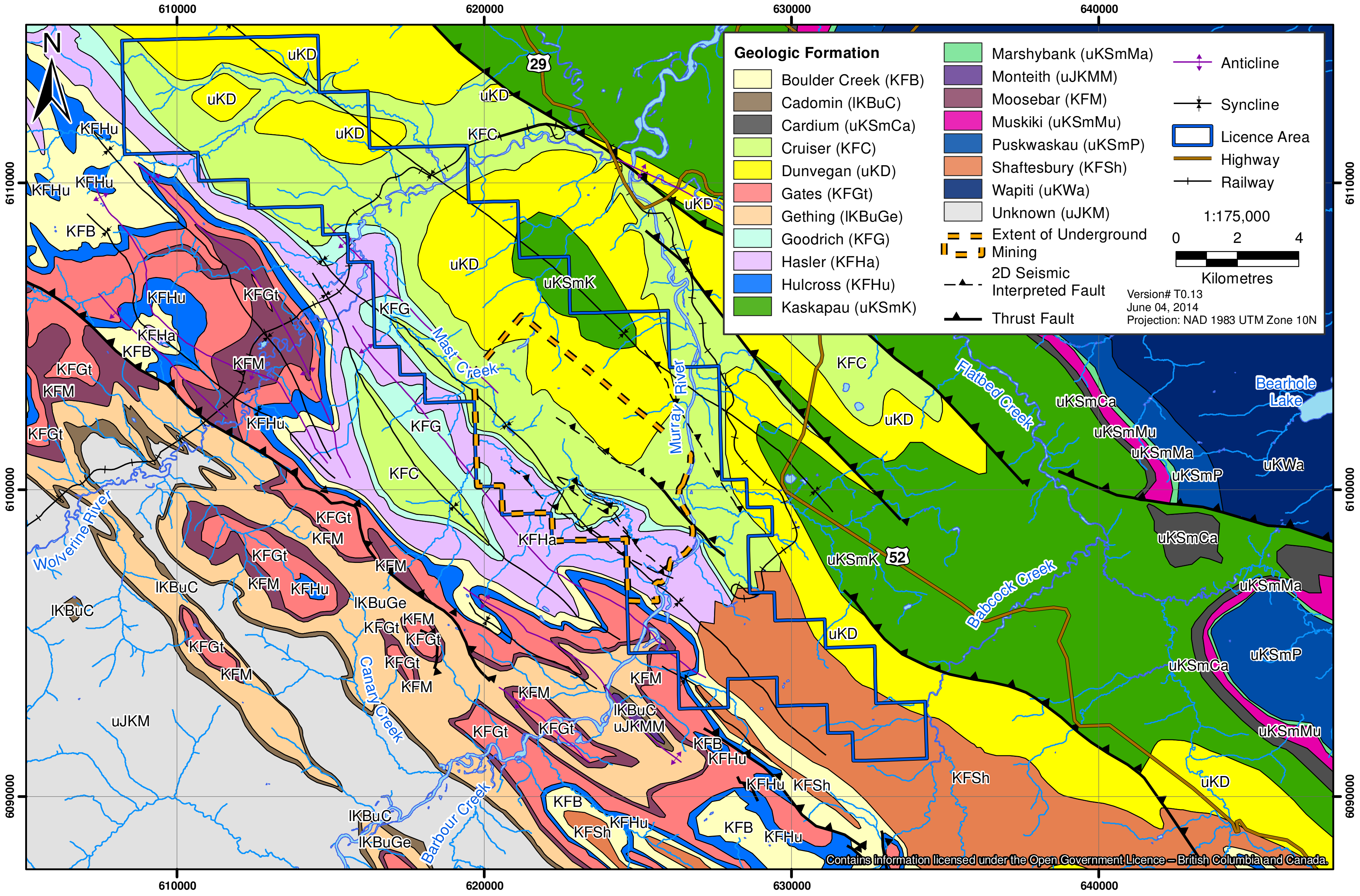
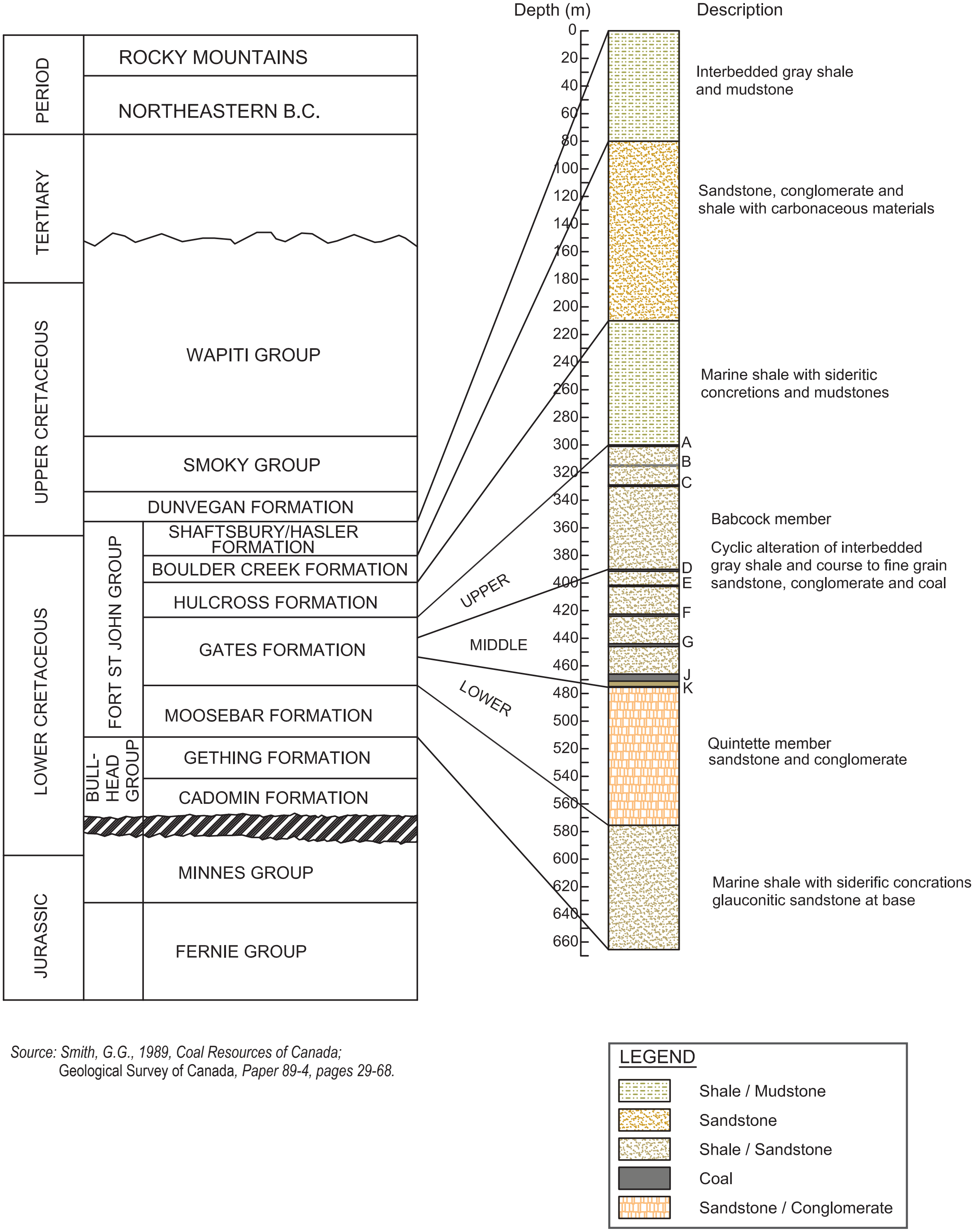


Figure 7.3-2

Regional Stratigraphic Section of Upper Jurassic - Tertiary Units of Northeast British Columbia



Source: Smith, G.G., 1989, Coal Resources of Canada;
Geological Survey of Canada, *Paper 89-4, pages 29-68.*

1. Moosebar Formation

The basal sequence of the Moosebar Formation is a dark grey to black marine shale with sideritic concretions, bentonite, and siltstone. The upper parts comprise banded or fissile sandy shale, very fine-grained sandstone, and sandstone intercalated shale. This transition is a pro-deltaic (highstand systems tract) transition from marine sediments to the massive continental sandstones that mark the overlying Gates Formation. The Bluesky Member is a chert pebble conglomerate that is found locally at the base of the Moosebar Formation.

2. Gates Formation (Fort St. John Group)

The Gates Formation conformably overlies the Moosebar Formation. The lower portion of the formation is termed the Quintette or Torrens member and consists of massive, light gray, medium-grained sandstone, with minor carbonaceous and conglomeratic horizons. The Quintette member is overlain by several cyclical sequences of coal deposition that occur over a stratigraphic interval of approximately 80 m collectively referred to as the Middle Gates. The coal seams identified (up to 10 separate seams) at the Murray River Project site are belonging to the Gates Formation.

The lower portion of the Upper Gates is massive, medium- to coarse-grained sandstone and overlain by a predominantly shale sequence containing two to three poorly developed coal seams intercalated with sandy shale and very fine sandstone. A very thin bed of chert pebbles with ferruginous cement marks the contact of the Upper Gates with the overlying marine sediments of the Hulcross Formation.

3. Hulcross Formation

The Hulcross Formation is comprised predominantly of dark grey marine shale approximately 100 metres thick. The base of the Formation is more homogeneous and arenaceous, and can contain sideritic concretions. The upper portion of the Formation is dominated by thinly laminated interbeds of siltstone and very fine-grained sandstone. A few kaolinitic beds have also been observed. The Hulcross Formation is usually distinguished from the Moosebar Formation by the absence of glauconitic sandstones at the base of the Hulcross.

4. Boulder Creek Formation

The Boulder Creek Formation is a 130 to 200 metre thick sequence of shale, greywacke, and conglomerate that conformably overlies the Hulcross Formation. The Boulder Creek Formation is a coarsening upward sequence with massive conglomerate and conglomeratic sandstone in the upper portions of the Formation and alternating medium- to fine-grained sandstones and shale in the middle of the Formation.

5. Hasler Formation

The Hasler Formation is predominantly dark grey marine shale with sideritic concretions and a minor sandstone and pebble conglomerate component; the basal layer is frequently pebbly.

Above the Hasler Formation, the Goodrich and Cruiser Formations form the uppermost units in the Fort St. John Group. According to regional geology maps, the Hasler, Goodrich, and Dunvegan formations comprise the majority of bedrock outcrop on the property.

7.3.4 Groundwater Development

Existing water supply wells for development of groundwater resources are shown in Figure 7.3-3 and Table 7.3-1. The information was accessed from the groundwater well database in the *Geographic Data Discovery Service of the DataBC* (BC MOE, 2011). In total, 40 water supply wells were identified, most of which are located near the town of Tumbler Ridge, and are about 5 to 10 km away from the proposed Project. A few wells are located at the Trend Coal Mine and Wolverine Coal Mine sites. Only one water supply well (No. 71325) is in the vicinity of the Project and it belongs to the historic Quintette Coal Mine, located on the east side of Murray River. This well is upgradient of the proposed Coal Processing Site, but it is no longer in use.

7.4 HISTORICAL ACTIVITIES

Several historic and current human activities are within close proximity to the proposed Project Area. These include mining exploration and production, oil and gas, forestry, tourism/recreation, and hunting/trapping. The legacy contribution of these historical and current activities to environmental quality has been captured during baseline studies undertaken for the proposed Project (Section 7.5).

The Quintette Coal Mine, about 20 km south of Tumbler Ridge, was an open pit mine that operated between 1982 and 2000. The mine consisted of five open pits in three discrete areas: Sheriff (Wolverine and Mesa Pits), Frame (Shikano Pit), and Babcock (Windy and Window Pits). Mine permits for the Wolverine and Mesa Pits were issued in December 1982 and mining commenced from 1983 until 1998 (Wolverine) and 2000 (Mesa). Raw coal was transported via an overland conveyor from the Mesa and Wolverine Pits to the Quintette plant site on the east bank of Murray River, for processing. The coal processing plant has been under care and maintenance since the end of mining in 2000; the overland conveyor, which previously crossed through a portion of HD Mining's Decline Site, was decommissioned by Teck in 2011. Teck is currently securing the necessary approvals to re-initiate mining in the Babcock area.

The Bullmoose Coal Mine operated from 1983 to 2003, located north of the Wolverine River. It was the largest open pit coal mine at the time. The 1.7-million-tonne-per-year operation consisted of an open-pit mine, a plant facility in the Bullmoose Creek valley below the mine, and a separate rail loadout facility on the B.C. Rail branchline.

Previous exploration in the area included seismic lines and drilling for oil and gas wells which helped target areas for coal exploration.

Twelve forest licenses exist within the baseline study area; three of these are held by the proponent. Large portions of the baseline study area have been recently harvested to remove pine-beetle affected timber.

Figure 7.3-3
Locations of Historic and Existing Groundwater Supply Wells in the Regional Study Area

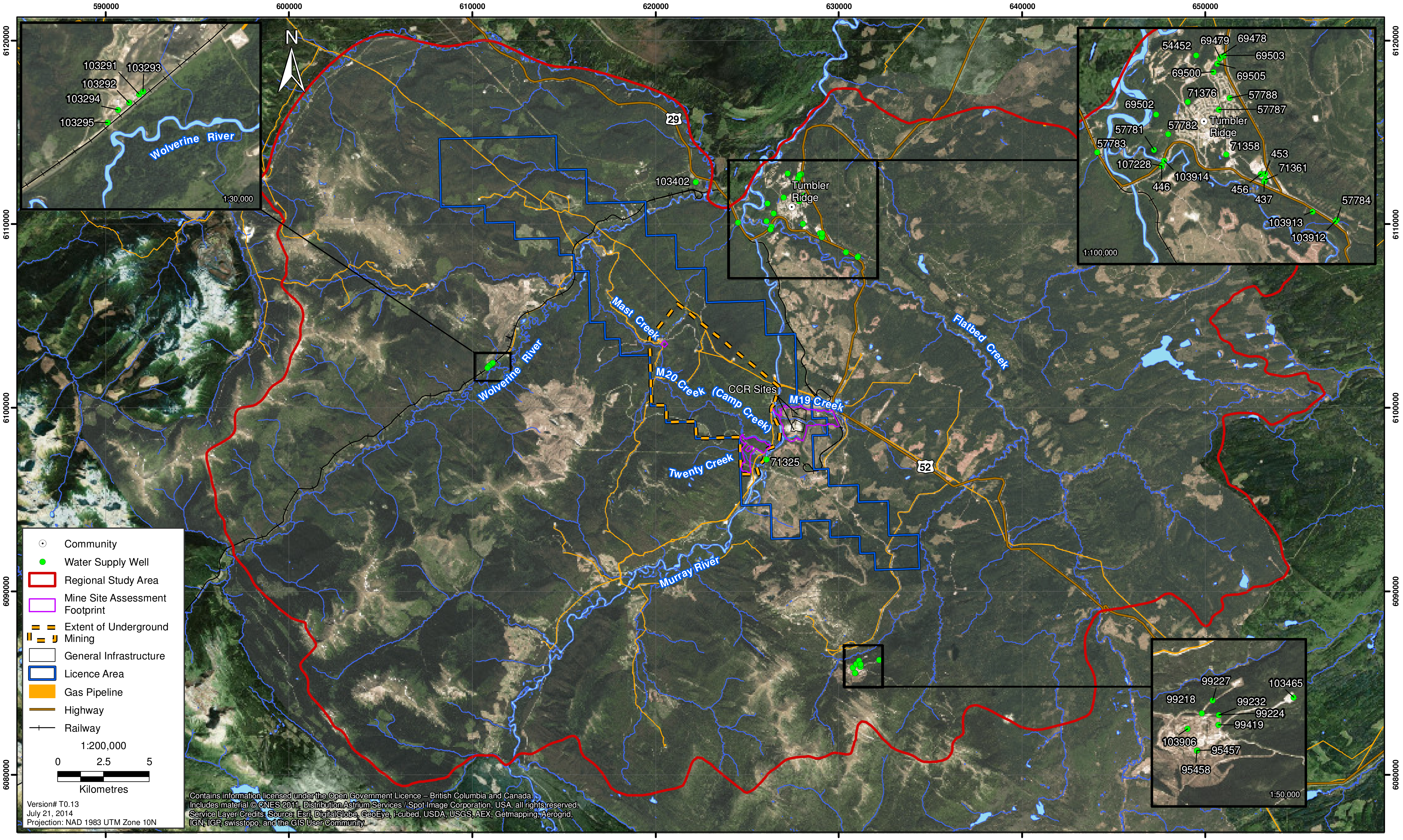


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Table 7.3-1. Details of Historic and Existing Groundwater Supply Wells in the Regional Study Area

Number	Well ID	Water Supply System Name	UTM East	UTM North	Well Location	Well depth (feet)	Diameter (inch)	Water Depth (feet)	Yield Value (Gallons per minute)	Aquifer Lithology Code	Water Supply Well Name
1	103402		622192	6112287	NOT PROVIDED	440		252	40	Bedrock	
2	71376		626980	6111485		60	10	21	60	Unconsolidated	
3	95457		630894	6085552	WELL 3a;	420	6	72	12	Unconsolidated	WELL 3A
4	95458		630886	6085548	WELL 3	416	8	41	75	Bedrock	WELL 3
5	69500		627683	6112298	TUMBLER RIDGE CAMP, NORTH OF TOWNSITE	300	6			Bedrock	
6	69503		627956	6112735	TUMBLER RIDGE CAMP, NORTH OF TOWNSITE	305	6			Bedrock	
7	57783		624496	6110107		260	6	90	1	Bedrock	
8	57787		627824	6111270		198	8			Unconsolidated	
9	57788		628119	6111588		164	8			Unconsolidated	
10	103291	WOLVERINE COAL MINE	611081	6102418	WOLVERINE MINE SITE. A0 KM EAST OF TUMBLER RIDGE. 17.5 KM ALONG WOLVERINE FOREST SERVICE ROAD.	79	9	27			WELL #1
11	446	TUMBLER RIDGE WATER SYSTEM	626261	6109732	PRODUCTION WELL 8	151	20	20	2060	Unconsolidated	PRODUCTION WELL #8
12	103292	WOLVERINE COAL MINE	611000	6102349	WOLVERINE MINE SITE. 10 KM EAST OF TUMBLER RIDGE. 17.5 KM ALONG WOLVERINE FOREST SERVICE ROAD.	43	9				WELL #5
13	103293	WOLVERINE COAL MINE	611115	6102441	WOLVERINE MINE SITE. A0 KM EAST OF TUMBLER RIDGE. 17.5 KM ALONG WOLVERINE FOREST SERVICE ROAD.	56	9				WELL #3
14	103294	WOLVERINE COAL MINE	610908	6102292	10KM EAST OF TUMBLER RIDGE. 17.5KM ALONG WOLVERINE FOREST SERVICE ROAD.	41	9	18			WELL #2
15	103295	WOLVERINE COAL MINE	610824	6102188	10KM EAST OF TUMBLER RIDGE. 17.5KM ALONG WOLVERINE FOREST SERVICE ROAD.	40.5	9	11			WELL #4
16	99419	PEACE RIVER COAL	631182	6085901	NOT PROVIDED.	420	6	72	12		WELL #3a
17	71358		628031	6110045		95	8	60		Unconsolidated	
18	71361	TUMBLER RIDGE WATER SYSTEM	629096	6109359	TUMBLER RIDGE TOWNSITE, PRODUCTION WELL #4. 2011-WAS A PRODUCTION WELL, NOW A SUPPLEMENTARY BACK-UP WELL.	132	8	88		Unconsolidated	PRODUCTION WELL 4
19	71325		626054	6097196		100	6	35			
20	57781		626053	6110168	WELL# 77-1.	293	8	30	150	Unconsolidated	
21	57784		631042	6108263		72	8			Unconsolidated	
22	69478		627882	6112706	TUMBLER RIDGE CAMP, NORTH OF TOWNSITE	61				Unconsolidated	
23	456		628972	6109512	PROPOSED INDUSTRIAL PARK SITE	180	8		25	Bedrock	
24	103906	PEACE RIVER COAL TREND MINE SITE	630758	6085846	TREND MINE SITE. NEAR WELL 3a						WELL #3
25	103912	TUMBLER RIDGE WATER SYSTEM	631012	6108230	PRODUCTION WELL 1						PRODUCTION WELL 1
26	103913	TUMBLER RIDGE WATER SYSTEM	630384	6108491	PRODUCTION WELL 3						PRODUCTION WELL 3
27	103914	TUMBLER RIDGE WATER SYSTEM	626329	6109878	PRODUCTION WELL #7						PRODUCTION WELL 7
28	54452		627209	6112759		400	6	174	20	Unconsolidated	
29	69502		626110	6111138	TUMBLER RIDGE TOWNSITE	330				Unconsolidated	
30	103465		632205	6086275	NOT PROVIDED	160		55	10		
31	69505		627783	6112516	TUMBLER RIDGE CAMP, NORTH OF TOWNSITE	205	6			Bedrock	
32	69479		627854	6112674	TUMBLER RIDGE CAMP, NORTH OF TOWNSITE	200				Bedrock	
33	99218		630954	6086055	ROMAN MTN	480			40	Bedrock	
34	99224		631184	6086036	NOT PROVIDED.	285				Bedrock	
35	99227		631100	6086234	NOT PROVIDED.	340			65	Bedrock	
36	99232		631185	6086037	NOT PROVIDED.	313			70	Bedrock	
37	437		629061	6109305	PW4a	136	10	77	188	Unconsolidated	PRODUCTION WELL 4A
38	453		629083	6109523	PROPOSED INDUSTRIAL PARK SITE	220	6		50	Bedrock	
39	107228	DISTRICT OF TUMBLER RIDGE WATER SUPPLY SYSTEM	626269	6109729							DISTRICT OF TUMBLER RIDGE WELL
40	57782		626443	6110607		187	8			Unconsolidated	

