RED MOUNTAIN UNDERGROUND GOLD PROJECT
VOLUME 3 | CHAPTER 11
GROUNDWATER QUALITY EFFECTS ASSESSMENT

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11 GROUNDWATER QUALITY EFFECTS ASSESSMENT

11.1 Introduction

Groundwater Quality is an aspect of the environment that may be altered by the proposed Red Mountain Underground Gold Project (the Project), as proposed by IDM Mining Ltd. (IDM). Figure 11.1-1 through Figure 11.1-3 below illustrate the established disturbance limits for the entire Project footprint and the established disturbance limits for the Mine Site (location of Upper and Lower Portals) and for Bromley Humps (location of Process Plant and Tailings Management Facility (TMF)), respectively.

Groundwater Quality is an intermediate component (IC) that is an effects pathway to the aquatic environment. This chapter describes the Groundwater Quality in the Project area and evaluates potential interactions between Groundwater Quality and proposed Project components and activities, including mine contact groundwater and seepage from the TMF during both operations and closure. Linkages to other components of the aquatic environment include the following valued components (VCs): Surface Water Quality (Volume 3, Chapter 13), Vegetation and Ecosystems (Volume 3, Chapter 15), Wildlife and Wildlife Habitat (Volume 3, Chapter 16), Fish and Fish Habitat (Volume 3, Chapter 18), and Human Health (Volume 3, Chapter 22).

The chapter follows the effects assessment methodology described in Volume 3, Chapter 6 of the Application for an Environmental Assessment Certificate / Environmental Impact Statement (Application/EIS).

Further information on Groundwater Quality baseline studies and modeling completed in support of the environmental assessment are provided in appended reports, notably the *Baseline Surface Water and Groundwater Quality Report* (Volume 8, Appendix 14-A) and the *Water and Load Balance Model Report* (Volume 8, Appendix 14-C).