Source: BC MOE 2011

(continued)

Table 7.3-1. Details of Historic and Existing Groundwater Supply Wells in the Regional Study Area (completed)

Number	Well ID	Well Use Name	BCGS ID	BCGS Number	General Remarks
1	103402	Water Supply System	11587	093P015233	INTENDED WATER USE ALSO: COMMERCIAL/INDUSTRIAL SHOP. WELL YIELD RATE: 40 GPM
2	71376	Unknown Well Use	10213	093P015242	2011-NO LONGER USED AS AN ACTIVE PRODUCTION WELL. STEEL CASING,1.0 TO 60.0,.250 THICK, CONTINUOUS,STAINLESS STEEL,PUMP TEST RATE USGM,
3	95457	Private Domestic	10399	093I086334	
4	95458	Commercial and Industrial	10399	093I086334	
5	69500	Unknown Well Use	10284	093P016133	CASING 0.0 TO 123.0, PUMP TEST RATE 1 GPM,
6	69503	Unknown Well Use	10284	093P016133	CASING 65.0 TO 8.0, PUMP TEST RATE 1 GPM,
7	57783	Commercial and Industrial	8002	093P015223	
8	57787		8006	093P016131	
9	57788	Unknown Well Use	8006	093P016131	
10	103291	Water Supply System	11500	093P004412	2012-ID PLATE 37107 SENT TO OWNER BUT DONT KNOW IF IT GOT ATTACHED TO WELL.
11	446	Water Supply System	11944	093P015224	ALSO KNOWN AS PRODUCTION WELL # 8 . SEE NTS REPORT 93 P/3 # 22.
12	103292	Water Supply System	11500	093P004412	2012-ID PLATE 37108 SENT TO OWNER BUT DONT KNOW IF IT GOT ATTACHED TO WELL. LIMITED INFO FROM HA FORM. CORA LYNN DRILLING.
13	103293	Water Supply System	11500	093P004412	CORA LYNN DRILLING.
14	103294	Water Supply System	11500	093P004412	2012-ID PLATE 37109 SENT TO OWNER BUT DONT KNOW IF IT GOT ATTACHED TO WELL. CORA LYNN DRILLING.
15	103295	Water Supply System	11500	093P004412	2012-ID PLATE 37110 SENT TO OWNER BUT DONT KNOW IF IT GOT ATTACHED TO WELL.
16	99419	Water Supply System	11145	093I096112	IRON - 2.2, PH - 8, HARDNESS - 10, TDS - 215. SANITARY SEAL, VENTED WELL CAP AND PITLESS ADAPTER.
17	71358	Commercial and Industrial	10285	093P016113	STEEL CASING,1.0 TO 95.0,.250 THICK, CONTINUOUS,STAINLESS STEEL,PUMP TEST RATE 100 USGM,
18	71361	Water Supply System	10285	093P016113	2011-WAS A PRODUCTION WELL, NOW A SUPPLEMENTARY BACK-UP WELL. STEEL CASING,1.0 TO 132.0,.280 THICK, CONTINUOUS,STAINLESS STEEL,PUMP TEST RATE 100 USGM. CURRENTLY THIS WELL IS NOT IN USE.
19	71325	Private Domestic	11540	093P005221	STEEL CASING,1.0 TO 100.0,.188 THICK,12 LBS,60 LBS STAINLESS STEEL,PUMP TEST RATE 100 USGM. 2012 - found out well no long in use. Water is trucked in and stored in a cistern.
20	57781	Unknown Well Use	11944	093P015224	WELL #77-1
21	57784	Unknown Well Use	8005	093P016121	
22	69478	Unknown Well Use	10284	093P016133	CASING STAINLESS STEEL,PUMP TEST RATE 25 GPM,
23	456	Commercial and Industrial	10285	093P016113	
24	103906	Water Supply System	11145	093I096112	LIMITED INFO FROM HA DATABASE.
25	103912	Water Supply System	8005	093P016121	LIMITED INFO FROM HA DATABASE.PRODUCTION WELL 1.
26	103913	Water Supply System	11945	093P016112	LIMITED INFO FROM HA DATABASE. PRODUCTION WELL 3.
27	103914	Water Supply System	11944	093P015224	2012-ID PLATE 37118 SENT TO OWNER BUT DONT KNOW IF IT GOT ATTACHED TO WELL. LIMITED INFO FROM HA DATABASE. PRODUCTION WELL #7. SEE WTN 52931 FOR LITHOGIC INFO, 52931 IS A TEST HOLE IMMEDIATELY ADJACENT TO THIS WELL, SO MAY HAVE USEFUL INFO.
28	54452	Water Supply System	10283	093P015244	
29	69502	Water Supply System	10213	093P015242	CASING
30	103465	Commercial and Industrial	13052	093I096121	CASING THICKNESS: SCHED 40. SCREEN TYPE: NATURAL.
31	69505	Unknown Well Use	10284	093P016133	CASING 0.0 TO 106.7,
32	69479	Unknown Well Use	10284	093P016133	CASING 0.0 TO 74.0, PUMP TEST RATE 1 GPM,
33	99218	Commercial and Industrial	11145	093I096112	
34	99224	Test	11145	093I096112	
35	99227	Test	11145	093I096112	LINER PERF., LINE SOLID, LINER PERF.
36	99232		11145	093I096112	
37	437	Unknown Well Use	10285	093P016113	ALSO KNOWN AS PRODUCTION WELL #4A . 2011-NO LONGER USED AS AN ACTIVE PRODUCTION WELL. SEE NTS REPORT 93P/3 # 22.
38	453	Commercial and Industrial	10285	093P016113	
39	107228	Water Supply System	11944	093P015224	LIMITED INFO FROM NHA FORMS.
40	57782	Water Supply System	10213	093P015242	

Source: BC MOE 2011

Subsistence activities, such as trapping, hunting, and fishing, are common land uses regionally. Three trapping tenures and four guide-outfitting tenures overlap the baseline study area. Multiple recreation tenures, as well as temporary and permanent residences, exist within the Project area. The nearest trapline cabin is 1.7 km from the Project on the west bank of Murray River, the nearest campground is 9.5 km north from the Project (near Tumbler Ridge), the nearest hunting camp is 26 km west from the Project, and the nearest residential area (Tumbler Ridge) is 12.4 km north from the Project.

There are multiple previously recorded archaeological sites (pre-contact lithic scatters) within 5 km of the proposed Project infrastructure.

The Project is located near two provincial parks and protected areas. Bearhole Lake Provincial Park and Protected Area is located approximately 17 km east of the Project, and Monkman Provincial Park is located approximately 27 km south of the Project.

7.5 BASELINE STUDIES

The details of the hydrogeological baseline studies conducted and the information used to characterize the hydrogeological system are available in Appendix 7-A. The information and data included for the hydrogeology baseline studies spanned from 1977 to 2014. The objectives of the hydrogeology baseline studies were to:

- characterize the baseline, pre-development groundwater conditions;
- characterize the overburden and bedrock types present and their hydraulic conductivities, and identify hydrostratigraphic units;
- characterize groundwater levels and flow directions, recharge and discharge zones, and groundwater quality;
- evaluate seasonal variability in groundwater levels and groundwater quality; and
- provide sufficient baseline information upon-which to base assessment of the Project's potential environmental effects and to design an appropriate groundwater monitoring program.

7.5.1 Data Sources

The sources of the hydrogeological baseline information and data as well as the relevant climate, hydrology, and geology within the LSA and RSA boundaries can be found in Appendix 7-A. This includes from the following technical reports:

- Rescan. 2013. *Murray River Coal Project: 2011 to 2012 Meteorology Baseline Report*. Prepared for HD Mining International Ltd. by Rescan Environmental Services Ltd.: Vancouver, British Columbia (Appendix 6-C).
- ERM Rescan. 2014. *Murray River Coal Project: 2011 to 2013 Hydrology Baseline Report*. Prepared for HD Mining International Ltd. by ERM Rescan: Vancouver, British Columbia (Appendix 8-A).

- ERM Rescan. 2014. *Murray River Coal Project: Hydrogeology baseline Report*. Prepared for HD Mining International Ltd. by ERM Rescan: Vancouver, British Columbia (Appendix 7-A).
- Norwest Corporation. 2010. Geology and Coal Resources of the Murray River Coal Property, Peace River Coalfield, British Columbia. June 30, 2010.
- AMEC. 2010. *Packer Testing to Assess Bedrock Permeability, Tumbler Ridge, BC*. Submitted to Canadian Dehua International Mines Group Inc. by AMEC Earth and Environmental, Prince George, BC. (included with Appendix 7-A)
- AMEC. 2012. *Single Well Reponse Tests: Proposed Murray River Underground Coal Mine, Tumbler Ridge, BC*. Submitted to Canadian Dehua International Mines Group Inc. by AMEC Environment and Infrastructure, Kamloops, BC. (included with Appendix 7-A)
- Western Canadian Coal Corp. (WCC). 2007. Hermann Mine Project. Application for an Environmental Assessment Certificate. February 2007. Vancouver, BC.
- SRK. 2012. Quintette Groundwater Technical Assessment Report - Appendix 4-A Groundwater Technical Data – Report prepared for Teck Coal Corporation, March 2012.

7.5.2 Methods

The methodologies for the Project-specific hydrogeological baseline studies for groundwater quantity and quality include:

1. Borehole drilling and logging;
2. Installation of groundwater monitoring wells and vibrating wire piezometers;
3. Groundwater monitoring well development;
4. Hydraulic conductivity testing (pumping tests, packer, and slug tests);
5. Measurement of groundwater levels, hydraulic gradients, groundwater flow directions and potentiometric surface; and
6. Groundwater quality sampling.

Details of these methods are available in Appendix 7-A. Figure 7.5-1 shows the existing groundwater monitoring instrumentation installed at nearby mining projects. Figure 7.5-2 shows the groundwater monitoring instrumentation installed at the Project site.

Field programs conducted as early as 1977 (for the Quintette Coal project prior to development) and as late as 2014 have generated datasets consisting of overburden and bedrock geologic properties, hydraulic conductivities, groundwater levels, and groundwater chemistry.

Soil and rock samples recovered during borehole advancement were used to characterize geologic conditions and develop hydrostratigraphic delineations. Core recovered from 34 exploration boreholes, ranging in depth from 500 to 1350 m, have been used to characterize the deep lithologies in the Underground Mine Zone. Soil and shallow bedrock samples have been collected from an additional 30 boreholes, which were drilled as a focussed effort to study the baseline hydrogeologic conditions for the Project.

Figure 7.5-1
Existing Groundwater Monitoring Instrumentation Installed at Nearby Mining Projects

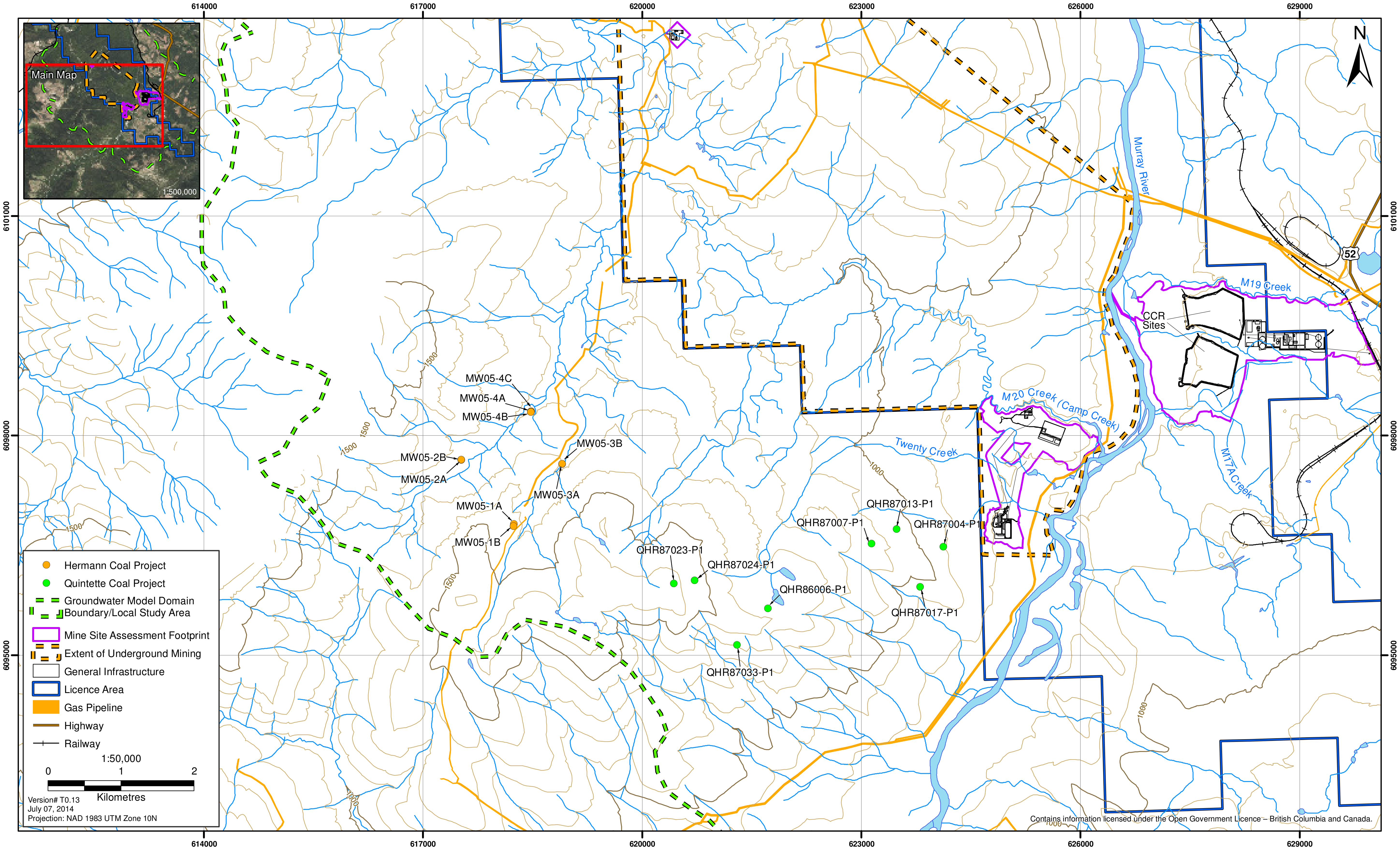
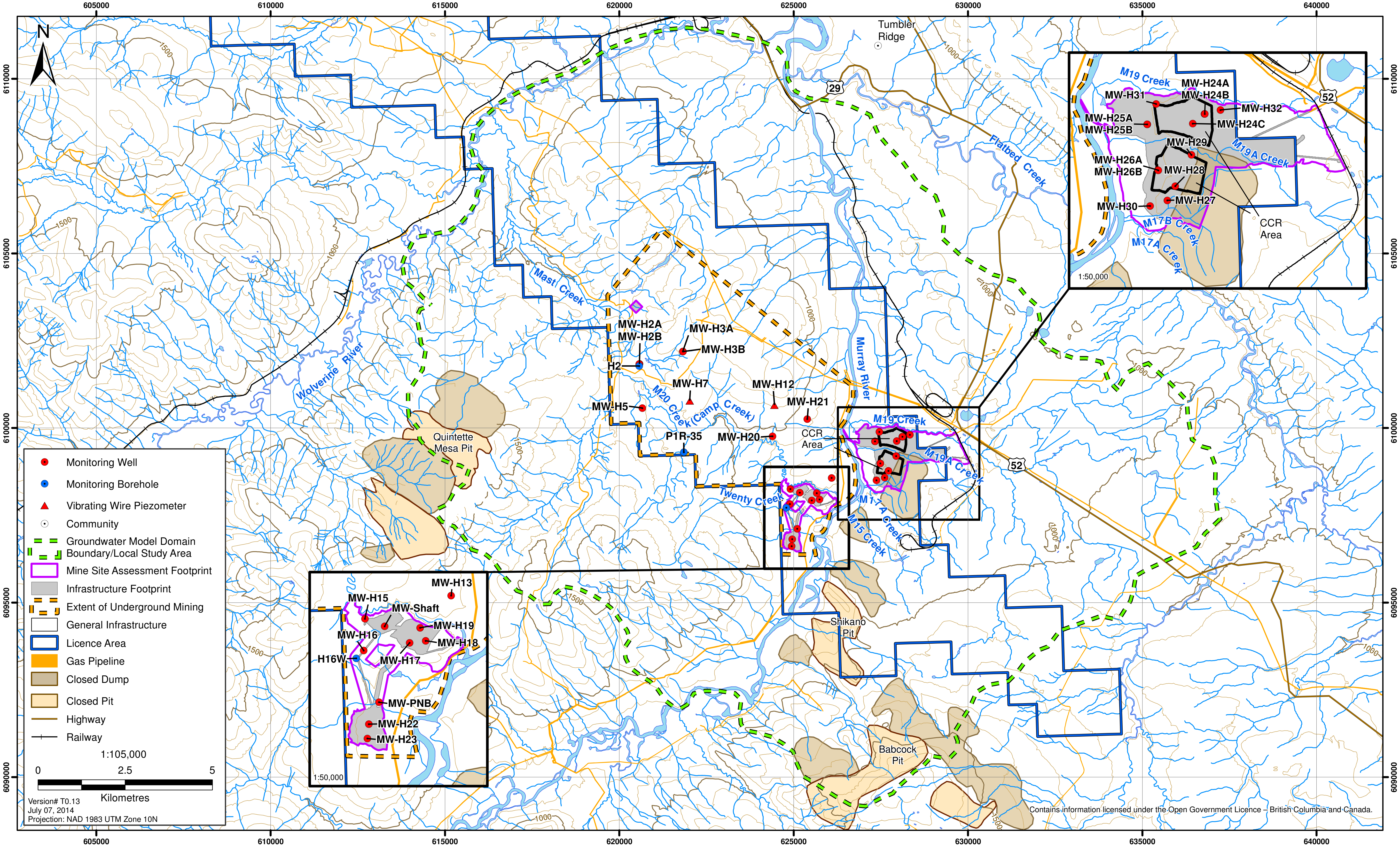


Figure 7.5-2
Groundwater Monitoring Instrumentation Installed at the Project Site



Hydraulic tests were conducted as drilling advanced through bedrock horizons, and used to measure hydraulic conductivity (K) of the medium. Hydraulic tests were used to measure K along ten deep (up to 955 metres below grade [mbg]) test intervals. Falling-head tests were conducted in packer zones along 26 intervals in nine boreholes during the baseline hydrogeology study. Also, 23 K measurements derived from single well response tests conducted for other Projects (Quintette and Hermann Coal Projects) within the local study area have been used.

Individual standpipe piezometers (wells) were installed in 30 boreholes following completion of drilling. Two vibrating wire piezometers (VWPs) were installed in each of two additional boreholes following completion of drilling. Wells were developed by air lifting with compressed air or surging and over pumping with an inertial pump. Single well response tests (rising and falling head slug tests) were conducted in 21 installed wells, serving to further characterize K of the saturated geologic materials. Groundwater levels were measured using an electric water level meter in all wells quarterly, and using a read-out box for VWPs. Continuous water level records were acquired using pressure transducers deployed in five wells.

The hydrogeology baseline study included collection of groundwater samples from 23 wells for characterization of groundwater quality. Samples collected for the Hermann and Quintette Coal Projects within the local study area have also been reviewed in characterizing groundwater quality trends in the area. Most wells were sampled on a seasonal basis to capture seasonal variability over a hydrologic year. Wells were purged sufficiently prior to the collection of samples. Field hydrochemical parameters were measured, and stabilisation criteria were used to determine completion of purging. Quality control protocol included the collection of duplicate samples, and use of field, travel, and equipment blanks.

7.5.3 Characterization of Groundwater Quantity and Quality Baseline Conditions

7.5.3.1 Hydrostratigraphic Features and Properties

The Project is situated within a folded and faulted series of Lower Cretaceous clastic sedimentary rocks, underlying a covering dominated by glacially-derived sediments and river sediments. The majority of the rock mass is composed of mudstones and siltstones, which are inter-bedded with sandstone and coal seams. The geometry of the strata may be controlled by structural features (presence of synclines, antyclines, and faults) and influenced by erosion (presence of river and creek valleys dissecting the bedrock formations).