Figure 11.1-1: Project Overview

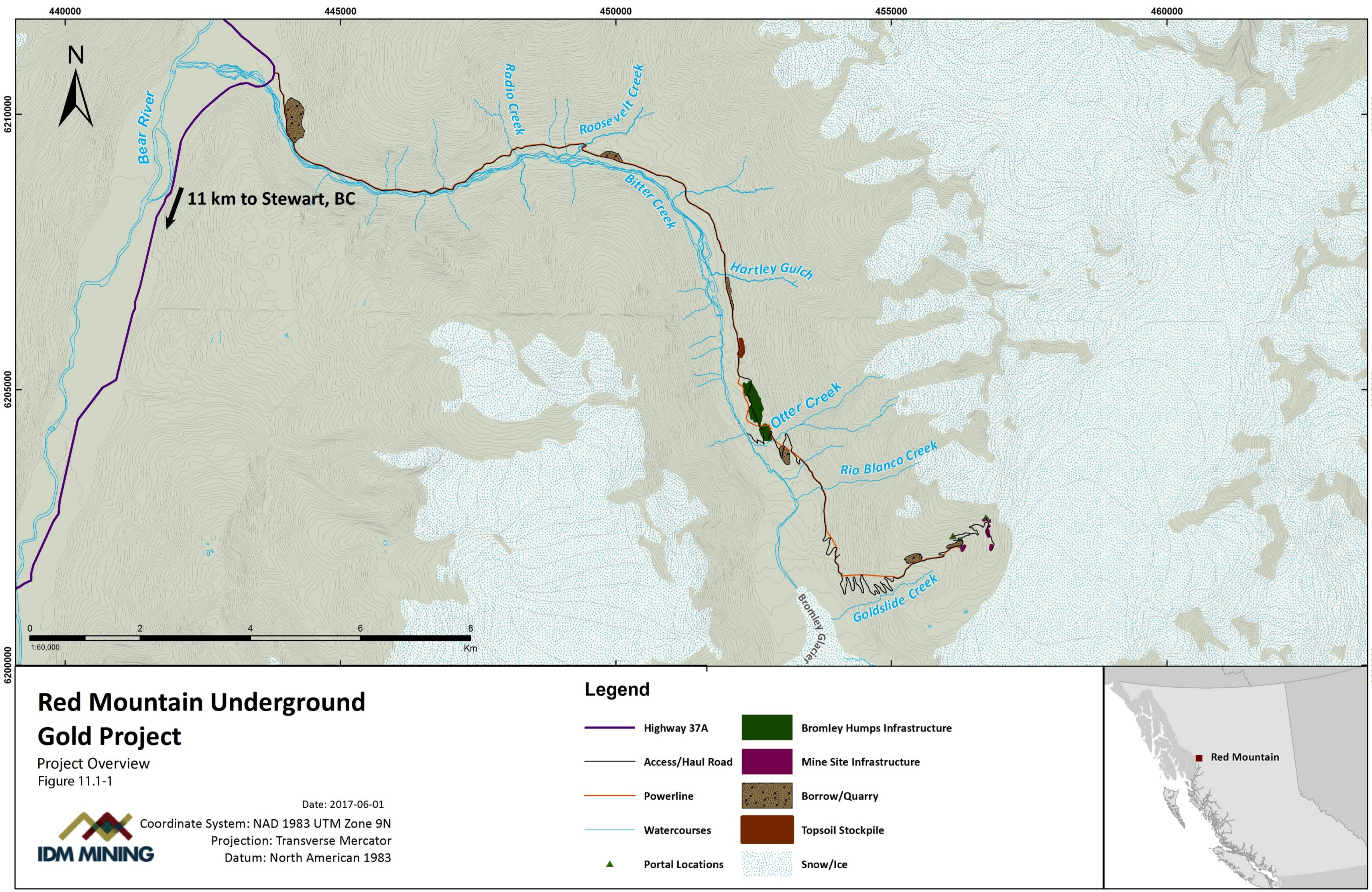


Figure 11.1-2: Project Footprint - Bromley Humps

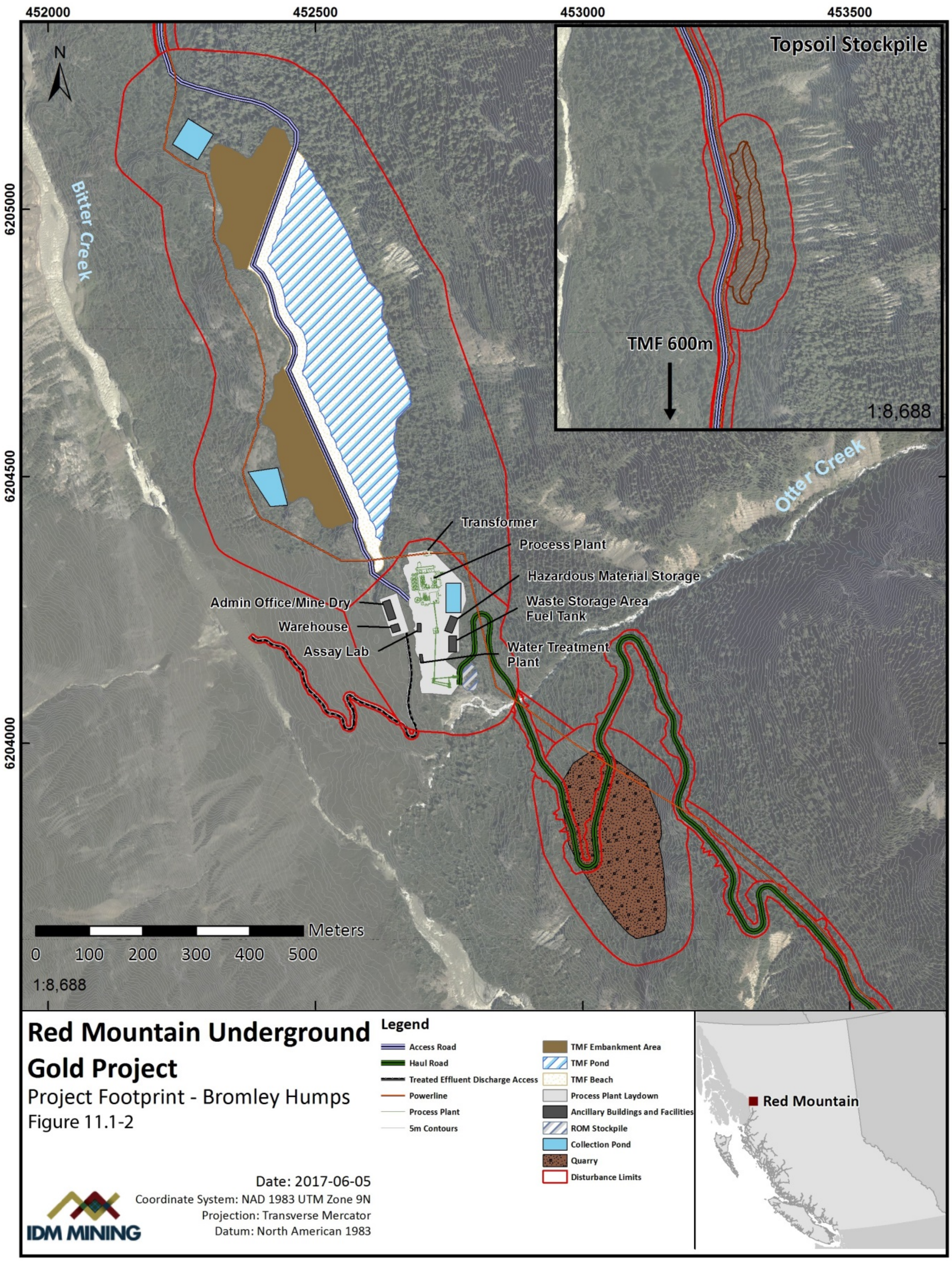
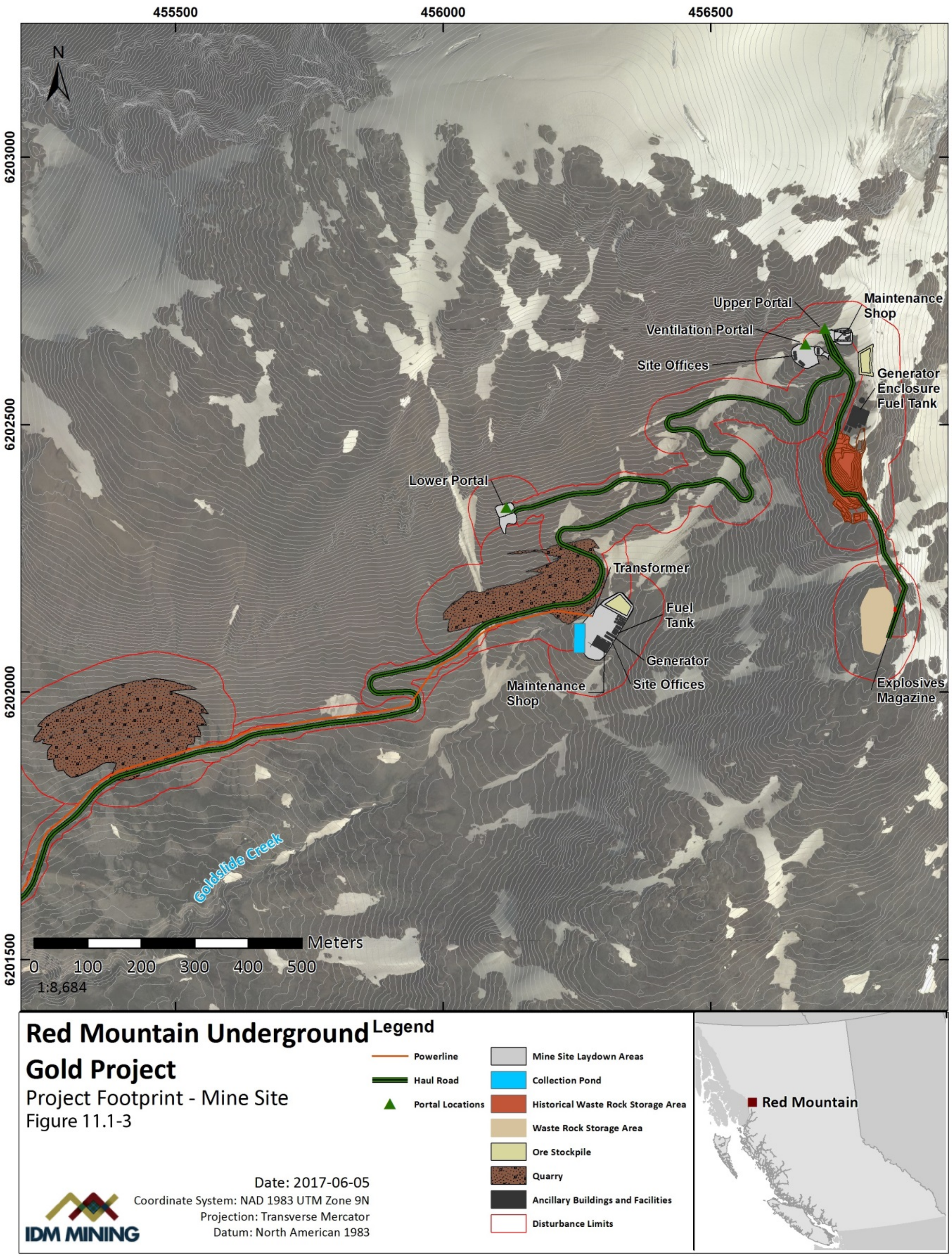