The bedrock is saturated except where it crops above the water table, and as such constitutes a fractured bedrock medium for saturated groundwater flow. The hydraulic testing results indicate that most of the bedrock formations have low permeability.

The Hasler Formation (and other undifferentiated sediments above the Boulder Creek Formation) has hosted 40 hydraulic conductivity (K) measurements within the LSA, which show K ranging from 6×10^{-6} m/s to 9×10^{-10} m/s (geometric mean of 8×10^{-8} m/s). The permeability appears to generally decrease with depth. The two K measurements in the Boulder Creek Formation were 5×10^{-9} m/s and 3×10^{-8} m/s. Two measurements spanning the lower Boulder Creek, Hulcross, and Upper Gates formations were 6×10^{-9} m/s and 2×10^{-9} m/s. The extent of the Gates Formation containing coal seams may present an isolated exception to the K versus depth trend: K has been reported to be as high as 2 x 10^{-7} m/s in the extent of the Gates Formation containing the F, G, and I coal seams.

Due to a sizeable presence of sandstone in the stratigraphic columns of the Boulder Creek and Gates formations, they may behave as aquifers on a regional scale. The Hasler and Hulcross formations may behave as regional aquitards due to the dominance of mudstones and siltstones in these formations. The limited hydraulic conductivity data available for the deeper strata of the Project area is not sufficient to clearly designate bedrock formations within the project area as aquifers or aquitards.

Surficial deposits vary greatly in thickness and lithological character from place to place. Principal deposit types include fluvial, glaciofluvial, morainal, colluvial, and wetland sediments. Fluvial and glaciofluvial sediments are present mainly along the bottoms of river valleys, morainal sediments cover much of the ground surface of the hills and mountains, colluvial sediments are common along steeper slopes, while wetland sediments accumulated in terrain depressions or at the base of significant groundwater seeps.

Grain size distribution is the primary factor determining hydraulic properties of surficial sediments. Sand/gravel and clay/silt are at the opposite ends of a spectrum of high-K and low-K sediments, respectively. Hydraulic conductivity of gravelly sand has ranged as high as 4 x 10^{-4} m/s, and measurements in fines as low as 4 x 10^{-9} m/s.

Groundwater levels in bedrock formations indicate confined conditions, except near bedrock outcrop / sub-crop areas close to deeply incised valleys. Groundwater in overburden deposits is most often present under unconfined conditions, although some wells at the Coal Processing Site exhibit confined conditions where a clay layer overlies a granular deposit.

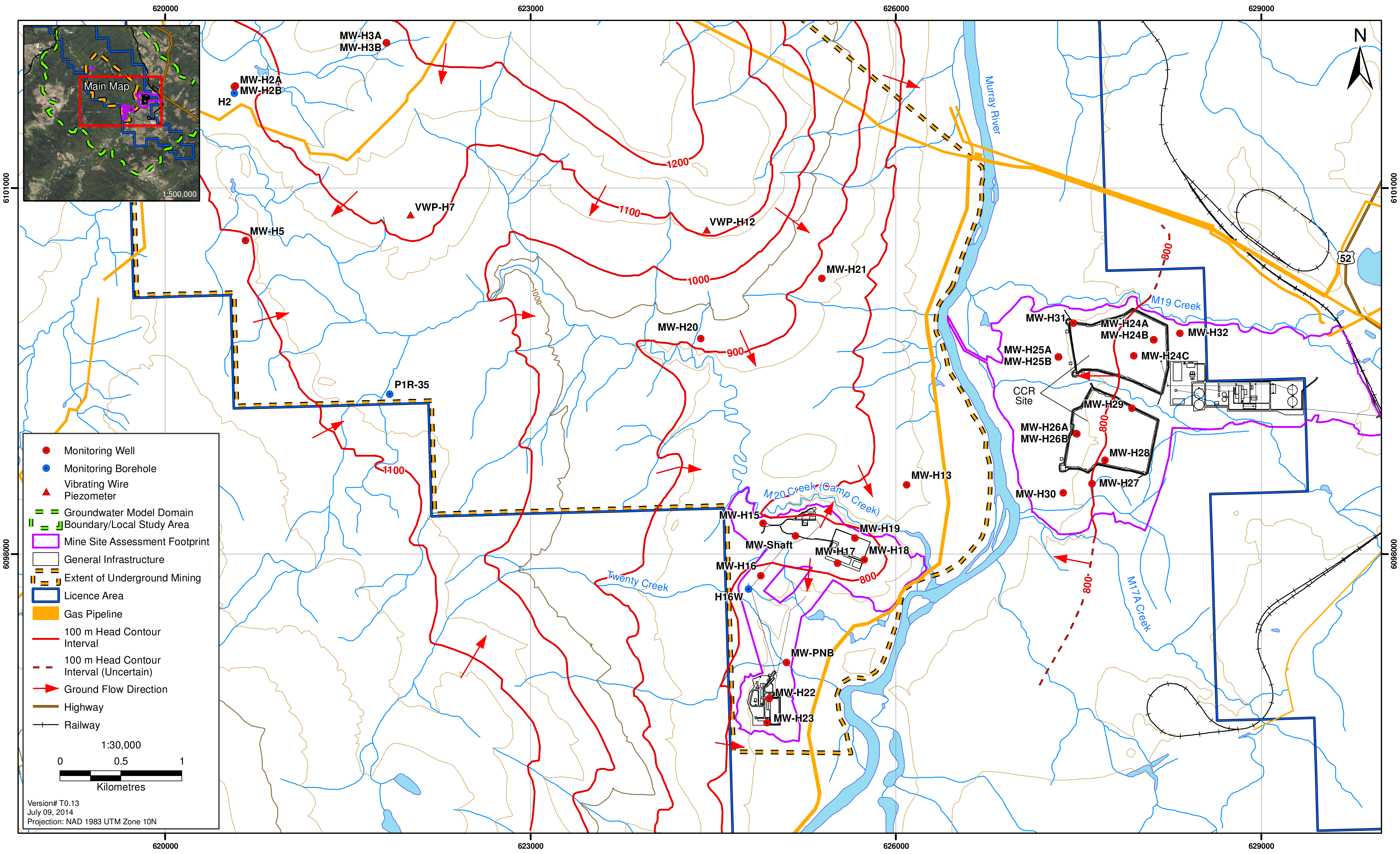
7.5.3.2 Groundwater Flow Regime (Flow Directions, Recharge/Discharge Zones)

The Project is located in a Mountain foothill area dissected by the broad valleys containing the Murray and Wolverine rivers. Foothills within the regional study areas rise over 1,000 meters above the valley bottoms (e.g. Mount Babcock at 1,855 masl, and the Murray River at 770 masl).

The groundwater flow system in the Project area is characterized by groundwater flowing from the upper foothills towards the Murray River (Figure 7.5-3). On the west side of Murray River, the M20 (Camp) Creek basin behaves as an intermediate catchment basin; the watersheds of Twenty Creek, and other minor tributaries within the extent of underground mine behave as local catchment basins as well. On the east side of Murray River, the small watersheds containing M19A, M17B, and M19 creeks behave as local catchment basins for shallow groundwater flow in the Coal Processing Site and adjacent areas.

Groundwater is recharged by greater precipitation at higher elevations (due to the orographic effects), while valley bottoms constitute groundwater discharge zones. Documented seasonal variations in groundwater levels have been as high as 2 m. Given the scale of topographic relief within the local study area, these water level variations are expected to be too small to give rise to meaningful changes in hydraulic gradients or the patterns of groundwater flow.

Figure 7.5-3
Potentiometric Surface Map



7.5.3.3 Surface Water – Groundwater Interactions

All streams are fed to a varying degree by precipitation, overland runoff, and groundwater discharge. Streamflow is dominated by groundwater discharge (often referred to as baseflow) during low flow in the winter. During freshet in the spring, streams may be recharging groundwater, particularly along reaches at higher elevations. Stream reaches at lower elevations are predominantly situated in groundwater discharge zones. The groundwater likely supports wetlands found along the flood plains of the Murray River during non-peak flow periods.

7.5.3.4 Groundwater Quality Conditions

Groundwater throughout the local study area is slightly basic (mean pH of 7.2 to 8.4). Calcium and bicarbonate tend to be the dominant ions in the shallow groundwater (less than 50 mbg), and sodium and bicarbonate dominate in the deeper groundwater. Total dissolved solids (TDS) trends upwards with depth.

Concentrations of dissolved barium, iron, lithium, and manganese have consistently exceeded the BC Ministry of Environment's guidelines for the protection of freshwater aquatic life or raw drinking water supply in samples collected from a number of well. Elevated concentrations of the aforementioned metals are considered natural baseline occurrences. Positive detections of aluminum, arsenic, chromium, copper, and selenium have exceeded guidelines for the protection of freshwater aquatic life or drinking water in isolated samples.

7.6 ESTABLISHING THE SCOPE OF THE EFFECTS ASSESSMENT FOR GROUNDWATER

This section includes a description of the scoping process used to identify potential effects on groundwater, select assessment boundaries, and identify the potential effects of the proposed Project as a result of interactions with groundwater. Scoping is fundamental to focusing the Application/EIS on those issues where there is the greatest potential to cause significant adverse effects. The scoping process for the assessment of groundwater consisted of the following steps:

- *Step 1:* conducting a desk-based review of available scientific data, technical reports, and other Project examples to compile a list of potential effects on groundwater in the vicinity of the Project;
- *Step 2:* carrying out detailed field baseline studies to fill information gaps and confirm presence/absence of groundwater;
- *Step 3:* considering feedback from the EA Working Group on the proposed studies of groundwater included in the AIR and the EIS Guidelines;
- *Step 4:* defining boundaries for assessment of the effects on groundwater; and
- *Step 5:* identifying key potential effects on groundwater.

These steps are described in detail below.

7.6.1 Selecting Valued Components

Valued components (VCs) are components of the natural and human environment that are considered to be of scientific, ecological, economic, social, cultural, or heritage importance (CEAA, 2012; BC EAO, 2013). To be included in the EA, there must be a perceived likelihood that the VC will be affected by the proposed Project. Valued components are scoped into the environmental assessment based on issues raised during consultation on the AIR and EIS Guidelines with Aboriginal communities, government agencies, the public and stakeholders. Consideration of certain VCs may also be a legislated requirement, or known to be a concern because of previous project experience.

7.6.1.1 Summary of Valued Components Selected for Assessment

Groundwater quantity and quality were selected as VCs as identified in the AIR approved by the BC Environmental Assessment Office (EAO, 2013) and the Environmental Impact Statement Guidelines (CEAA, 2012). These VCs were selected based on consultation with regulatory agencies, regulatory considerations and professional judgment. Table 7.6-1 presents the identifications and rationales for selecting groundwater quantity and quality as valued components. No identified groundwater-related VCs were excluded from the assessment.

Table 7.6-1. Groundwater Valued Components Included in the Effects Assessment

Valued Component	Identified by*			Rationale for Inclusion
	AG	G	P/S	
Groundwater Quantity	X	X	X	Groundwater is an inherent component of the water cycle and is therefore linked with the environmental conditions and ecosystems within the study area.
Groundwater Quality	X	X	X	Groundwater is an inherent component of the water cycle and is therefore linked with the environmental conditions and ecosystems within the study area

**AG = Aboriginal Group; G = Government; P/S = Public/Stakeholder*

Groundwater is an inherent component of the water cycle and is therefore linked with the environmental conditions and ecosystems within the study area. Groundwater quality and quality were selected as VCs because of their important relationships with surface water quantity and quality, aquatic resources, and wildlife. Groundwater is protected under the *Canada Water Act* (1985), *BC Water Act* (1996), and *BC Water Protection Act* (1996).

Project activities during Construction, Operation, Decommissioning and Reclamation, and Post Closure could affect groundwater quantity and quality. Potential adverse effects to groundwater aquifers may transfer to surface water systems in groundwater discharge zones along the streams and in Murray River.

7.6.2 Selecting Assessment Boundaries

Assessment boundaries (including spatial and temporal boundaries) define the maximum limit within which the effects assessment is conducted. They encompass the areas within, and times during which, the Project is expected to interact with groundwater, as well as the constraints that may be placed on the assessment of those interactions due to political, social, and economic realities, and limitations in predicting or measuring changes. The definition of these assessment boundaries is an integral part in scoping for groundwater, and encompasses possible direct, indirect, and induced effects of the Project on groundwater quantity and quality, as well as the trends in processes that may be relevant.

7.6.2.1 Spatial Boundaries

<u>Local Study Area</u>

The spatial boundary of the local study area (LSA) used for the groundwater quantity and quality effects assessment is shown in Figure 7.6-1, and it occupies an area of approximately 308 km^2. The LSA encompasses an area surrounding the proposed Project infrastructure within-which direct effects from the Project may be anticipated. The LSA boundary has also been developed following natural terrain and drainage boundaries in order to be hydrogeologically relevant. The LSA boundary for the groundwater effects assessment is identical to the local hydrogeology baseline study area (Appendix 7-A) and the numerical groundwater modeling area (Appendix 7-B).

<u>Regional Study Area</u>

The spatial boundary of the regional study area (RSA) used for the groundwater quantity and quality effects assessment is shown in Figure 7.6-2, and it covers an area of approximately 1,812 km^2. The RSA is intended to encompass an area beyond-which effects of the Project would not be expected. It is also intended to be hydrogeologically relevant, based on the groundwater catchment divides indicated by terrain and rivers / streams in the region. The RSA boundary for the groundwater effects assessment is identical to the regional hydrogeology baseline study area (Appendix 7-A). The RSA boundary includes the neighbouring projects (e.g. Quintette Coal Mine, Hermann Coal Mine, Wolverine Coal Mine, Roman-Trend Coal Mine, Natural Gas Pipelines, and Wind Energy Projects) as well as groundwater supply wells that may potentially have interactions with the Project and cumulative effects on the Project.

7.6.2.2 Temporal Boundaries

The temporal boundaries used for the groundwater quantity and quality effects assessment are aligned with the key phases of the Project and are defined as follows:

- **Construction**: 3 years;
- **Operation**: 25-year run-of-mine life;
- **Decommissioning and Reclamation**: 3 years (includes project decommissioning, abandonment and reclamation activities, as well as temporary closure, and care and maintenance); and
- **Post Closure**: 30 years and up to 200 years (includes ongoing reclamation activities and post-closure monitoring), from the groundwater perspective.

A temporal boundary is established for the assessment of Project-related and cumulative effects. The Project-related effects assessment begins when the Project activities commence during Construction. The potential effects of the mine activities are expected to reach the maximum at the end of Operation and reduce gradually during Post Closure until groundwater levels re-stabilize. Using the numerical models, the water table drawdown in the underground mine zone was simulated until full recovery during Post Closure, and the potential solute migration plume from the CCR Piles was simulated for 200 years during Post Closure.

7.6.3 Identifying Potential Effects on Groundwater Quantity and Quality

7.6.3.1 Methodologies for Identifying Potential Effects

The details of the design and planning of the Project was outlined in Section 3.6 of the Project Description. Table 7.6-2 presents the key Project phases along with the potential interactions of the mine activities with the groundwater quantity and quality. The potential interactions of the Project activities with groundwater were identified using the following indictors, and professional judgment and experience at other mining projects in BC.

For groundwater quantity, the potential effects were identified with the indicator: the change of groundwater levels and flow patterns (referring to flow directions, hydraulic gradients and flow rates collectively), due to Project activities (e.g. the underground mine dewatering). For groundwater quality, the potential effects were identified with the indicator: the change of the groundwater quality, due to the mine activities (e.g. seepage of contact groundwater from the CCR piles).

As shown in Table 7.6-2, among all the proposed mine activities, the underground mine development (together with the mine shafts) and the operation of the CCR piles are identified to be the major ones that may potentially cause some adverse effects to groundwater quantity and quality during the mine life and Post Closure. The following section provides the high-level scoping summary of the potential effects identified on groundwater quantity and quality in different mine phases.

7.6.3.2 Scoping Summary of Potential Effects on Groundwater Quantity and Quality

Construction

During Construction, the Production Decline and development of underground service bays, sumps, conveyor headings, etc. are identified to have potential adverse effects on groundwater quantity. Opening up these areas underground will result in groundwater inflow to the underground workings, which in turn will be reflected in potential changes of groundwater levels and flow patterns. These kinds of effects are expected to be highly localized given the short duration and limited extent of underground development during this period. Potential effects associated with water table drawdown are discussed in the underground mine dewatering effect assessment for Operation; a separate treatment of those potential effects during Construction is not warranted.

Figure 7.6-1
Local Study Area Boundary for Groundwater Effects Assessment

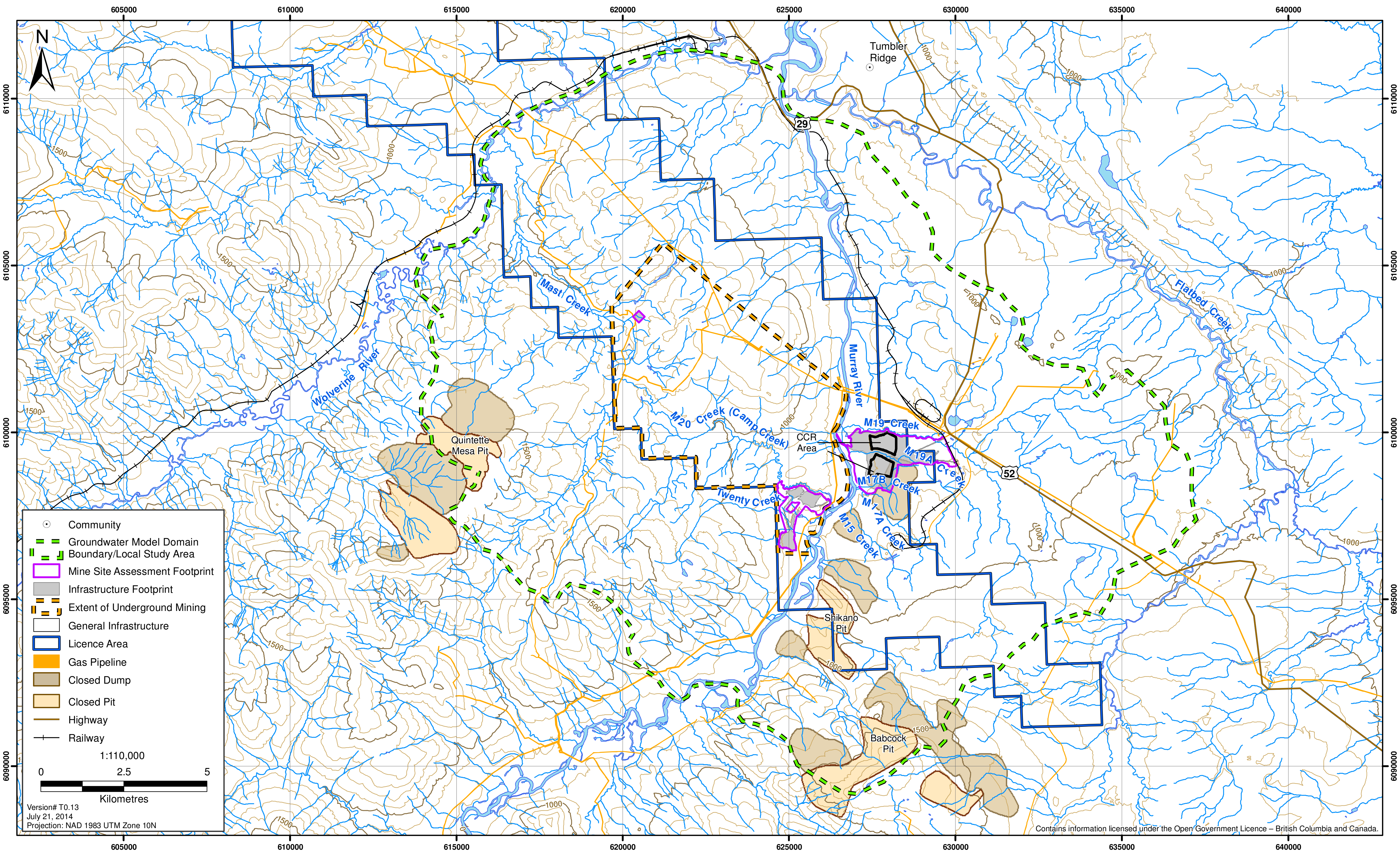
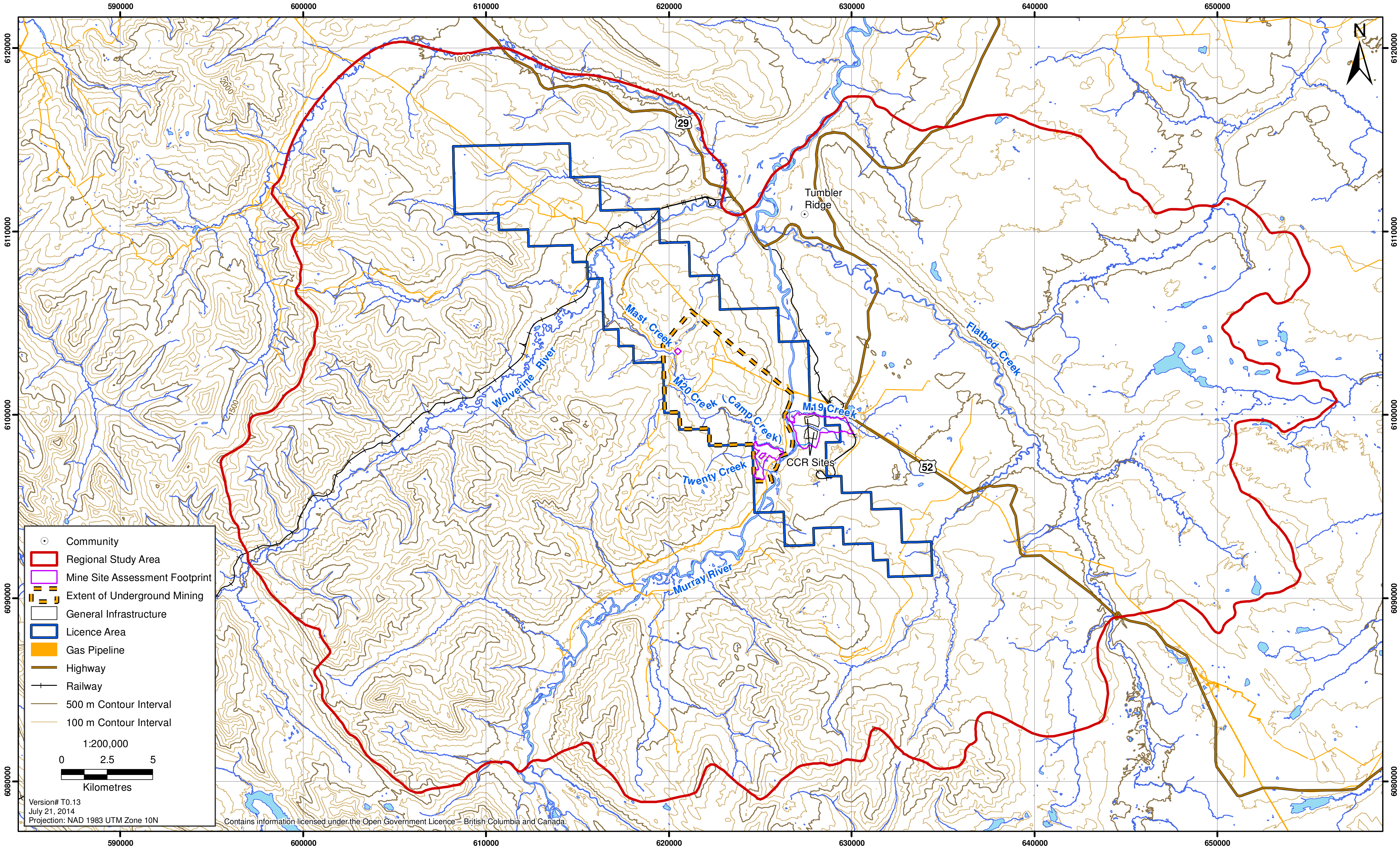


Figure 7.6-2
Regional Study Area Boundary for Groundwater Effects Assessment



Version# T0.13
July 21, 2014
Projection: NAD 1983 UTM Zone 10N

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Table 7.6-2. Ranking Potential Effects On Groundwater Quantity and Quality

		Potential Effects on Groundwater Quantity and Quality	
	Project Activities	Change of Groundwater Quantity (Water Levels, Flow Patterns)	Change of Groundwater Quality due to Seepage of Contact Groundwater
Construction	**Underground Mine**		
	Construction of Production Decline (2 headings - surface and underground)	M	L
	Haul of waste rock from Production Decline portal to Shaft Site	-	L
	Ventilation during construction	-	-
	Development mining of underground service bays, sumps, conveyor headings, etc.	M	L
	Construct underground conveyor system	-	-
	Coal Processing Site		
	Surface Preparation		
	Establish site drainage and water management	L	L
	Site clearing and stripping (CPP site, CCR North)	L	L
	Soil salvage for reclamation	L	L
	Upgrade access roads, parking and laydown areas	L	L
	Heavy machinery use	-	-
	Buildings and Services		
	Install domestic water system	-	-
	Install sanitary sewer system	-	-
	Install natural gas and electricity distribution network	-	-
	Construct main fuel station	-	-
	Construct buildings (e.g., maintenance, administration, warehouse)	-	-
	Construct raw coal and clean coal stockpile areas	-	-
	Construct coal preparation plant buildings and install/commission equipment	-	-
	Construct surface conveyor system	-	-
	Construct rail load-out facilities	-	-
	Shaft Site		
	Upgrades to infrastructure within existing site	-	-
	Addition of waste rock within existing storage area	L	L
	Management of runoff from waste rock pile and release to receiving environment (M20 Creek)	-	-
	Decline Site		
	Upgrades to infrastructure within existing site	-	-
	Management of water from underground activities and release by exfiltration to ground	L	L
	Traffic and Transportation		
	Transportation of materials to and from site	-	-
	Recycling and solid waste disposal	-	-
	Shuttling workforce to and from site	-	-
	Workforce and Administration		
	Hiring and management of workforce	-	-
	Taxes, contracts, and purchases	-	-

(continued)

Table 7.6-2. Ranking Potential Effects On Groundwater Quantity and Quality (continued)

Project Activities		Potential Effects on Groundwater Quantity and Quality	
		Change of Groundwater Quantity (Water Levels, Flow Patterns)	Change of Groundwater Quality due to Seepage of Contact Groundwater
Operation	**Underground Mine**		
	Longwall panel mining, and development mining	H	L
	Ventilation from underground	-	L
	Methane management	-	-
	Secondary shaft construction	L	L
	Underground seepage collection and water management	L	L
	Surface subsidence	M	L
	Coal Processing Site		
	Coal Processing Plant		
	Stockpiles of raw coal	L	L
	Operation of coal preparation plant and conveyor system	-	-
	Stockpiles of clean coal and middlings	L	L
	Operation of rail loadout	-	L
	CCR		
	CCR Pile development	M	M
	Site clearing and stripping (expansion of CCR North, construction of CCR South)	L	L
	Seepage collection system	L	L
	Water Management		
	Management of water brought to surface from underground	L	L
	Management of seepage from CCR	L	L
	Management of other site contact water	L	L
	Maintenance of site ditching and water management infrastructure	L	L
	Release of excess contact water to receiving environment	L	L
	Shaft Site		
	Maintenance of infrastructure within existing site	-	-
	Progressive reclamation of waste rock pile	L	L
	Management of runoff from waste rock pile and release to receiving environment (M20 Creek)	L	L
	Decline Site		
	Maintenance of infrastructure within existing site	-	-
	Secondary Shafts Site		
	Site preparation and construction of shafts	M	L
	Maintenance of infrastructure within existing site	-	-
	Utilities, Power, and Waste Handling		
	Electrical power use	-	-
	Natural gas use	-	-
	Domestic water use	-	-
	Domestic sewage handling	-	-
	Recycling and solid waste disposal	-	-

(continued)

Table 7.6-2. Ranking Potential Effects On Groundwater Quantity and Quality (completed)

		Potential Effects on Groundwater Quantity and Quality	
	Project Activities	Change of Groundwater Quantity (Water Levels, Flow Patterns)	Change of Groundwater Quality due to Seepage of Contact Groundwater
Operation *(cont'd)*	**Heavy Machinery, Traffic, and Transportation**		
	Shuttling workforce to and from site	-	-
	Transportation of materials to and from site	-	-
	Surface mobile equipment use	-	-
	Road maintenance	-	-
	Fuel storage	-	-
	Workforce and Administration		
	Hiring and management of workforce	-	-
	Taxes, contracts, and purchases	-	-
Decommissioning and Reclamation	**Infrastructure Removal and Site Reclamation**		
	Facility tear down and removal	-	-
	Reclamation of plant site	-	-
	Reclamation of on-site roads and rail lines	-	-
	Recycling and solid waste disposal	-	-
	Heavy Machinery, Traffic, and Transportation		
	Shuttling workforce to and from site	-	-
	Transportation of materials to and from site	-	-
	Surface mobile equipment use	-	-
	Fuel storage	-	-
	CCR		
	Reclamation of CCR	M	M
	Seepage collection system	L	M
	Site water management and discharge to receiving environment	L	L
	Underground Mine		
	Infrastructure tear down and removal	-	-
	Geotechnical and hydrogeological assessment and bulkhead installation	L	L
	Groundwater recovery and monitoring	M	M
	Workforce and Administration		
	Hiring and management of workforce	-	-
	Taxes, contracts, and purchases	-	-
Post Closure	**Shaft Site**		
	Waste rock pile seepage monitoring	L	L
	CCR		
	Seepage collection system	L	M
	Site water management and discharge to receiving environment	L	L
	Underground Mine		
	Groundwater recovery and monitoring	L	L

L	*Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required, no further consideration warranted.*
M	*Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*
H	*Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

According to the mine plan, groundwater inflow into the mine during Construction will be collected and managed as contact water, with either re-use in the mine, or discharge to surface water. No effect is expected on groundwater quality.

Operation

During Operation, underground mine development is identified to have a potential effect on groundwater quantity with continuous changes of water levels and flow patterns (flow directions, hydraulic gradients, and flow rates) in the area above and some distance around the mine. This development includes the construction of the secondary shafts later in the mine life (Year 15).

Dewatering of the underground mine and associated changes in water levels are not anticipated to cause significant effects on the quality of groundwater in the overlying strata.

In addition to dewatering of groundwater, underground mining will result in deformations and displacements of the overlying rocks, which will propagate up to the surface causing subsidence. Given that topography plays a large role in groundwater recharge/discharge and the resultant water levels and flow patterns, subsidence may result in potential effects to groundwater quantity. However, given the predicted magnitude of subsidence (in the range of 1 to 9 m, depending on the number of coal seams to be mined; Appendix 3-C), relative to the total range of topography relief of about 730 m across the local study area (from 770 m at Murray River to around 1,500 m at the highest mountain in the LSA), the nature of any effects related to subsidence are expected to be highly localized, and they could not be predicted with any certainty at this stage.

CCR pile development is identified to potentially have adverse effects on both the quantity (change of groundwater levels and flow patterns) and the quality of groundwater during Operation. The seepage collection system, which includes geomembrane liner and overdrains, that will be installed under and around both of the piles will minimize recharge of "CCR pile impacted contact water" into groundwater under and around the CCR piles. Any potential effect of CCR pile development is expected to be limited to the shallow groundwater within the local catchments of M19, M19A and M17B creeks on only the east side of the Murray River.

Decommissioning and Reclamation

Decommissioning and Reclamation will mark a transition from dewatering of groundwater, toward recovery of groundwater levels as underground workings are allowed to flood. Potential effects for this phase are identified to be highly similar to Operation and Post Closure. Potential effects associated with dewatering are assessed for Operation, while potential effects associated with recovery are assessed for Post Closure.

As part of Decommissioning and Reclamation, a closure cover will be installed over the CCR piles, including a low permeability layer, and a reclaimed topsoil layer. Potential effects for this phase are identified to be highly similar to Operation and Post Closure. Potential effects associated closure management of the CCR piles are assessed for Post Closure.

Post Closure

During Post Closure, as the groundwater levels in the underground mine zone recover, the effect on groundwater quantity will gradually decrease and eventually diminish when the water levels are close to the pre-mining conditions.

Due to exposure of the rock within the mine to air and water over the mine life, the quality of groundwater that floods the underground workings may be deteriorated. Depending on the flow paths of this water, it may affect the groundwater quality in the surrounding formations (Table 7.6-2).

The closure cover on the CCR piles will minimize the amount of seepage that is able to infiltrate through the piles during Post Closure; however, a small amount of seepage is expected. During Operation, seepage will be directed as make-up water to the wash plant. During Post Closure, it is currently planned to collect this water, but then to allow it to exfiltrate back to the groundwater system. Any potential effect of CCR seepage is expected to be limited to the shallow groundwater within the local catchments of M19 and M19A Creeks.

7.7 EFFECTS ASSESSMENT AND MITIGATION FOR GROUNDWATER QUANTITY AND QUALITY

7.7.1 Methodology for Prediction of the Potential Effects

The potential effects of the above identified key mine components and activities of the Project (including the underground mine development and the operation of the CCR piles) to groundwater quantity and quality are assessed based on the predictions of three-dimensional numerical groundwater modeling (Appendix 7-B), as well as professional judgment.

The numerical groundwater modelling work for the Project was conducted in accordance with the Groundwater Modelling Guidelines developed by the British Columbia Ministry of Environment (BC MOE 2012c). The model was constructed using the graphical user interface of the industry standard software package Visual MODFLOW Premium version 4.3 (Schlumberger 2008), together with MODFLOW-Surfact flow version 3.0 (HydroGeologic Inc. 1996). MODFLOW is a three-dimensional finite difference flow model developed by the United States Geological Survey (Harbaugh et al. 2000). It uses an equivalent porous medium approach to represent discretely fractured bedrock. This approach has been commonly accepted for simulations of groundwater flow in bedrock environments at regional scales.

The software package allows simulation of variably saturated groundwater flow and solute transport. MODFLOW has been tested thoroughly and applied successfully for decades in mining and resources development related hydrogeological analysis and environmental impact assessments (Appendix 7-B).

The high-level methodologies and steps that were used to develop the models for the proposed Project include:

- collecting, reviewing, and analyzing all relevant regional and local climatological, hydrological, geologic and geomorphologic, geotechnical and hydrogeological information and test data available as of May 2014;
- developing a representative conceptual hydrogeological model based on the available information and data;
- building a three-dimensional hydrogeology baseline numerical model founded on the conceptual model to represent the pre-mining hydrogeological conditions on the site;
- calibrating the baseline model to multiple targets, including the measured groundwater levels in monitoring wells/piezometers and the observed low flows (assumed to approximate baseflows) in M20 Creek;
- identifying sensitive input parameters most influencing the model calibration (including permeability of the geological materials and the recharge rates into the groundwater system);
- running the calibrated baseline model to simulate steady-state hydrogeological conditions and baseflows under the pre-mining baseline conditions; and
- using the calibrated baseline model to assess the potential effects of the proposed underground mine development and the operation of the CCR piles on groundwater quantity and quality. The effects of the underground mine development were assessed by steady-state and transient flow model simulations. The effects of the operation of the CCR piles were assessed by steady-state flow and solute transport simulations.

The details of the groundwater modeling including methodologies, conceptual model, baseline model inputs and calibration, baseline model outputs and sensitivities, predictive simulations of the model for underground mine dewatering and operation of the CCR piles, and sensitivities and uncertainties of the predictions are provided in Appendix 7-B.

7.7.2 Key Effects on Groundwater Quantity

7.7.2.1 Underground Mine

According to the Project design (Chapter 3), the underground mine is divided into four large coal Blocks (see Figure 7.1-1 in Section 7.1), with each Block consisting of 10 to 30 longwall panels in all levels of coal seams. The current underground mine layout includes a total of 84 panels. Mining will start from Block 1. This Block is 4.7 km long from east to west, and 1.3 km wide from north to south, with total area of 5.9 km^2.

The 6 Mtpa coal mining capacity will be achieved by simultaneously mining two longwall working faces throughout the 25 year life of mine.

Mine Dewatering during Operation

In order to mine the coal, dewatering of the underground mine blocks would be required during the Operation. To be conservative for the purpose of the EA, the potential effects of the underground mine development on groundwater quantity were assessed based on the groundwater modeling predictions, for two scenarios: the full development of the Block 1; and the full development of the entire mine, respectively. The predicted effect of the full development of the entire mine at the end of Operation would represent the maximum of the effects on groundwater.

The groundwater modeling predictions for the potential effects of the underground mine on groundwater quantity during the Operation included: (1) the groundwater inflow rates into the underground mine, (2) the water table drawdown caused by the underground mine dewatering, (3) the reductions of the groundwater discharge (as baseflows) into the major creek (M20 Camp Creek), due to the mine dewatering.

The potential effects of the underground mine were predicted in multiple model scenarios: the Base Case, the Wetter Climate, the Lower Permeability, the Upper Case, and the Uppermost scenarios. The Base Case Scenario was simulated by using the calibrated baseline groundwater model with the input parameters calibrated to the baseline pre-mining conditions at the Project site. The other scenarios were simulated with the modified baseline model to assess the sensitivities of the model predictions in association with the uncertainties in the groundwater recharge and the permeability of the geological materials.

Table 7.7-1 lists of the scenarios of the steady-state model simulations for the underground mine development, including the model set-ups, and the calculated groundwater inflow rates into each mine blocks and all of the mine blocks in total, the calculated reduction of groundwater discharge into M20 Creek, as well as the predicted water table drawdown caused by the underground mine dewatering. Figures 7.7-1 and 7.7-2 illustrate the predicted water table drawdown caused by the underground mine dewatering.

The results indicate that in the Base Case, the groundwater inflow rate is 1,891 m^3/day (or 22 L/s) for the entire mine dewatering (with the assumption of all of the four blocks are being dewatered simultaneously to their maximum extents), and 892 m^3/day (or 10 L/s) for Mine Block No. 1 dewatering only (see Table 7.7-1). The water table drawdowns are limited within the mine footprint, and they are about 1-2 m at most locations, and the maximum is less than 2.5 m, when the entire mine is dewatered with the assumption that all the four blocks are dewatered simultaneously to their maximum extents (see Table 7.7-1 and Figure 7.7-1). The reduction of groundwater discharge into M20 Camp Creek is 3.5% of the estimated baseflow in that creek, under the condition that the entire mine is completely dewatered at the same time (see Table 7.7-1).

In the Upper Case Scenario, in which the hydraulic conductivity of the zone encapsulating the mine was assumed higher (increased tenfold from 5×10^{-10} m/s from the Base Case to 5×10^{-9} m/s), the model predicts the higher groundwater inflow rates into the mine (6,002 m^3/day vs 1,891 m^3/day in the Base Case) and larger water table drawdowns (the maximum of 11.5 m in the upper case vs. 2.5 m in the base case, see Figure 7.7-2) for the entire mine dewatering (with the assumption of all of the four blocks are being dewatered simultaneously to their maximum extents).

In the Uppermost Scenario, in which the hydraulic conductivity of the zone encapsulating the mine was increased twenty and forty times (from 5 x 10^{-10} m/s to 1 x 10^{-8} and 2 x 10^{-8} m/s, respectively), in comparison with the Base Case, the model predicts not only the much higher groundwater inflow rates into the mine (from 7,837 to 12,748 m^3/day, see Table 7.7-1), but also much larger water table drawdowns (from the maximum of 14.5 m to 19.5 m), with the assumption that the entire mine of all of the four blocks is dewatered simultaneously to their maximum extents. The loss of groundwater discharge to M20 Camp Creek varies from 22% to 26% of the estimated baseflow.

The other scenarios (Wetter Climate, Lower Permeability) had relatively limited effect on model predictions relative to the Base Case.

The results from all of these scenarios show that the underground mine zone will become a groundwater sink throughout Operation, and therefore the groundwater flow patterns will be altered in the local area (flow directions and hydraulic gradients will be changed toward the mine blocks), in comparison to the baseline pre-mining conditions. The mine dewatering would result in some loss of the stream flow in the M20 Camp Creek; however, this would change slowly over time in reality due to the fact that the underground mine will be developed block by block (not all blocks simultaneously).

The closest groundwater supply well (at the Quintette Mine) is located on the east side of Murray River (see Figure 7.3-3 in Section 7.3.4), and therefore no effect is expected to the water levels in any of the supply wells in the LSA and the RSA, during Operation.

Mine Flooding and Water Table Recovery through Post Closure

After the mine operation is completed, groundwater will be allowed to fill in the post-mine voids and, then, the water table will gradually recover to pre-mining levels.

Based on the planned panel heights (partly 5.1 m, partly 2.1m), widths (220m) and lengths, the total volume of the post-mine underground voids is calculated to be 113,104,134 m^3. Using the model calculated rates of groundwater inflow into the mine (see Table 7.7-1), the time needed to completely flood the post-mine voids with groundwater is estimated to be 164 years, 52 years and 24 years, respectively, for the Base Case, the Upper Case and the Uppermost Case, under the assumption that the entire mine zone of all four mine blocks are mined out completely before the flooding.

Once the post-mine voids are filled with groundwater, water levels in the groundwater system affected by mine operation will start recovering. Figure 7.7-3 shows the transient flow model simulated progress of water table recovery with time (starting from the moment the mine is fully flooded) at a location with the maximum water table drawdown (near the center of the mine Blocks 1 and 2) for the Base Case and Upper Case scenarios. The result indicates that it would take an additional 40 years (above the calculated time for flooding the post-mine voids) for the water table to reach 80% recovery of the pre-mining level. After 25 years of mine dewatering, drawdowns will reach about 60% of the maximum drawdown.