Figure 11.1-3: Project Footprint - Mine Site



11.2 Regulatory and Policy Setting

The Application Information Requirements (AIR) for the Project, approved by the British Columbia Environmental Assessment Office (EAO) in March 2017 as well as the Guidelines for the Preparation of an Environmental Impact Statement pursuant to the *Canadian Environmental Assessment Act, 2012*, (the EIS Guidelines) issued by the Canadian Environmental Assessment Agency (the Agency) in January 2016 outline the requirements of the Groundwater Quality effects assessment to meet both the Provincial and Federal environmental assessment requirements under the *BC Environmental Assessment Act* (2002) and *Canadian Environmental Assessment Act, 2012*, respectively.

Additional environmental regulations and guidelines are listed below and were consulted to help with the characterization of Groundwater Quality baseline conditions and the assessment of potential Project influences on Groundwater Quality:

- *Canadian Environmental Assessment Act, 2012*;
- The EIS Guidelines issued for the Project; and
- Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators, Version 2, BC Ministry of Environment.

The Project is within the Nass Area and the Nass Wildlife Area, as set out in the Nisga'a Final Agreement (NFA). Pursuant to the NFA, Nisga'a Nation, as represented by Nisga'a Lisims Government (NLG) has Treaty rights to the management and harvesting of fish, wildlife, and migratory birds within the Nass Wildlife Area and the larger Nass Area. The Project is also within the asserted traditional territory of Tsetsaut Skii km Lax Ha (TSKLH) and is within an area where Métis Nation BC (MNBC) claims Aboriginal rights.

11.3 Scope of the Assessment

11.3.1 Information Sources

The following information sources were reviewed as part of a desktop study for Groundwater Quality:

- *Environmental Baseline Data Report* prepared by Hallam Knight Piésold Ltd. for Lac Minerals Ltd. in 1992 (HKP 1992);
- *Preliminary Assessment, Tailings Disposal and Hydrogeology* draft report prepared by Klohn-Crippen for Lac North America Ltd. in 1994 (KC 1994a);
- *Hydrogeology Assessment* draft report prepared by Klohn-Crippen for Lac North America Ltd. in 1994 (KC 1994b);

- *Red Mountain Project 1994: Synopsis of Environmental Programs Undertaken, with Springs/Seeps Sample Locations & Environmental Files Location and Description* prepared by Rescan Consultants for Lac Minerals Ltd. In 1994 (Rescan 1994);

- *Draft Application for Mine Development Certificate* prepared by Rescan Consultants for Lac North America Ltd. In 1995 (Rescan 1995); and

- *Results from the ongoing environmental baseline monitoring program (as described in Appendix 14-A).*

IDM has consulted the predictions and analyses presented in other relevant effects assessment chapters concurrent to the development of the Groundwater Quality Effects Assessment. Specifically, the Hydrogeology Effects Assessment (Volume 3, Chapter 10, Sections 10.7 to 10.10), Hydrology Effects Assessment (Volume 3, Chapter 12, Sections 12.7 to 12.10), the Surface Water Quality Effects Assessment (Volume 3, Chapter13, Sections 13.7 to 13.10), the Surface Water and Groundwater Quality Baseline Report (Volume 8, Appendix 14-A), and the Water and Load Balance Model Report (Volume 8, Appendix 14-C).

As outlined in Chapter 6 (Effects Assessment Methodology), IDM has not conducted primary traditional use or traditional ecological knowledge (TEK) surveys in support of the Project due to the preferences of Nisga'a Nation, as represented by NLG, and EAO's and the Agency's direction for comparatively low levels of engagement with the other Aboriginal Groups potentially affected by the Project. IDM has committed to using TEK where that information is publicly available. As no TEK relevant to this effects assessment was publicly available at the time of writing, no TEK has been incorporated.

11.3.2 Input from Consultation

IDM is committed to open and honest dialogue with regulators, Aboriginal Groups, community members, stakeholders, and the public.

IDM conducted consultation with regulators and Aboriginal Groups through the Working Group co-led by EAO and the Agency. Where more detailed and technical discussions were warranted, IDM and Working Group members, including sometimes NLG representatives, held topic-focused discussions, the results of which were brought back to EAO and the Working Group as a whole.