Table 7.7-1. List of the Murray River Groundwater Model Scenarios for Mine Dewatering Simulations

				Discharge to Mine Zones					Model Mass Balance Error
Scenario Name	Description of the Scenario	Modifications from the Calibrated Baseline Model	Model Predictions	Mine Block 1 (m^3/day)	Mine Block 2 (m^3/day)	Mine Blocks 3 & 4 (m^3/day)	All Mine Blocks (m^3/day)	All Mine Blocks (L/sec)	
Base Case Scenarios									
Base Case - Entire Mine Dewatering	Base case model for simulating mine dewatering	Set drains within the mine footprint; K for Zone No. 19 = 1E-5 m/s; K for Zone No. 20 = 1E-8 m/s;	Groundwater inflow rate into mine = 22 L/sec; 3.5% reduction in groundwater discharge to M20 Camp Creek; max drawdown < 2.5 m	715	538	638	1,891	22	-0.07%
Base Case - Block 1 Mine Dewatering	Base case model for simulating mine dewatering from Mine Block No. 1 only	Set drains only within the footprint of mine block No. 1;	Groundwater inflow rate into mine = 10 L/sec	892	NA	NA	892	10	0.00%
Wetter Climate Scenario	Model developed from base case model to simulate wetter climate scenario	Recharge in all model recharge zones increased by 25%, compared to baseline model	Groundwater inflow rate into mine = 23 L/sec	798	542	642	1,982	23	-0.04%
Lower Permeability Scenario	Model developed from base case model to simulate lower hydraulic conductivity scenario	K for Zone No. 19 = 1E-6 m/s; K for Zone No. 20 = 1E-8 m/s;	Groundwater inflow rate into mine = 22 L/sec	716	536	629	1,881	22	-0.06%
Upper Case Scenarios									
Upper Case - Entire Mine Dewatering	Model developed from base case model to simulate high hydraulic conductivity scenario	K for Zone No. 5 = 5E-9 m/s;	Groundwater inflow rate into mine = 69 L/sec; 15% reduction in groundwater discharge to M20 Camp Creek; max drawdown 11.5 m	1,721	2026	2256	6,002	69	-0.02%
Upper Case - Block 1 Mine Dewatering	Model developed from base case model to simulate high hydraulic conductivity scenario for Mine Block No. 1 only	Set drains only within the footprint of mine block No. 1; K for Zone No. 5 = 5E-9 m/s; K for Zone No. 19 = 1E-5 m/s; K for Zone No. 20 = 1E-8 m/s	Groundwater inflow rate into mine = 35 L/sec	3,056	NA	NA	3,056	35	-2.23%
Uppermost Case Scenarios									
Uppermost Case 1 - Entire Mine Dewatering	Model developed from base case model to simulate very high hydraulic conductivity scenario	K for Zone No. 5 = 1E-8 m/s;	Groundwater inflow rate into mine = 91 L/sec; 22% reduction in groundwater discharge to M20 Camp Creek; max drawdown 14.5 m	2,189	2,650	2,998	7,837	91	-0.04%
Uppermost Case 2 - Entire Mine Dewatering	Model developed from base case model to simulate very high hydraulic conductivity scenario	K for Zone No. 5 = 2E-8 m/s; K for Zone No. 20 = 4E-8 m/s;	Groundwater inflow rate into mine = 148 L/sec; 26% reduction in groundwater discharge to M20 Camp Creek; max drawdown 19.5 m	3,867	3,710	5,172	12,748	148	-0.08%

Figure 7.7-1

Map of Water Table Drawdown Caused by Mine Dewatering – Base Case Scenario

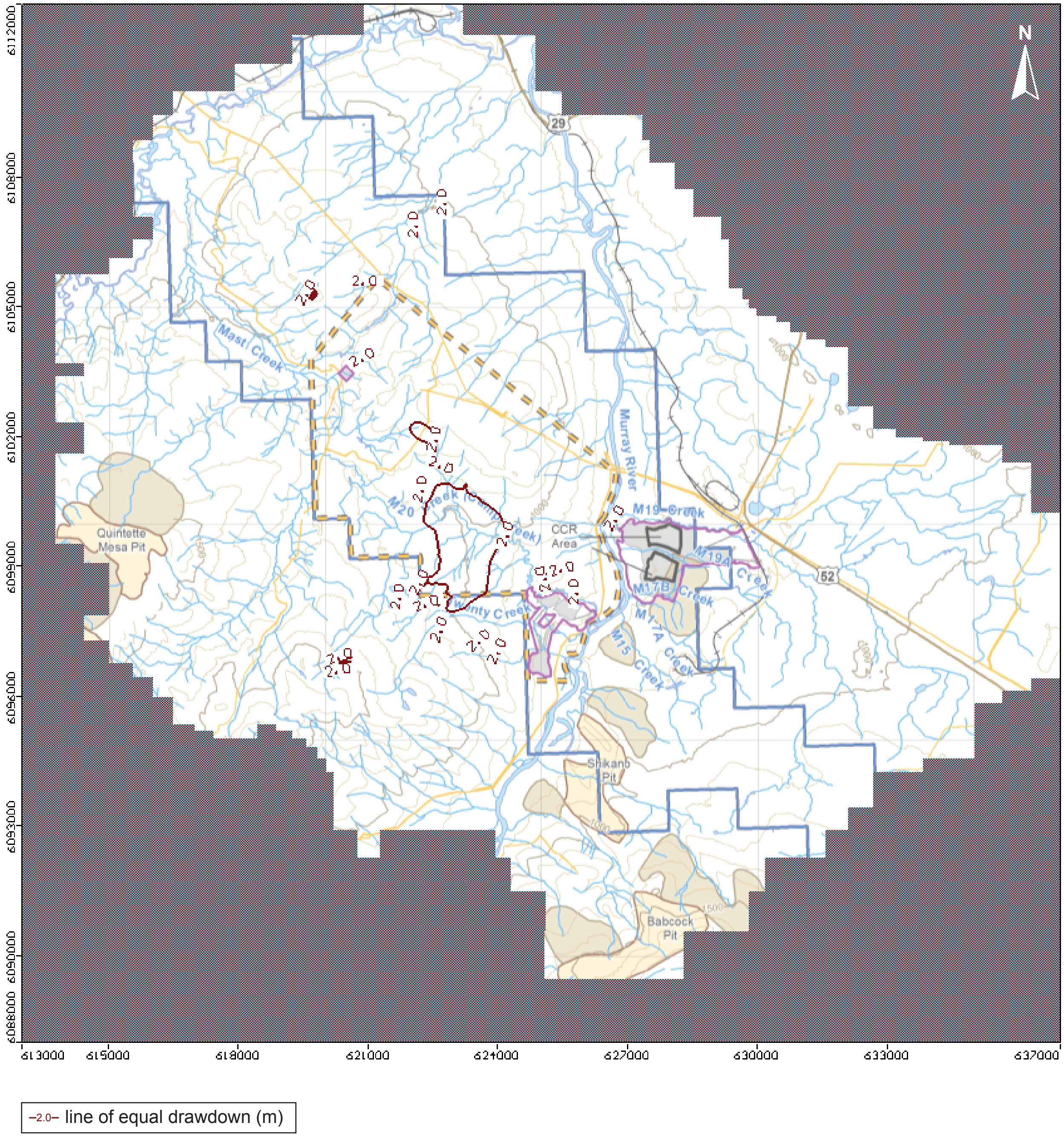


Figure 7.7-2

Map of Water Table Drawdown Caused by Mine Dewatering – Upper Case Scenario

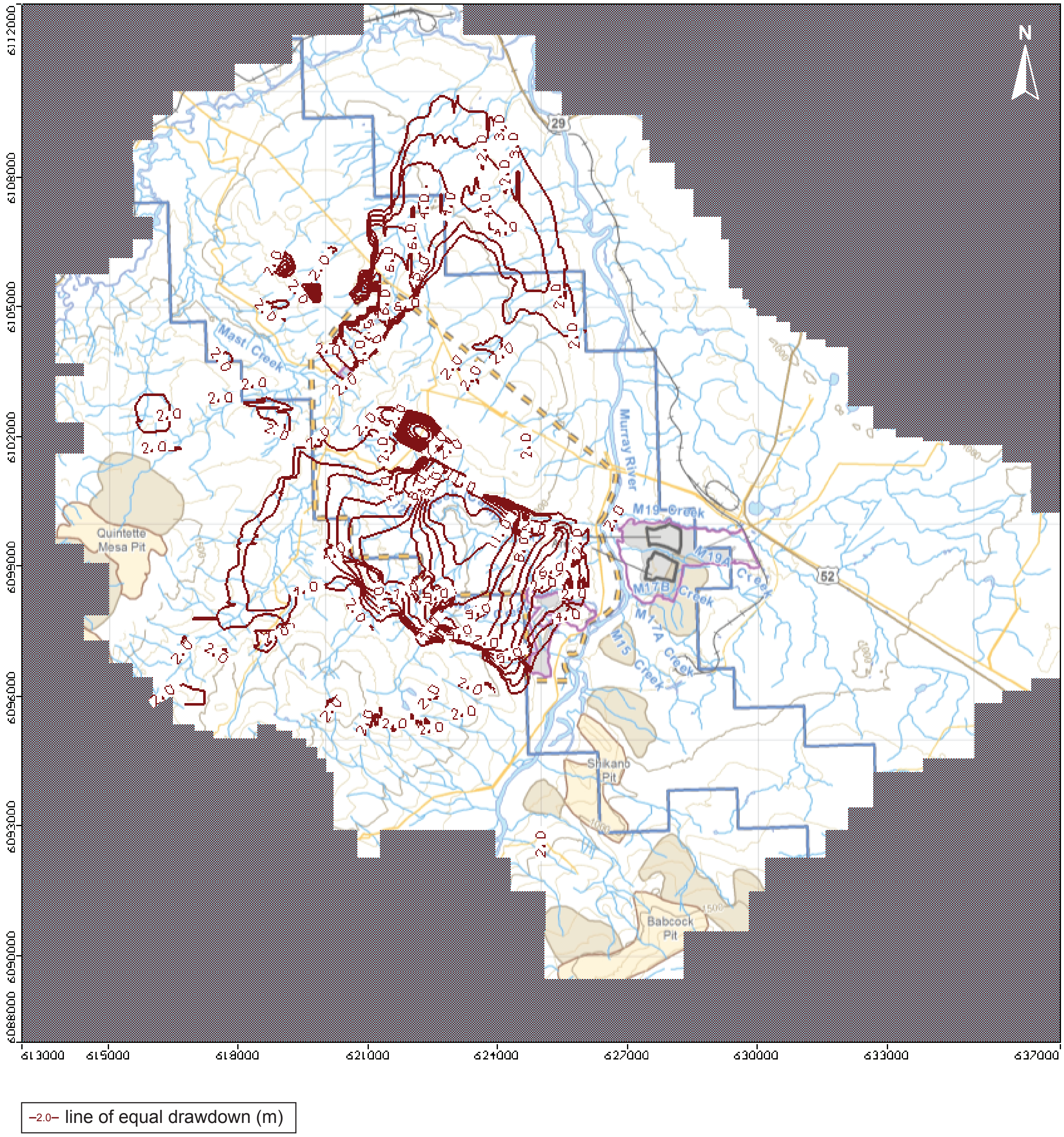
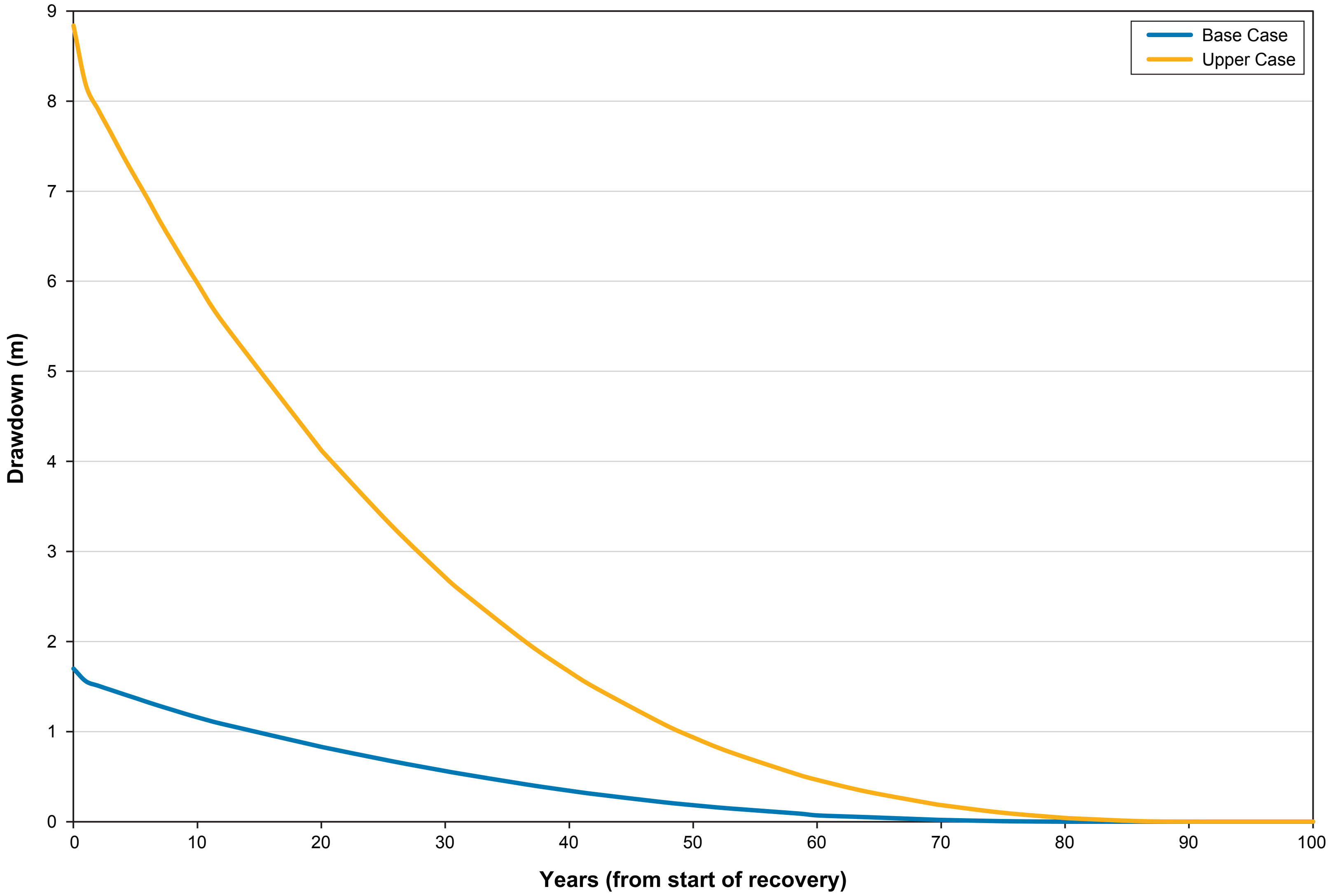


Figure 7.7-3

Decreasing Drawdown vs. Time – Base and Upper Case Scenarios



The calculations for the post-mine flooding and water table recovery are considered highly conservative, due to the following reasons: (1) the mine voids (gobs) are assumed not to be filled with rock collapsed from the ceiling; (2) all mined areas are assumed to be free draining throughout the mine life (e.g., no storage of water during Operation); and (3) all of the four blocks are modelled to be dewatered simultaneously to their maximum extents. The cone of depression and the water table drawdowns are most likely to be smaller than the model predicted, and the time for the mine flooding and water table recovery is likely to be shorter (though within the range of sensitivity estimates).

Through Post Closure, the water table is expected to gradually recover close to the baseline conditions. The altered groundwater flow directions and hydraulic gradients (towards the mine zone) due to the dewatering will eventually reverse to the pre-mining conditions.

7.7.2.2 Surface Subsidence

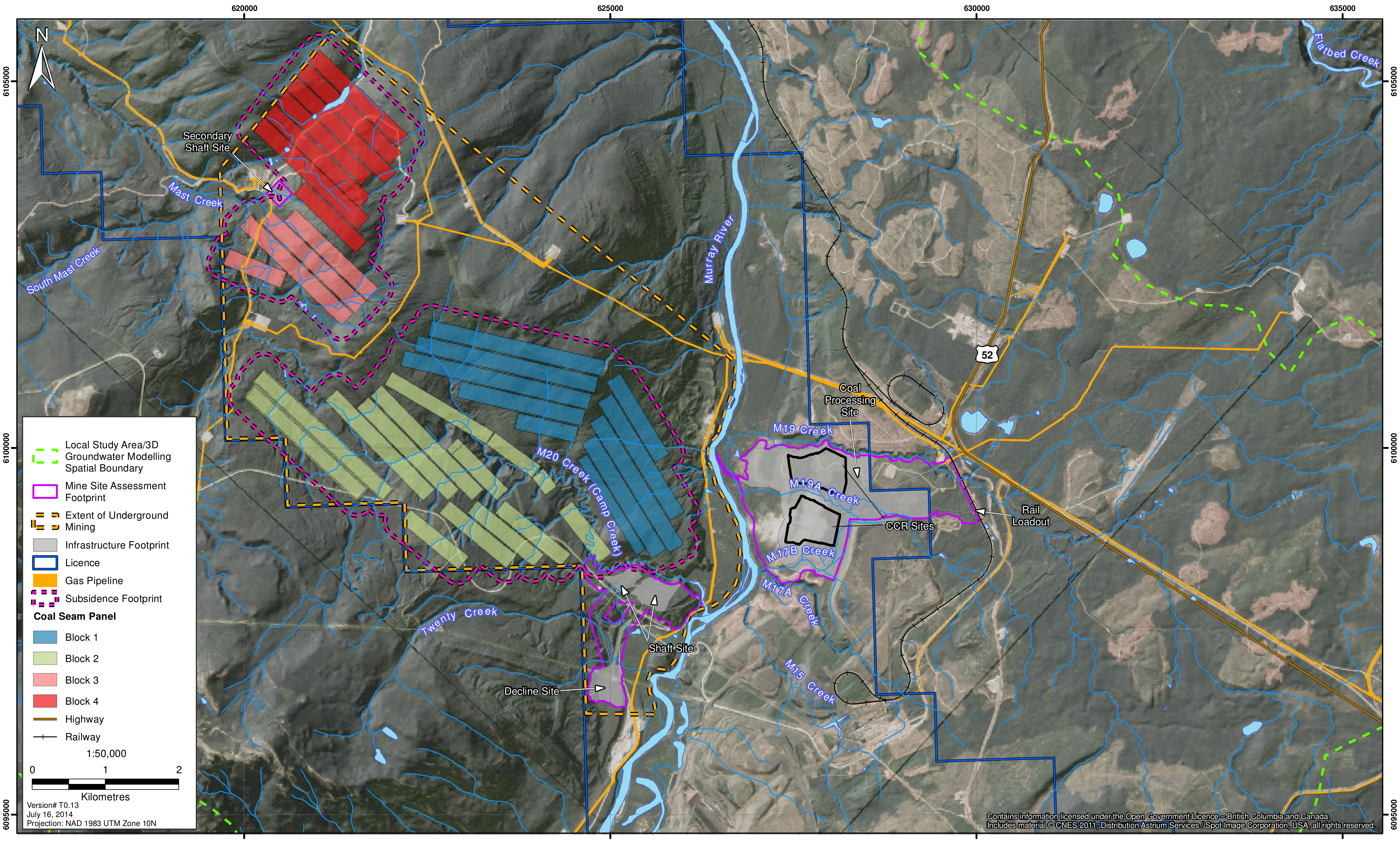
The creation of any underground opening influences the stress state of the surrounding ground with related deformation and displacements of the material. As the size of the underground opening increases, the rock will eventually collapse causing further stress redistribution in the overlying rocks; in the end the deformations and displacements propagate up to the surface causing subsidence. With longwall mining, the gob is generated immediately when the coal seam is mined in the panel. The rocks overlying the gob will gradually deform downwards, and cause further inter-connected cracking of the above bending zone, which may eventually result in surface fracturing and subsidence as time goes on.

Figure 7.7-4 shows the expected horizontal extent of subsidence, based on review of the subsidence study that was completed (Appendix 3-C); this area is just slightly larger than the footprint of the underground mine blocks. The magnitude of the subsidence is predicted to vary at each individual mine blocks and panels, after different coal seams are mined. The predicted subsidence in the mine Block 1 zone is < 4 m in the first 3 years of mining, and the maximum final subsidence is predicted to be about 5.7 m (at the northeast part of the Block 1) when all the coal seams are mined in this zone. The predicted subsidence in most of the mine Block 2 zone is < 4.5 m in the first 3 years of mining, and the maximum final subsidence is predicted to be about 9 m (at the northwest part of the Block 1, between the Block 1 and Block 2) when all the coal seams are mined in this zone. The predicted subsidence in Block 3 and Block 4 is much smaller than that in the other two blocks, due to deeper depth of coal; the maximum subsidence is predicted to be about 2.8 m (at the centre of the Blocks 3 and 4), when all the coal seams are mined in these zones.

It is expected that the subsidence will occur during Operation and that the new topography that is established will remain through Post Closure. This may impact hydrogeology-influencing features (e.g. topography, geological structures and discontinuities, overburden and bedrock permeability). Consequently, it may affect the groundwater levels and flow patterns on the local scale. However, given the predicted small magnitude of subsidence relative to the total range of topography relief of about 730 m across the local study area, the subsidence related changes in groundwater levels and flow directions are expected to be limited. It is expected that the potential effect will be limited within and immediately adjacent to the underground mine footprint.

Figure 7.7-4

Predicted Surface Subsidence Extent of the Underground Mine



Version# T0.13
July 16, 2014
Projection: NAD 1983 UTM Zone 10N

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7.7.2.3 *Coarse Coal Rejects (CCR) Piles*

According to the mine plan (Chapter 3), the CCR Site was designed to accommodate two mine coal reject storage areas during 25 years of Operation: CCR North and CCR South (see Figure 7.1-2 in Section 7.1). CCR North will be built over for the first 14 years of Operation, while the South Pile will be built over the remaining 11 years. Both CCR North and CCR South are designed with a seepage collection system that includes the use of very low permeability geomembrane liner and an overdrain system. The first phase of the CCR North pile will be constructed during Construction. This will include installation of the liner to cover an area that would support the first 5 years of mining. Site preparation will commence at the early stage of Construction. It will include topsoil and subsoil removal, earth work, grading, geomembrane liners, and high density polyethylene (HDPE) pipe networks, embankments, runoff ditches, waste water seepage collection ponds and drainage system.

The baseline hydrogeological information (Appendix 7-A) shows that the proposed CCR site is located within a regional groundwater discharge zone. The water table depth is relatively deep (> 4 m) under the CCR North footprint and shallower under the CCR South footprint. A thick layer of silty clay is present below a thin veneer of glaciofluvial sandy sediments at the middle and bottom terraces around the CCR Site. At some distance between the CCR Site and Murray River, this clay formation ends and a glacial till formation occurs. Both silty clay and glacial till rest on mudstone inter-bedded with sandstone. This bedrock formation is exposed along the banks of Murray River near the CCR Site. The permeability of the overburden and bedrock materials at the CCR Site is generally low.

The effect of the CCR piles on groundwater quantity during Operation and Post Closure was assessed based on the numerical groundwater modeling simulations (see Appendix 7-B for the modeling details). In the model, two recharge zones with very low recharge rates were applied under the footprints of the CCR North and South piles to reflect the effect of the geomembrane liners (for Operation and Post Closure) and the soil covers (for Post Closure) in minimizing the seepage to the groundwater beneath. Surface water drains were assigned on the south and west sides of the CCR piles to represent the seepage drain collection systems.

The recharge values applied under the footprint of the CCR piles were estimated conservatively assuming 5% of the water infiltrating into the piles will escape through the liners. This was based on the assumption that 5% of the area of the liner at the bottom of each pile will fail. The calculated recharge values are 6 mm/year for CCR North and 7 mm/year for CCR South from the results of the SEEP/W model performed by Ausenco for the geotechnical design of the CCR Piles. These rates were applied to simulate the groundwater flow in the Base Case during the Operation of the CCR Piles (Table 7.7-2).

Four scenarios were simulated to examine the effects of the CCR Piles on groundwater during Operation (Table 7.7-2): Base Case, Wetter Climate, High Permeability, Low Permeability scenarios. The Base Case was simulated using the calibrated baseline groundwater model with the input parameters calibrated to the baseline pre-mining conditions at the CCR site. The other scenarios were simulated with the modified baseline model to assess the sensitivities of the model predictions in association with the uncertainties in the groundwater recharge and the permeability of the geological materials. In the Wetter Climate scenario, the recharge applied to all recharge zones except under the CCR site was increased by 25%, compared to the baseline model. Considering the higher precipitation under the wetter climate, the recharge to water table from below the CCR piles were increased to 17 and 20 mm/year for the North and South Piles (from SEEP/W model results), respectively.

Table 7.7-2. List of the Murray River Groundwater Model Scenarios for CCR Site Simulations

Model File Name	Description of the Scenario	Recharge Rate (mm/year)	
		North Pile	South Pile
CCR Facility Operation			
Base Case	Base Case model	6	7
Wetter Climate Scenario	Model developed from Base Case model to simulate CCR Site Operation under wet climate scenario	17	20
Higher Permeability Scenario	Model developed from Base Case model to simulate CCR Site Operation in high hydraulic conductivity scenario	6	7
Lower Permeability Scenario	Model developed from Base Case model to simulate CCR Site Operation in low hydraulic conductivity scenario	6	7

The model results indicate that installation of the CCR piles do not result in any noticeable changes on the groundwater levels and flow patterns (compared to pre-construction baseline conditions) in the local catchments of M19, M19A and M17B creeks during Operation and Post Closure. However, it may create some changes on the hydraulic gradients in the small area between the footprints of the two piles along the M19A Creek section. This may results in a small reduction (around 10%) of the groundwater discharge into the M19A Creek section (about 400 m long only) adjacent to the piles during Operation and the Post Closure, in comparison to the baseline conditions. However, as the contribution of groundwater discharge in the much larger catchment area of the M19 Creek (compared to the area around the CCR piles) up-gradient and down-gradient of the CCR footprint is not affected by the CCR piles, the change of the baseflow volume in the entire M19A Creek is expected to not be measurable. A model simulation was run for Post Closure with 4 mm/year of infiltration through the closure cover, of which 0.01 mm/year is assumed to pass through the liners at the base of the CCR piles, and the rest drains to a seepage collection pond, and then is allowed to exfiltrate back to the groundwater system. The result was similar to the results for Operation phase, with an ultimate groundwater flow path for both phases to M19A and M19 creeks.

7.7.3 Mitigation Measures for Groundwater Quantity

No specific mitigation measures are planned to minimize the effect on groundwater quantity related to underground mine dewatering or subsidence, except that the groundwater flow into the underground mine zone will be collected and managed during Operation. After the mine is closed, however, the underground mine will be allowed to flood, with groundwater levels recovering, eventually toward the pre-mining conditions.

At the CCR site, the mitigation includes installation of the geomembrane liners and seepage collection drain system, as well as the closure covers (for Post Closure). These measures will limit the amount of CCR seepage that reaches the groundwater system. In addition, during Post Closure, the collected seepage (expected to be small) from the covered CCR piles will be allowed to exfiltrate from the seepage collection pond into the groundwater system (if the water quality meets the requirements for discharge), which will mitigate the effect of the CCR piles on groundwater quantity to some degree (e.g. the reduction of groundwater recharge due to the caps, liners and seepage collection drain system).

7.7.4 Key Effects on Groundwater Quality

7.7.4.1 Underground Mine

Mine Dewatering during Operation

During Operation, according to the mine plan, the groundwater flow into the underground mine zone will be collected and managed in a consistent manner. Groundwater inflow into the underground mine will be collected in the mine water sump and sedimentation pond at the Underground Operation Hub and then be pumped to water management facilities at the surface. After providing make-up water to the Coal Preparation Plant, excess water will be discharged to the Murray River. Therefore, it is expected that during Operation, groundwater quality in the mine area will not be affected by dewatering of the mine.

The closest groundwater supply well (at the Quintette Mine) is located on the east side of Murray River (see Figure 7.3-3 in Section 7.3.4), and therefore no effect is expected to the water quality in any of the supply wells, because of the proposed Project during Operation.

Mine-Contact Groundwater Migration through Post Closure

After mining is complete, the mine cavity will be infilled with collapses of rock (gob) and flooded with groundwater. The water table will eventually recover toward the baseline pre-mining conditions. Due to exposure of the rock within the mine to air and water over the mine life, the quality of groundwater that floods the underground workings may be deteriorated.

A groundwater flow particle tracking model was used to evaluate flow paths and travel times for contact water within the flooded mine workings during Post Closure. Steady-state simulations of the groundwater flow particle-tracking indicated that in the Base Case and Uppermost Case scenarios, most of the contact water will eventually discharge into Murray River along its reach closest to the mine. The travel time of contact water varies depending on the distance from the river. The shortest estimated travel times are for the groundwater that contacts the post-mine voids on the eastern edge of the mine Block No. 1 – the area closest to the river. The calculated times are 1,000 and 400 years for the Base Case and the Uppermost Case (higher permeability case), respectively.

A small portion of contact water - from the northwestern edges of the mine Blocks No. 3 and 4 - could potentially discharge into Wolverine River. The model calculated travel times for these pathlines are measured in tens of thousands of years.

By accounting for the time of the mine flooding and the water table recovery, the calculated minimum times are about 1,200 years and 460 years in the Base Case and the Uppermost Case, respectively. Those travel times were calculated assuming no retardation and dispersion. This is a conservative assumption, particularly with regard to not simulating retardation. Retardation of some metals transported by groundwater is known to be strong. The long travel times (calculated without considering retardation) indicate that mass flux of contaminants of concern is going to be small and that mixing of contact groundwater with ambient waters large.

For any potential future groundwater use, wells that may possibly be constructed in the areas of contact groundwater discharge will likely be installed in unconsolidated materials (bedrock is characterized as of low permeability compared to unconsolidated deposits) and mixing of shallow groundwater (migrating mainly through more permeable unconsolidated deposits) and deep groundwater (generally migrating through much less permeable mudstones) will also be strong. Thus, the effects of mining on shallow groundwater and surface water quality during Post Closure are likely to be small.

It is possible that mining-caused subsidence will result in increase of hydraulic conductivities of bedrock. That might increase the mass flux of discharging contact water, particularly if subsidence were to affect bedrock formations along the entire migration route (between post-mine voids and regional discharge areas). However, subsidence is estimated to affect only the area of the proposed mine’s footprint and a small buffer zone around (see Figure 7.7-4). Thus, groundwater will be migrating from the flooded mine workings toward regional discharge zones through the rock formations both affected and not affected by subsidence. Assuming a subsidence-caused increase in hydraulic conductivity, flow through rock masses that are not affected by subsidence will serve as a “bottle-neck” for flow. The net result will be an overall slight decrease (compared to hydraulic conductivity not affected by subsidence) in travel time for contact groundwater migrating from the post-mine voids to regional discharge areas.

7.7.4.2 Surface Subsidence

Although a potential effect on the groundwater quantity (changes of water levels, hydraulic conductivities and flow patterns) in the local area may occur related to the subsidence (as discussed in Section 7.7.2.2), no measurable effect is expected to occur on groundwater quality due to the subsidence.

7.7.4.3 Coarse Coal Rejects (CCR) Piles

To assess the potential effect of the CCR piles on groundwater quality, in addition to the simulations of the flow pathlines, conservative solute transport model simulations were carried out for the same scenarios as listed in Table 7.7-2 of the Section 7.7.2.3.

An arbitrarily set unit recharge concentration equal to 1 was set for the recharge zones assigned to the CCR piles (as the source zones), assuming a generic non-reactive contaminant species leaving the CCR piles as solutes. This kind of a setup results in the model calculating a fraction of a concentration of leachate originating at the pile reaching any given point down-gradient from the pile, at a given time. CCR North and CCR South are the only sources of contaminants migrating through the groundwater system in the transport model simulations.

Figure 7.7-5 presents the Base Case modelsimulated pathlines of groundwater flow particle-tracking from the CCR piles to the receiving creeks. Figure 7.7-6 presents the Base Case model simulated contaminant plumes originating from the CCR Piles at year 30, under the assumption that both the piles are full and occupy the entire areas of the footprints. This is considered to be very conservative. The extent of the plumes is defined with a concentration contour interval of 10% of the concentration of the source (the CCR piles) and a cut-off contour line of 1% of the concentration at the source (the CCR piles). As the figure demonstrates, the model calculated 30-year plume will not reach Murray River and will be discharging into M19A and M19 Creeks. The plumes' extents calculated by the model for other scenarios are very similar to the Base Case, and the plumes are limited in the shallow groundwater close to groundwater surface. The solute concentrations beneath the CCR piles and in the downstream receiving groundwater environment are predicted to be low. The concentrations in the groundwater discharging into the creeks (M19 and M19A) are predicted to be lower than 5% of the source of the seepage water leaching through the CCR piles and escaping from the seepage collection drain systems. This result was estimated without consideration of dilution and attenuation, hence it is highly conservative. As the CCR site is located in a groundwater discharge zone, the fresh groundwater flux discharge from the upper and down-gradients will dilute the seepage and further reduce the concentrations.

As discussed in the previous Section 7.7.2.3, the SEEP/W model calculated seepage leaching through the geomembrane liners beneath the CCR piles into the groundwater system are very low (6 mm/year for CCR North and 7 mm/year for CCR South) during Operation. During Post Closure, 4 mm/year (2% of effective precipitation) is estimated to infiltrate through the closure cover. Except for a small portion leaking through the liners, the rest would be captured by the seepage collection system (overdrains), and based on current water quality predictions (Appendix 8-C), the seepage will be allowed to exfiltrate from the seepage collection pond into the groundwater system.

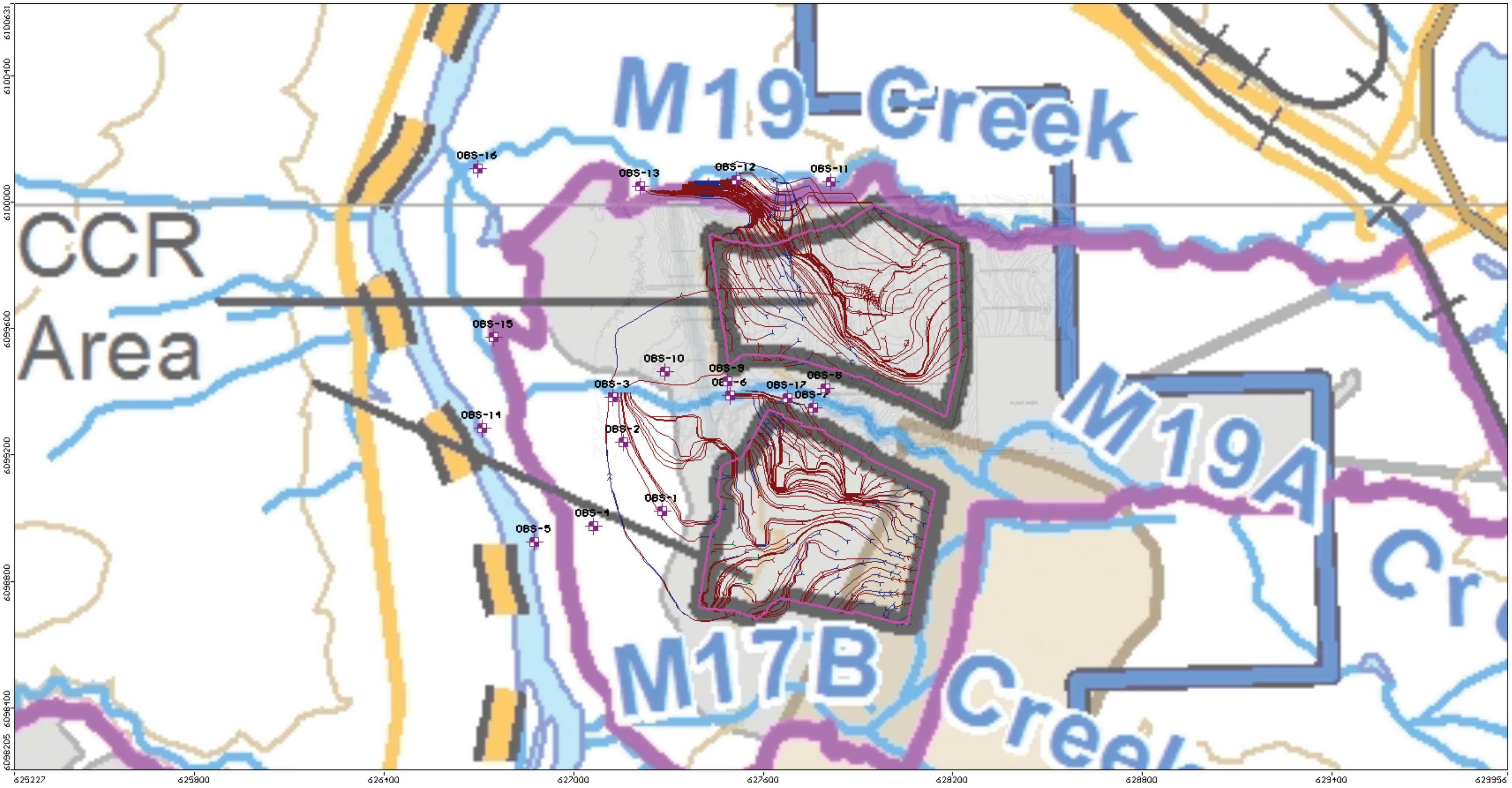
The model simulation for Post Closure indicates that a plume will develop in the shallow groundwater beneath and downgradient of each CCR pile and seepage pond, similar to that in Operation. In the model simulation, it was assumed that 5% of the water infiltrating into the covered piles (0.01 mm/year) will leak through the liners, while 95% of that water will be collected by the drainage systems and diverted into the seepage collection ponds. Further, the collected water was assumed to exfiltrate into the groundwater system (assuming the water quality is acceptable). The model results indicate that the spatial extent of the plumes will be limited to a small area between the CCR piles and M19 and M19A creeks. Surface water quality modelling (Chapter 8) has also taken this source of groundwater recharge into account.

7.7.5 Mitigation Measures for Groundwater Quality

At the CCR site, mitigation measures (including the low permeable liners and seepage collection drain systems) have been incorporated into the mine design, in order to minimize and collect the potential seepage of contact water from the CCR piles. The collected seepage water from the CCR piles will be stored in lined ponds and pumped back into the coal processing circuit for recycling utilization during Operation.

Figure 7.7-5

Groundwater Flow-paths from CCR Piles to Receiving Creeks – Base Case Scenario

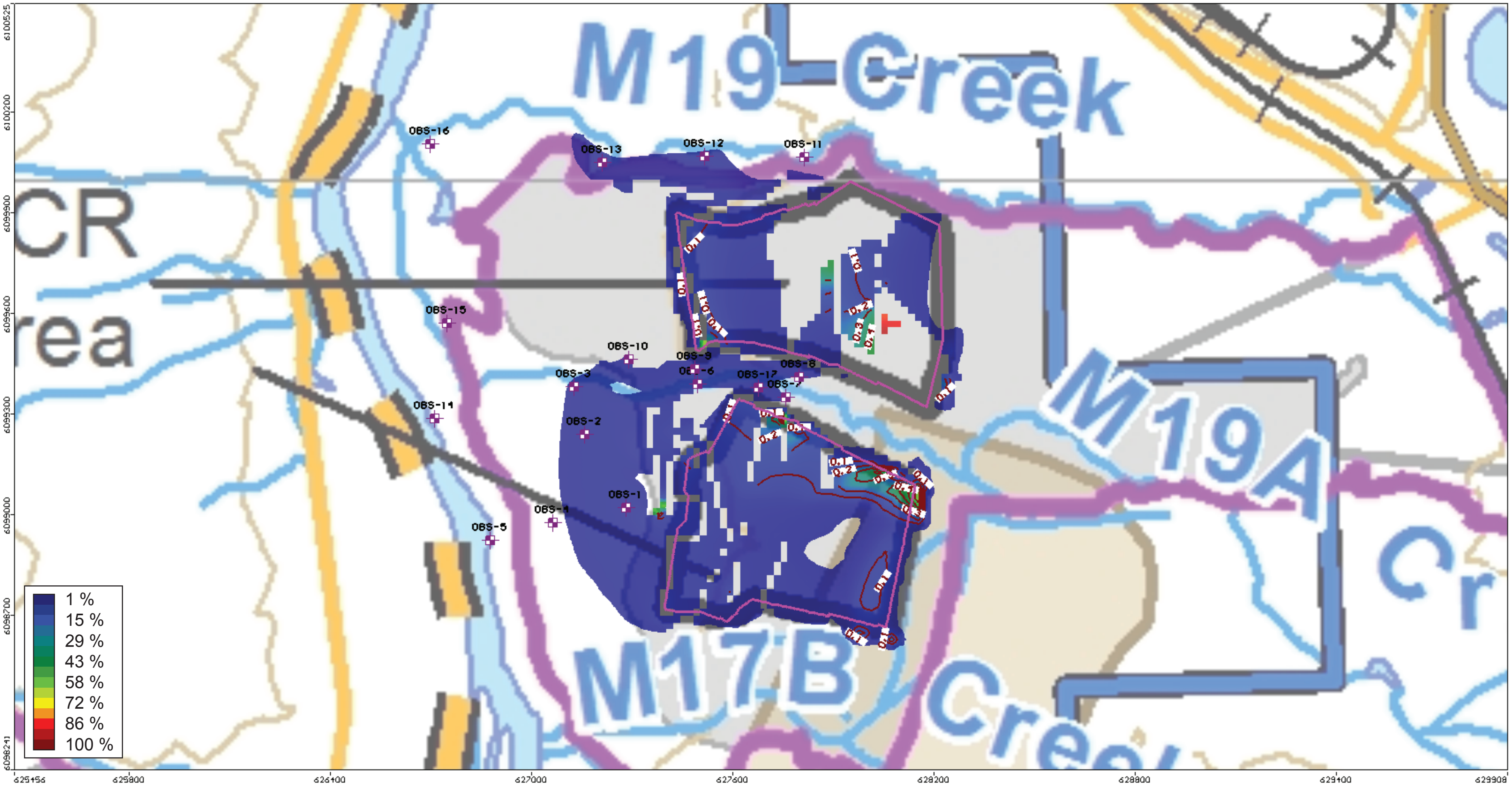


— Groundwater pathline (inward/down direction)
— Groundwater pathline (outward/up direction)

Note: Time markers on pathline every 10 years.

Figure 7.7-6

Groundwater Contaminant Plumes Originating from CCR Piles at Time 30 Year – Base Case Scenario



At Post Closure, in addition to the liners and seepage collection system on the bottom, the CCR piles will be covered with low permeability layer and topsoil and then re-vegetated. This will reduce infiltration into the piles.

A long-term monitoring well network is proposed downslope of the CCR piles (Figure 7.7-7). These wells will be used to monitor the potential effect (if any) on groundwater quality at the CCR site, and if necessary, an adaptive mitigation plan can be developed based on the monitoring results.

7.8 RESIDUAL EFFECTS ON GROUNDWATER QUANTITY AND QUALITY

The residual effects of Project activities on groundwater quantity and quality during Construction, Operation, and Post Closure, after the mitigation measures are implemented, are shown in Tables 7.8-1 and 7.8-2, respectively.

For groundwater quantity, as shown in Table 7.8-1, the underground mine is expected to have residual effect during Operation through Post Closure (until full recovery of water table), which includes water table drawdown, alteration of groundwater flow pattern (flow direction, hydraulic gradient) toward the mine zone as a local groundwater sink, and potential reduction of groundwater discharge to the creeks. The predicted surface subsidence is expected to have some residual effect during Operation and Post Closure, including potential changes in groundwater levels and flow patterns, and groundwater discharge at the local scale. The residual effect of the CCR piles during Operation and Post Closure is expected to include slight change of hydraulic gradients and hence a small reduction of groundwater discharge in the small area between the footprints of the two piles along the M19A Creek section.

For groundwater quality, as shown in Table 7.8-2, only the proposed CCR piles are expected to have residual effect during Operation and Post Closure, with the development of a small plume in shallow groundwater beneath and downgradient of each CCR pile; however, spatial extent will be limited to a short flow path to M19A and M19 creeks.

7.9 CHARACTERIZING RESIDUAL EFFECTS, SIGNIFICANCE, LIKELIHOOD AND CONFIDENCE ON GROUNDWATER QUANTITY AND QUALITY

The residual effects of the Project on groundwater quantity and quality are characterized using the standard criteria (i.e. the magnitude, duration, frequency, geographic extent, reversibility, and ecological context). The standard ratings (e.g. minor/low, medium/neutral, and major/high) for these characterization criteria are provided in the methodology chapter (Chapter 5). The definitions for each characterization criteria for the residual effect on groundwater quantity and quality are summarized in Table 7.9-1.

7.9.1 Residual Effects Characterization for Groundwater Quantity

As discussed in Section 7.8 and shown in Table 7.8-1, for groundwater quantity, the underground mine, the predicted surface subsidence, and the CCR piles are expected to have residual effect on groundwater quantity, including potential changes of water levels, hydraulic conductivities and flow patterns (flow directions, hydraulic gradients, and groundwater discharge into the creeks), during Operation and Post Closure. The characterization of the potential residual effects of these mine components and activities on groundwater quantity, their significance, probability and confidence are shown in Table 7.9-2.

Figure 7.7-7

Proposed Long-term Groundwater Monitoring Wells Network at the CCR Site

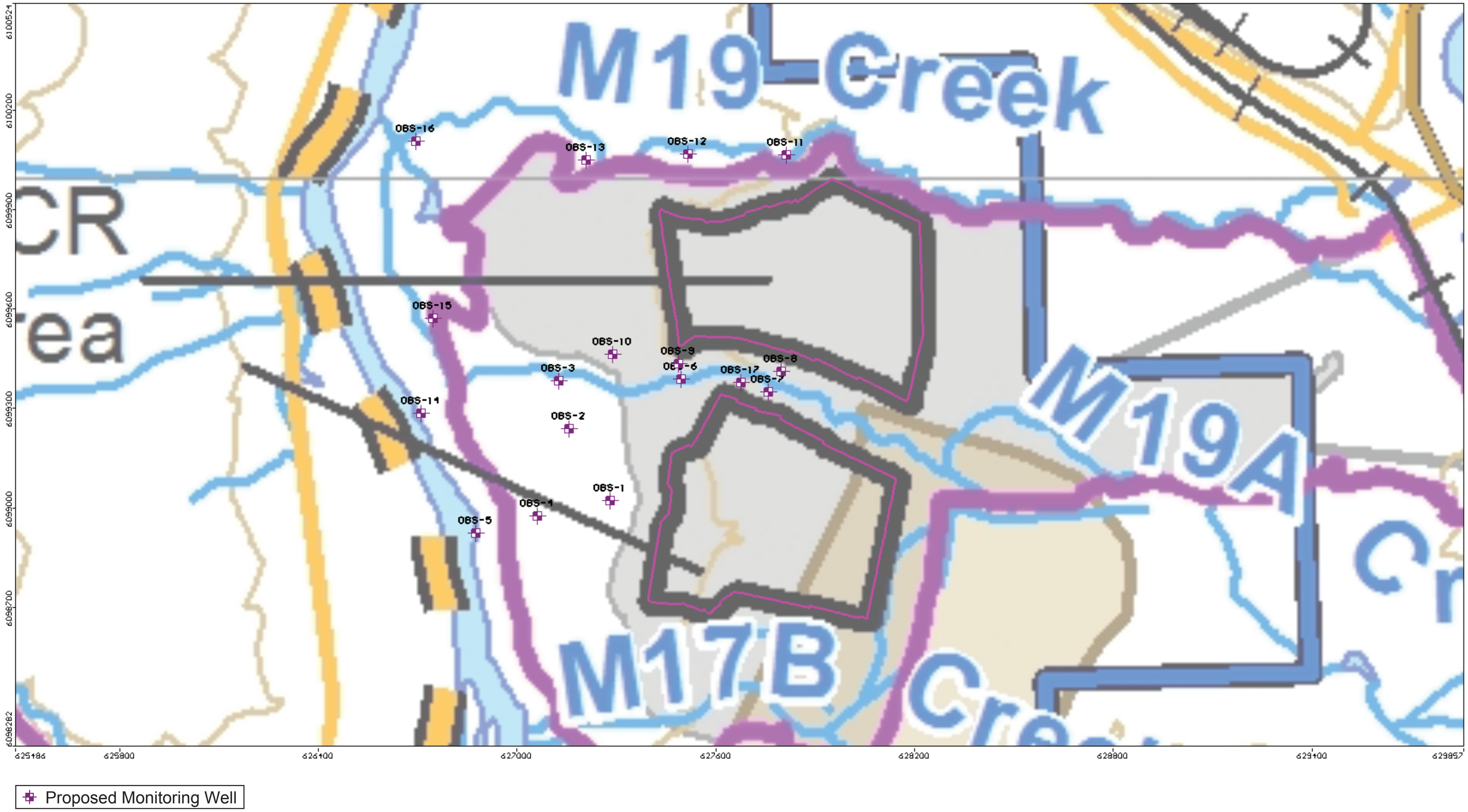


Table 7.8-1. Summary of Residual Effects on Groundwater Quantity

Valued Component	Project Phase	Project Component/ Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Groundwater Quantity	Construction	Declines and Shafts for Mine Access	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater discharge)	Collection of groundwater flow into the declines and shafts and pumping to the water treatment facility. Once completed, the lining the declines and shafts with reinforced concrete / bolts shotcrete.	No
		Coarse Coal Rejects (CCR) Piles	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater recharge and discharge)	Installation of geomembrane liner under the CCR North pile and seepage drain collection systems.	No
	Operation	Declines and Shafts for Mine Access	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater discharge)	Collection of groundwater flow into the declines and shafts and pumping to the water treatment facility. Once completed, the lining the declines and shafts with reinforced concrete / bolts shotcrete.	No
		Underground Mine	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater discharge)	Collection and management of groundwater flow into the underground mine zone during the Operations.	Water table drawdown, alteration of groundwater flow pattern (flow direction, hydraulic gradient) toward the mine zone as a local groundwater sink, reduction of groundwater discharge to M20 Creek and its tributaries.
		Surface Subsidence	Change of groundwater levels and flow patterns (flow directions, hydraulic conductivities, hydraulic gradients and groundwater discharge)	Exclusion zones ("pillars") planned underneath major existing surface infrastructures and facilities in the underground mine zone. Monitoring subsidence.	Potential changes in groundwater levels, hydraulic conductivities and flow patterns, as well as groundwater discharge in the local to a certain degree, due to the surface subsidence.
		Coarse Coal Rejects (CCR) Piles	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater recharge and discharge)	Installation of geomembrane liner under the CCR South pile and seepage drain collection systems. Collection and management of the seepage from the CCR piles.	Slight change of hydraulic gradients causing a small reduction of groundwater discharge in the small area between the two piles along the M19A Creek section.

(continued)

Table 7.8-1. Summary of Residual Effects on Groundwater Quantity (completed)

Valued Component	Project Phase	Project Component/ Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Groundwater Quantity *(cont'd)*	Post Closure	Declines and Shafts for Mine Access	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater discharge)	Plugging the declines and shafts	No
		Underground Mine	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater discharge)	Flooding the underground mine and water table recovery	Water table drawdown, alteration of groundwater flow pattern (flow direction, hydraulic gradient) toward the mine zone, and potential reduction of groundwater discharge to M20 Creek, until the water table fully recovers to the baseline conditions.
		Surface Subsidence	Change of groundwater levels and flow patterns (flow directions, hydraulic conductivities, hydraulic gradients and groundwater discharge)	Exclusion zones ("pillars") planned underneath major existing surface infrastructures and facilities in the underground mine zone. Monitoring subsidence.	Potential changes in groundwater levels, hydraulic conductivities and flow patterns, as well as groundwater discharge in the local to a certain degree, due to the surface subsidence.
		Coarse Coal Rejects (CCR) Piles	Change of groundwater levels and flow patterns (flow directions, hydraulic gradients and groundwater recharge and discharge)	Coverage of the CCR piles on top and reclamation.	Slight change of hydraulic gradients causing a small reduction of groundwater discharge in the small area between the two piles along the M19A Creek section.

Table 7.8-2. Summary of Residual Effects on Groundwater Quality

Valued Component	Project Phase	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Groundwater Quality	Construction	Declines and Shafts for Mine Access		Collection of groundwater flow into the declines and shafts and pumping to the water treatment facility. Once completed, the lining the declines and shafts with reinforced concrete / bolts shotcrete.	No
		Coarse Coal Rejects (CCR) Piles		Installation of geomembrane liner under the CCR North pile and seepage drain collection systems.	No
	Operation	Declines and Shafts for Mine Access		Collection of groundwater flow into the declines and shafts and pumping to the water treatment facility. Once completed, the lining the declines and shafts with reinforced concrete / bolts shotcrete.	No
		Underground Mine	Degradation of groundwater quality due to underground mine seepage of contact water.	Collection and management of groundwater flow into the underground mine zone during the Operations.	No
		Surface Subsidence		Exclusion zones ("pillars") planned underneath major existing surface infrastructures and facilities in the underground mine zone. Monitoring subsidence.	No
		Coarse Coal Rejects (CCR) Piles	Degradation of groundwater quality due to seepage of contact water from the piles.	Installation of geomembrane liner under the CCR South pile and seepage drain collection systems. Collection and management of the seepage from the CCR piles.	Plume of minimal seepage leaching from the CCR Piles through the liners, in very low concentrations due to dilution and attenuation.
	Post Closure	Declines and Shafts for Mine Access		Plugging the declines and shafts	No
		Underground Mine	Degradation of groundwater quality due to underground mine seepage of contact water.	Natural mixing of deep, contact groundwater with shallow non-impacted groundwater	No

(continued)

Table 7.8-2. Summary of Residual Effects on Groundwater Quality (completed)

Valued Component	Project Phase	Project Component / Physical Activity	Description of Cause-Effect	Description of Mitigation Measure(s)	Description of Residual Effect
Groundwater Quality *(cont'd)*	Post Closure *(cont'd)*	Surface Subsidence		Exclusion zones ("pillars") planned underneath major existing surface infrastructures and facilities in the underground mine zone. Monitoring subsidence.	No
		Coarse Coal Rejects (CCR) Piles	Degradation of groundwater quality due to seepage of contact water from the piles.	Coverage of the CCR piles on top and reclamation.	Plume of minimal seepage leaching from the CCR Piles through the liners, in very low concentrations due to dilution and attenuation.

7.9.1.1 *Significance of Residual Effects on Groundwater Quantity*

Underground Mine

The residual effect of the underground mine will occur as a result of mine dewatering during Operation. The effect includes water table drawdown, potentially changed hydraulic conductivities (within the zone of subsidence), alteration of groundwater flow pattern (flow direction, hydraulic gradient) toward the mine zone as a local groundwater sink, and potential reduction of groundwater discharge to the creeks. The effect will last until the water table recovers close to the baseline conditions at Post Closure.

Using the criteria developed in Table 7.9-1, the magnitude of the residual effect of the underground mine dewatering on groundwater quantity is between major and moderate. While water table drawdowns are predicted to go beyond the range of natural variations of the water levels, the resultant predicted change in groundwater discharge into the M20 Camp Creek is relatively small. The duration of the effect is considered medium-term, and the residual effect will be continuous during Operation through Post Closure. The geographic extent of the effect is expected to be limited to within the mine footprint and not to extend beyond the local catchments where the underground mine is located. No groundwater supply wells (for human consumption, agriculture or industry usage) exist within the area of water table drawdown in the underground mine area (compare the content of Figure 7.3-3 with Figures 7.7-1 and 7.7-2), and the likelihood for future well installation is considered low. The effect will be reversible, as the water table will eventually recover after the mine is completed. The effect is considered Not Significant (moderate).

Surface Subsidence

Surface subsidence is predicted to have some residual effect on groundwater quantity during Operation and Post Closure, including some potential changes in groundwater levels, hydraulic conductivities and flow patterns, and possibly groundwater discharge in local areas. However, given the predicted small magnitude of subsidence, relative to the total range of topography relief in the LSA, the nature of any effects related to subsidence would limited and localized.

Using the standard criteria developed in Table 7.9-1, the residual effect of the subsidence on groundwater quantity is assessed to be Not Significant (moderate) during Operation and Post Closure (Table 7.9-2). The magnitude of the residual effect is assessed to be medium for the purpose of being conservative, as the water levels, hydraulic conductivities and flow patterns could be changed substantially from the baseline conditions in some areas. The residual effect will be continuous and extend to the far future as the subsidence would establish a new topography, but it will be limited to within the mine footprint and local catchments/creek reaches. The residual effect is considered to be irreversible.

Coarse Coal Rejects (CCR) Piles

The residual effect of the CCR piles on groundwater quantity during Operation and Post Closure includes slight change of hydraulic gradients, and hence a reduction of groundwater discharge in the small area between the footprints of the two CCR piles along the section of M19A Creek (about 400 m long only).

Table 7.9-1. Definitions of Characterization Criteria for Residual Effects on Groundwater Quantity and Quality

						Likelihood of Effects	
Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Ecological Context	Probability	Confidence Level
Negligible: No or very little detectable changes on groundwater quantity (water levels and flow patterns) and quality from baseline conditions	**Short-term:** Effect lasts 1 to 5 years.	**Once:** Effect occurs once during any phase of the project.	**Local:** Effect is limited to the project footprint.	**Reversible Short-term:** Effect can be reversed relatively quickly within 5 years.	**Low:** The background groundwater quantity has been disturbed, and groundwater quality has been degraded considerably by other activities before this Project.	**Low:** Effect is unlikely but could occur.	**Low:** < 50% confidence. The cause-effect relationships between the Project and its interaction with the groundwater environment are poorly understood, there are a number of unknowns, and data for the Project area are incomplete, leading a high degree of uncertainties in predicted groundwater effects.
Minor: Minor changes in groundwater quantity (water levels and flow patterns) and quality from the average value for baseline conditions. Change of groundwater discharge (as baseflow) into creeks is within 10% of baseline conditions.	**Medium-term:** Effect lasts 6 to 25 years.	**Sporadic:** Effect occurs at sporadic or intermittent intervals during any phase of the Project.	**Landscape:** Effect extends beyond the project footprint, but does not extend beyond the immediate drainage basin or the LSA.	**Reversible Long-term:** Effect can be reversed within 200 years of Post Closure.	**Neutral:** The background groundwater quantity and quality is considered average.	**Medium:** Effect is likely, but may not occur.	**Medium:** 50 to 80% confidence. The cause-effect relationships between the Project and its interaction with the groundwater environment are not fully understood, there are a number of unknowns, or data for the Project area are incomplete, leading a moderate degree of uncertainties in predicted groundwater effects; while results may vary, predictions are relatively confident.
Medium: Groundwater quantity (water levels and flow patterns) and quality change substantially from the average value for baseline conditions and approaches the limits of natural variation, or change of groundwater discharge (as baseflow) into creeks is within 50% of baseline conditions.	**Long-term:** Effect lasts between 26 and 50 years.	**Regular:** Effect occurs on a regular basis during any phase of the Project.	**Regional:** Effect extends beyond the LSA and across the broader region of the RSA.	**Irreversible:** an effect cannot be reversed (i.e., is permanent).	**High:** The background groundwater quantity and quality is considered pristine.	**High:** Effect is highly likely to occur.	**High:** > 80% confidence. There is a good understanding of the cause-effect relationship between the Project and the groundwater environment, and all necessary data are available for the Project area. There is a low degree of uncertainties in predicted groundwater effects, and the variations of the predicted effects are expected to be low.
Major: Groundwater quantity (water levels and flow patterns) and quality change substantially from the average value for baseline conditions and beyond the limits of natural variation, or change of groundwater discharge (as baseflow) into creeks by more than 50% of baseline conditions.	**Far Future:** Effect lasts more than 50 years.	**Continuous:** Effect occurs constantly during any phase of the Project.	**Beyond Regional:** Effect extends beyond the RSA, and may extend across or beyond the province.				

Table 7.9-2. Characterization of Residual Effects, Significance, Confidence and Likelihood on Groundwater Quantity and Quality

	Residual Effects Characterization Criteria						Significance of Adverse Residual Effects	Likelihood and Confidence	
Residual Effect	Magnitude	Duration	Frequency	Geographic Extent	Reversibility	Context		Probability	Confidence
Groundwater Quantity									
Underground Mine (Operation, Post Closure)	Medium/Major	Long-term	Continuous	Local	Reversible Long-term	Neutral	Not Significant (moderate)	High	Medium
Surface Subsidence (Operation, Post Closure)	Medium	Far Future	Continuous	Local	Irreversible	Neutral	Not Significant (moderate)	High	Low
Coarse Coal Rejects (CCR) Piles (Operation, Post Closure)	Minor	Long-term	Continuous	Local	Irreversible	Neutral	Not Significant (minor)	High	High
Groundwater Quality									
Coarse Coal Rejects (CCR) Piles (Operation, Post Closure)	Minor	Long-term	Continuous	Local	Irreversible	Neutral	Not Significant (minor)	High	High

Using the standard criteria developed in Table 7.9-1, the residual effect of the CCR piles on groundwater quantity is assessed to be Not Significant (minor) during Operation and Post Closure (Table 7.9-2), because of the predicted insignificant changes of the hydraulic gradients and the groundwater recharge in the local. The magnitude of the residual effect is assessed to be minor, because the changes of the hydraulic gradients and the reduction (< 10%) of the groundwater discharge have been predicted to be minor by the numerical modeling. The residual effect is assessed to be long-term, continuous throughout Operation and Post Closure, and irreversible, considering the permanent occupation of the areas by the CCR piles. The residual effect is predicted to be in the local catchments of M19 and M19A creeks.

7.9.1.2 Likelihood and Confidence for Residual Effects Conclusions on Groundwater Quantity

The likelihood for the residual effect on groundwater quantity during the underground mine dewatering will be high (Table 7.9-2). The effect is predicted based on the model calculated results of the water table drawdowns and the groundwater discharge (as baseflow) into the M20 Creek with sensitivity analysis, using the available baseline data. The confidence for the prediction is considered medium, due to the uncertainties and unknowns of the hydrogeological properties of the bedrock formations existing in the subsurface, especially in the deep underground mine zone (500 to 1,000 meters below the surface).

The likelihood for the residual effect of the subsidence on groundwater quantity during Operation and Post Closure is expected to be high (Table 7.9-2). However, the confidence for the prediction is low, because the specific locations of subsidence and groundwater interactions cannot be predicted with any certainty at this stage.

The likelihood for the residual effect of the CCR piles on groundwater quantity (e.g. changing the hydraulic gradients) during Operation and Post Closure will be high (Table 7.9-2). The effect is predicted based on the groundwater flow model simulations, using the available baseline data. The confidence for the predicted effect is high, due to the fact that the CCR piles will be lined at the bottom together with the seepage collection systems (during Operation and Post Closure) and that the piles will be capped on the top (during Post Closure), which will reduce the seepage and its effect to minimal.

7.9.2 Residual Effects Characterization for Groundwater Quality

As discussed in Section 7.8 and shown in Table 7.8-2, only the proposed CCR piles are expected to have residual effect on groundwater quality. Using the standard criteria developed in Table 7.9-1, the characterization of the potential residual effects of the CCR piles on groundwater quality, their significance, probability and confidence are shown in Table 7.9-2.

The magnitude of the residual effect of the CCR piles on groundwater quality is assessed to be minor (Table 7.9-2), because of the implementation of mitigation measures, including liners and seepage collection systems during Operation, and closure cover through Post Closure. The residual effect is assessed to be long-term, continuous, and irreversible, considering the permanent occupation of the areas by the CCR piles. The residual effect is predicted to be in the local catchments of M19 and M19A creeks.

The residual effect of the CCR piles on groundwater quality is assessed to be Not Significant (minor) during Operation and Post Closure (Table 7.9-2). The effect is predicted with the conservative solute transport modeling simulations without consideration of attenuation and dilution of the plumes by the fresh groundwater flux from the upper and down-gradients of the CCR site. The confidence for the predicted effect is high, considering the mitigation measures and the model predictions of the Base Case and sensitivity runs.

7.10 SUMMARY OF RESIDUAL EFFECTS ASSESSMENT AND SIGNIFICANCE FOR GROUNDWATER QUANTITY AND QUALITY

The summary of the residual effects assessment and significance for groundwater quantity and quality is shown in Table 7.10-1.

For groundwater quantity, the residual effect of the underground mine will occur during Operation through Post Closure (until full recovery of water table), including water table drawdown, alteration of groundwater flow pattern toward the mine zone, and potential reduction of groundwater discharge to the creeks. The residual effect of the underground mine will be limited to within the mine footprint, and it is assessed to be Not Significant (moderate), as the water table will eventually recover close to the baseline conditions. The residual effect of the expected subsidence during Operation and Post Closure may cause some changes in groundwater levels and flow patterns, and groundwater discharge at the local scale; the effect is assessed to be Not Significant (moderate). The residual effect of the CCR piles during Operation and Post Closure is expected to include a slight change in hydraulic gradients and hence a small reduction of groundwater discharge in the small area between the footprints of the two piles along the M19A Creek section, and the residual effect is assessed to be Not Significant (minor).

Table 7.10-1. Summary of Residual Effects, Mitigation, and Significance on Groundwater Quantity and Quality

Residual Effects	Project Phase	Mitigation Measures	Significance
Groundwater Quantity			
Underground Mine	Operation, Post Closure	Groundwater flow into the mine will be collected and managed.	Not Significant (moderate)
Surface Subsidence	Operation, Post Closure		Not Significant (moderate)
Coarse Coal Rejects (CCR) Piles	Operation, Post Closure	Liners under the CCR Piles, seepage collection drain systems, top covers at Post- Closure	Not Significant (minor)
Groundwater Quality			
Coarse Coal Rejects (CCR) Piles	Operation, Post Closure	Liners under the CCR Piles, seepage collection drain systems, top covers at Post Closure	Not Significant (minor)

For groundwater quality, the residual effect of the CCR piles will be Not Significant (minor), because of the implementation of mitigation measures, including liners and seepage collection system during

Operation, and closure cover through Post Closure. The residual effect is predicted to be in the local catchments of M19 and M19A creeks.

7.11 CUMULATIVE EFFECTS ASSESSMENT

7.11.1 Introduction

Cumulative effects are the result of a project-related effect interacting with the effects of other human actions (i.e., anthropogenic developments, projects, or activities) to produce a combined effect. A cumulative effects assessment is a requirement of the AIR and the EIS Guidelines, and is necessary for the proponent to comply with the *Canadian Environmental Assessment Act* (2012) and the BC *Environmental Assessment Act (2002)*.

The method for assessing cumulative effects generally follows the same steps as the Project-specific effects assessment:

1. scoping and identification of potential effects;
2. description of potential effects and mitigation measures, with subsequent identification of residual cumulative effects; and
3. characterization of residual cumulative effects.

However, because of the broader scope and greater uncertainties inherent in CEA (e.g., data limitations associated with some human actions, particularly future actions), there is greater dependency on qualitative methods and expert judgement. This method for assessing cumulative effects is tailored to how much information is available and facilitates comparison between the project-specific assessment and the cumulative effects assessment. It also facilitates comparison between assessment categories.

7.11.2 Establishing the Scope of the Cumulative Effects Assessment

The scoping process involves identifying those activities for which residual effects on groundwater quantity and quality are predicted, defining the spatial and temporal boundaries of the assessment, and examining the relationship between the residual effects of the Project and those of other projects and activities.

The following two criteria for the relevance of evidence pertaining to other human actions are considered in the scoping of the CEA:

1. A residual effect of the Project must be demonstrated to operate cumulatively with the effects of another human action; and
2. The other human action must be known to have been carried out, or it must be probable (using best professional judgement) that it *will be* carried out.

7.11.2.1 Spatial Boundaries

The cumulative effects assessment spatial boundary is intended to encompass an area beyond which effects of the Project would not cumulatively interact with effects of other Projects. The RSA (Figure 7.6-2) was selected as a suitable boundary to base the cumulative effects assessment on.

7.11.2.2 Temporal Boundaries

The temporal boundaries for the CEA go beyond the phases of the Project, beginning before major human actions were undertaken in the region, and extending into the future. While precisely forecasting which other human actions will occur at the end of the Project's Post Closure phase would be pure conjecture, an extrapolation of a likely future development scenario for the next several decades—based on information available today—is attempted.

The following temporal periods are evaluated as part of the CEA: past (1940-2010), present (2010 to 2014) and future.

7.11.3 Identification of Potential Cumulative Effects

The potential for cumulative effects on groundwater quantity and quality arising due to the interactions with nearby projects and human activities was investigated. All identified Project-specific residual effects were included in the cumulative effects assessment. These include: (1) mine dewatering and water level management; and (2) seepage of contact groundwater and management.

Figure 7.11-1 shows the footprints of the past, present and future projects located within the RSA for the cumulative effects assessment on groundwater. Table 7.11-1 shows the screening for residual effects to interact cumulatively with potential effects of other projects on groundwater quantity and quality. Within the RSA, only the following projects are considered to have a potential spatial or temporal overlap with the residual effects of this Project on groundwater quantity and quality:

- the historic Quintette (Babcock) Mine;
- the proposed Hermann Mine; and
- the proposed expansion of Quintette Mine.

7.11.4 Description of Potential Cumulative Effects and Mitigation

Teck's historic Quintette (Babcock) Mine spatially overlaps with both the underground mine zone and the CCR site of the Project (as shown in Figure 7.11-1). It opened in 1983, mining over 135 Mt of coal from four open pits in three separate mining areas before its closure in 2000. As shown on the satellite map, on the west side of Murray River, the historic open pits of this mine are located adjacent to the proposed underground mine footprint of the Murray River Project, but they are located on the other side of the M20 Creek catchment. These pits were mined 14 years ago, and they are small and shallow, and the groundwater flow and quality in these pits should have stabilized. These pits have been represented with drain boundaries in the baseline groundwater model built for the Murray River Project, and their effect to the baseline conditions has been accounted for in the characterization. Therefore, no residual cumulative effect from these pits is expected on groundwater quantity effect to be caused by the Murray River Project's underground mining and subsequent subsidence.

Figure 7.11-1

Footprints of Past, Present and Future Projects in the Regional Study Area for Cumulative Effects Assessment on Groundwater

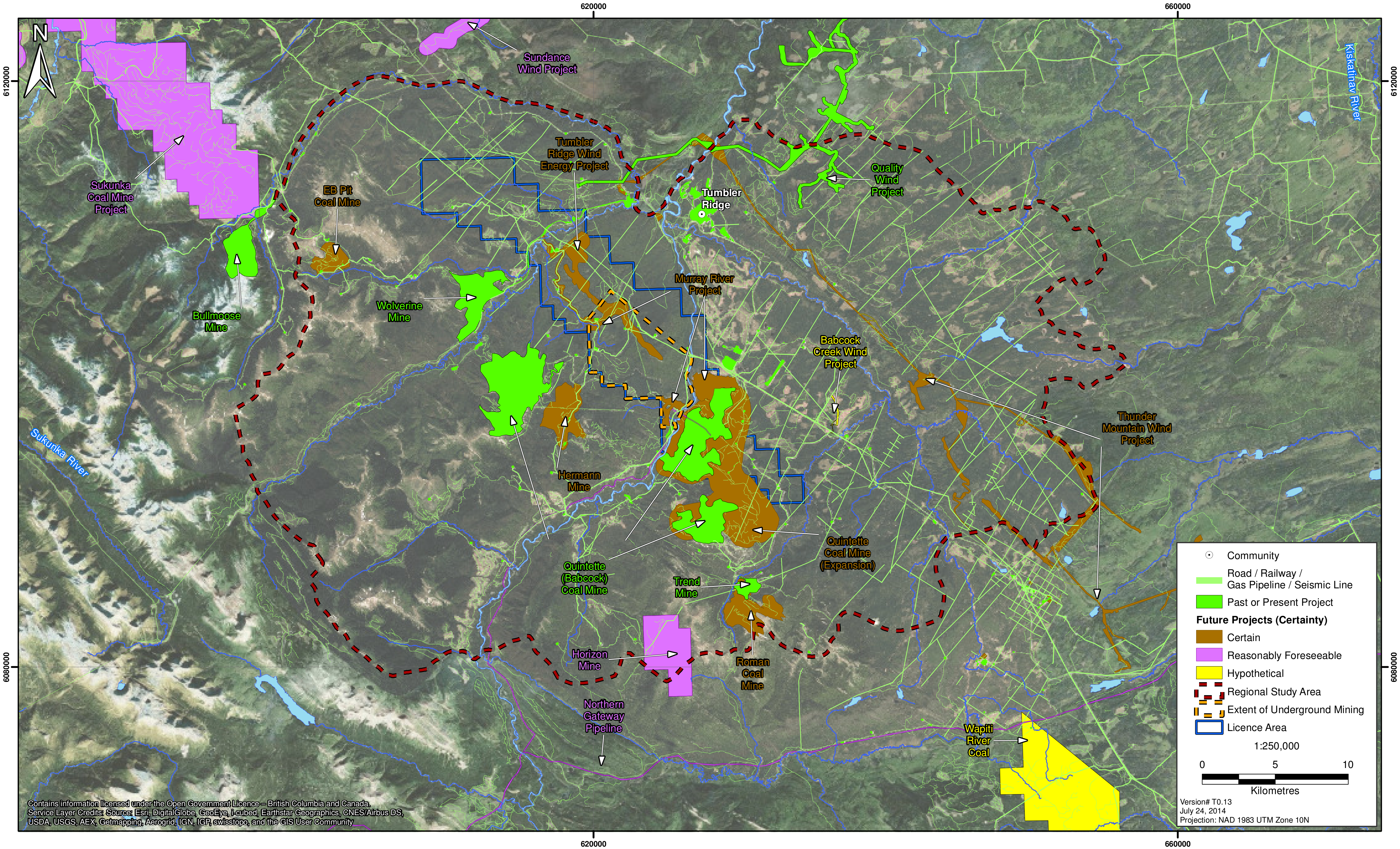


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Table 7.11-1. Screening for Residual Effects to Interact Cumulatively with Effects of Other Human Actions on Groundwater Quantity and Quality

	Potential for Cumulative Effect with Other Human Actions																	
	Time Frame																	
	Past						Present						Future					
	Historic		Recent										Certain					
Murray River Coal Project Residual Effect	Hasler Coal Mine	Sukunka (Bullmoose) Mine	Bullmoose Mine	Dillon Coal Mine	Quintette (Babcock) Mine	Willow Creek Mine	Brule Mine	Trend Mine	Quality Wind Project	Peace Canyon Dam	Wolverine Mine (Perry Creek) and EB Pit	WAC Bennett Dam	Hermann Mine	Quintette Mine	Roman Mine Project	Thunder Mountain Wind Park	Tumbler Ridge Wind Project	Wartenbe Wind Project
Groundwater Quantity																		
Underground Mine	-	-	-	-	L	-	-	-	-	-	-	-	L	-	-	-	*O*	-
Surface Subsidence	-	-	-	-	L	-	-	-	-	-	-	-	L	-	-	-	*O*	-
Coarse Coal Rejects (CCR) Piles	-	-	-	-	L	-	-	-	-	-	-	-	-	L	-	-	-	-
Groundwater Quality																		
Coarse Coal Rejects (CCR) Piles	-	-	-	-	L	-	-	-	-	-	-	-	-	L	-	-	-	-

	Potential for Cumulative Effect with Other Human Actions *(cont'd)*																
	Time Frame *(cont'd)*																
	Future *(cont'd)*																
	Reasonably Foreseeable										Hypothetical						
Murray River Coal Project Residual Effect	Echo Hill Mine	Coastal Gaslink Project	Horizon Mine	Meikle Wind Energy Project	Northern Gateway Pipeline	Rocky Creek Energy Project	Site C Clean Energy Project	Sukunka Coal Mine Project	Sundance Wind Project	Wildmare Wind Energy Project	Babcock Creek Wind Project	Belcourt Saxon Coal Project	Huguenot Mine	Moose Lake Wind Power	Septimus Creek Wind Power Project	Suska Mine	Wapiti River Coal Project
Groundwater Quantity																	
Underground Mine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surface Subsidence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coarse Coal Rejects (CCR) Piles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Groundwater Quality																	
Coarse Coal Rejects (CCR) Piles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

-	*No spatial or temporal overlap.*
O	*Spatial and temporal overlap, but no interaction anticipated; no further consideration warranted.*
L	*Negligible to minor adverse effect expected; implementation of best practices, standard mitigation and management measures; no monitoring required; no further consideration warranted.*
M	*Potential moderate adverse effect requiring unique active management/monitoring/mitigation; warrants further consideration.*
H	*Key interaction resulting in potential significant major adverse effect or significant concern; warrants further consideration.*

On the east side of Murray River, a historic tailings pile from the Quintette (Babcock) Mine is located immediately upgradient of the proposed CCR site of the Murray River Project. The baseline groundwater quality sampling data collected by HD Mining up to May 2014 shows no evidence that this tailings pile is generating any significant groundwater contamination towards the CCR site. Therefore, this tailings pile causes no residual cumulative effect on the predicted effect to be caused by the Murray River Project on groundwater quality.

The Hermann Mine Project of the Walter Energy possesses a total of 40 Mt of proven coal reserves. It has an approved EA certificate and is awaiting approvals for production. The proposed mine facilities include four open pits, two ex-pit dumps and one in-pit dump, and a water management facility. As shown in Figure 7.11-1, this mine project is located in the headwaters of M20 (Camp) Creek, about 5 km away from the proposed underground mine footprint of the Murray River Project. The design for this mine shows that the sizes of the pits are relative small and the waste rock dumps are located inside or immediately upgradient of the pits, which means any potential seepage from the waste rock dumps will most likely be captured in the pits. Therefore, with the implementation of best practices, standard mitigation and management measures, no residual cumulative effect is expected to be generated by this mine project on the predicted residual effect to be caused by the Murray River Project activities (underground mining and subsequent subsidence) on groundwater quantity and quality.

The proposed expansion of Quintette Mine is located on the east side of Murray River, as shown in Figure 7.11-1. Teck recently received the required regulatory permits to proceed with a restart of the Babcock mining area of the original Quintette Mine; the new operation would re-open one of the original pits and develop a new pit. The major activities for the expansion of this mine are located to the south and east (over 5 to 10 km away from the CCR site of the Murray River Project). The old tailings pile (located at upgradient of the CCR site) is not planned to be re-activated. Any potential effects from this mine to groundwater quantity and quality are not expected to cause a residual cumulative effect on the CCR site of the Murray River Project.

7.11.5 Characterization of Residual Cumulative Effects, Significance, Likelihood, and Confidence

No residual cumulative effects were identified to be carried forward for assessment, as shown in Table 7.11-2.

Table 7.11-2. Summary of Residual Cumulative Effects on Groundwater Quantity and Quality

Valued Component	Murray River Activity	Other Human Action Activity	Description of Potential Cumulative Effect	Description of Mitigation Measure(s)	Description of Residual Cumulative Effect
Groundwater Quantity					
	Underground Mine	• the historic Quintette (Babcock) Mine • the proposed Hermann Mine	No	No	No
	Surface Subsidence	• the historic Quintette (Babcock) Mine • the proposed Hermann Mine	No	No	No

(continued)

Table 7.11-2. Summary of Residual Cumulative Effects on Groundwater Quantity and Quality (completed)

Valued Component	Murray River Activity	Other Human Action Activity	Description of Potential Cumulative Effect	Description of Mitigation Measure(s)	Description of Residual Cumulative Effect
Groundwater Quantity *(cont'd)*					
	Coarse Coal Rejects (CCR) Piles	• the historic Quintette (Babcock) Mine • the proposed Quintette Mine	No	No	No
Groundwater Quality					
	Coarse Coal Rejects (CCR) Piles	• the historic Quintette (Babcock) Mine • the proposed Quintette Mine	No	No	No

7.12 EFFECTS ASSESSMENT CONCLUSIONS FOR GROUNDWATER QUANTITY AND QUALITY

The overall assessment of the residual effects of the proposed Project on groundwater quantity and quality is shown in Table 7.12-1. In order to mine the coal, dewatering of the underground mine workings is required during the Operation. This may result in lowering of the water table in the range of 1 to 15 m, which will have associated changes in flow directions, hydraulic gradients, and baseflow discharge to local streams. While predicted drawdown will be outside the range of natural variability in some areas, there are no groundwater users (drinking water, agriculture or industry) in the area. Following the end of the mine life, the workings will be flooded, and the water table will rebound, eventually returning to near pre-mine conditions. The residual effect is rated Not Significant (moderate).

Table 7.12-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Groundwater Quantity and Quality

			Significance of Residual Effects	
Residual Effects	Project Phase	Mitigation Measures	Project	Cumulative
Groundwater Quantity				
Underground Mine	Operation, Post Closure	Groundwater flow into the mine will be collected and managed.	Not Significant (moderate)	No
Surface Subsidence	Operation, Post Closure	-	Not Significant (moderate)	No
Coarse Coal Rejects (CCR) Piles	Operation, Post Closure	Liners under the CCR Piles, seepage collection drain systems, top covers at Post Closure	Not Significant (minor)	No

(continued)

Table 7.12-1. Summary of Project and Cumulative Residual Effects, Mitigation, and Significance for Groundwater Quantity and Quality (completed)

			Significance of Residual Effects	
Residual Effects	Project Phase	Mitigation Measures	Project	Cumulative
Groundwater Quality				
Coarse Coal Rejects (CCR) Piles	Operation, Post Closure	Liners under the CCR Piles, seepage collection drain systems, top covers at Post Closure	Not Significant (minor)	No

Imprinted within the area of water table drawdown, surface subsidence is also predicted to occur, ranging from 1 to 9 m, depending on the number of coal seams mined vertically. The changes in topography associated with subsidence are anticipated to have less influence on groundwater tables than mine dewatering; however, localized changes may be observed in some areas. The residual effect is rated Not Significant (moderate).

At the Coal Processing Site, the two CCR piles will result in reduced recharge to the groundwater system in the local area between the footprints of the two piles; however, the resultant change in groundwater quantity is very small. The residual effect is rated Not Significant (minor).

The CCR piles are designed with a geomembrane liner, overdrains, and seepage collection systems. This mitigation results in very limited potential for loss of contact water to groundwater during Operation. For the purposes of the assessment, it has been conservatively modelled that 5% of the water infiltrating through the piles (6 mm/year under North Pile and 7 mm/year under South Pile) and leaks through imperfections in the liner and into the groundwater system. During Post Closure, infiltration through the closure cover (4 mm/year) continues to be collected by the seepage collection system, and then is allowed to exfiltrate to groundwater. Flow path and solute transport analyses show that seepage would stay in shallow groundwater beneath and downgradient of each CCR pile, discharging to M19 and M19A creeks a short distance downslope. The residual effect of the CCR piles on groundwater quality is assessed to be Not Significant (minor)

No residual cumulative effects to groundwater quantity and quality are expected from other projects during Operation and Post Closure.

REFERENCES

Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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