Further consultation with Aboriginal Groups, community members, stakeholders, and the public has been conducted as outlined by the Section 11 Order and EIS Guidelines. More information on IDM's consultation efforts with Aboriginal Groups, community members, stakeholders, and the public can be found in Chapter 3 (Information Distribution and Consultation Overview), Part C (Aboriginal Consultation), Part D (Public Consultation), and Appendices 27-A (Aboriginal Consultation Report) and 28-A (Public Consultation Report). A record of the Working Group's comments and IDM's responses can be found in the comment-tracking table maintained by EAO.

Input from consultation incorporated in the Groundwater Quality Effects Assessment is summarized in Table 11.3-1.

Table 11.3-1: Summary of Consultation Feedback on Groundwater Quality

Topic	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
Aquatic Resources Fish Fish Habitat Groundwater Quality Hydrogeology Hydrology Sediment Quality Surface Water Quality	X				NLG requested a conceptual aquatic effects monitoring program (AEMP) design be included in the Application.	A conceptual AEMP has been included in the Application/EIS.
Groundwater Quality		X			Ministry of Energy and Mines (MEM) requested that hydrogeological modeling be conducted at relevant phases in the mine life.	Hydrogeological modeling has been conducted for relevant phases of the mine life, such as the end of operations and post-closure. This modeling has been incorporated into the hydrogeological effects assessment.
Groundwater Quality		X			MEM requested further information on the scoping of the water quality modeling approach, methods, inputs, and outputs.	This information has been included in Appendix 14-C, Water and Load Balance Model Report.
Groundwater Quality		X			British Columbia Ministry of Environment (BC MOE) and Ministry of Forests, Lands and Natural Resource Operations (FLNRO) requested that IDM consider developing a conceptual site model (CSM) to synthesize all groundwater information, concentrating on the Bromley Hump and the mine areas.	Conceptual models of the groundwater system at Bromley Humps and the Mine Site have been included in Appendix 10-A and Appendix 10-B, the Hydrogeology reports for the Mine Site and Bromley Humps area.

Topic	Feedback by*				Consultation Feedback	Response
	NLG	G	P/S	O		
Groundwater Quality		X			FLNRO requested that seepage from the TMF be considered as an effects pathway.	Groundwater seepage from the mine, the ore and waste rock storage area (WRSA), and the TMF have been included as effects pathways in the Groundwater Quality effects assessment.

*NLG = Nisga'a Lisims Government;
G = Government - Provincial or federal agencies;
P/S = Public/Stakeholder - Local government, interest groups, tenure and license holders, members of the public;
O = Other

11.3.3 Intermediate Components and Measurement Indicators

Potential effects pathways may include accidental spills, discharges, or accidental releases of contact water (including surface water and groundwater seepage associated with the underground mine working, the ore and waste rock stockpiles, and the TMF), as well as sediment runoff, and are further discussed in Section 11.5.

The Groundwater Quality effects assessment follows the structure indicated in the AIR (IDM 2017) using the measurement indicators listed in Table 11.3-2. Changes in parameter concentrations were evaluated for almost all of the parameters that have provincial or federal surface or groundwater quality guidelines or that were relevant in the interpretation of results. A complete list of the parameters considered in the evaluation is provided in Volume 8, Appendix 14-C, Section 3.4.2 and Table 3.4-2.

Although both total and dissolved metal data were characterized as part of the baseline studies, changes in total metal concentrations were not considered in the effects assessment for the reasons explained in Volume 8, Appendix 14-C, Section 3.4.2. However, guidelines for total metals were considered in evaluating predicted changes to dissolved metal concentrations. Rational for excluding other parameters is provided in Volume 8, Appendix 14-C, Section 3.4.2 and Table 3.4-3.

Table 11.3-2: Measurement Indicators for Groundwater Quality

Intermediate Component	Primary Measurement Indicators
Groundwater Quality	Change in parameter concentrations compared to baseline and provincial or federal guidelines for freshwater aquatic life. Changes in parameter concentrations were evaluated for all parameters that have provincial or federal surface or groundwater quality guidelines or that were relevant in the interpretation of results, as listed in Volume 8, Appendix 14-C, Section 3.4.2 and Table 3.4-3. Rational for excluding total metals and other parameters is provided in Volume 8, Appendix 14-C, Section 3.4.2 and Table 3.4-3.

11.3.4 Assessment Boundaries

11.3.4.1 Spatial Boundaries

Spatial boundaries define the limit within which changes to the IC Groundwater Quality will be evaluated. Four spatial boundaries were considered for the Groundwater Quality Effects Assessment: the Regional Study Area (RSA), the Local Study Area (LSA), and two Technical Study Areas (TSA).

The LSA encompasses the Project footprint and extends beyond it to include the surrounding area where there is a reasonable potential for adverse Project-specific effects to occur.

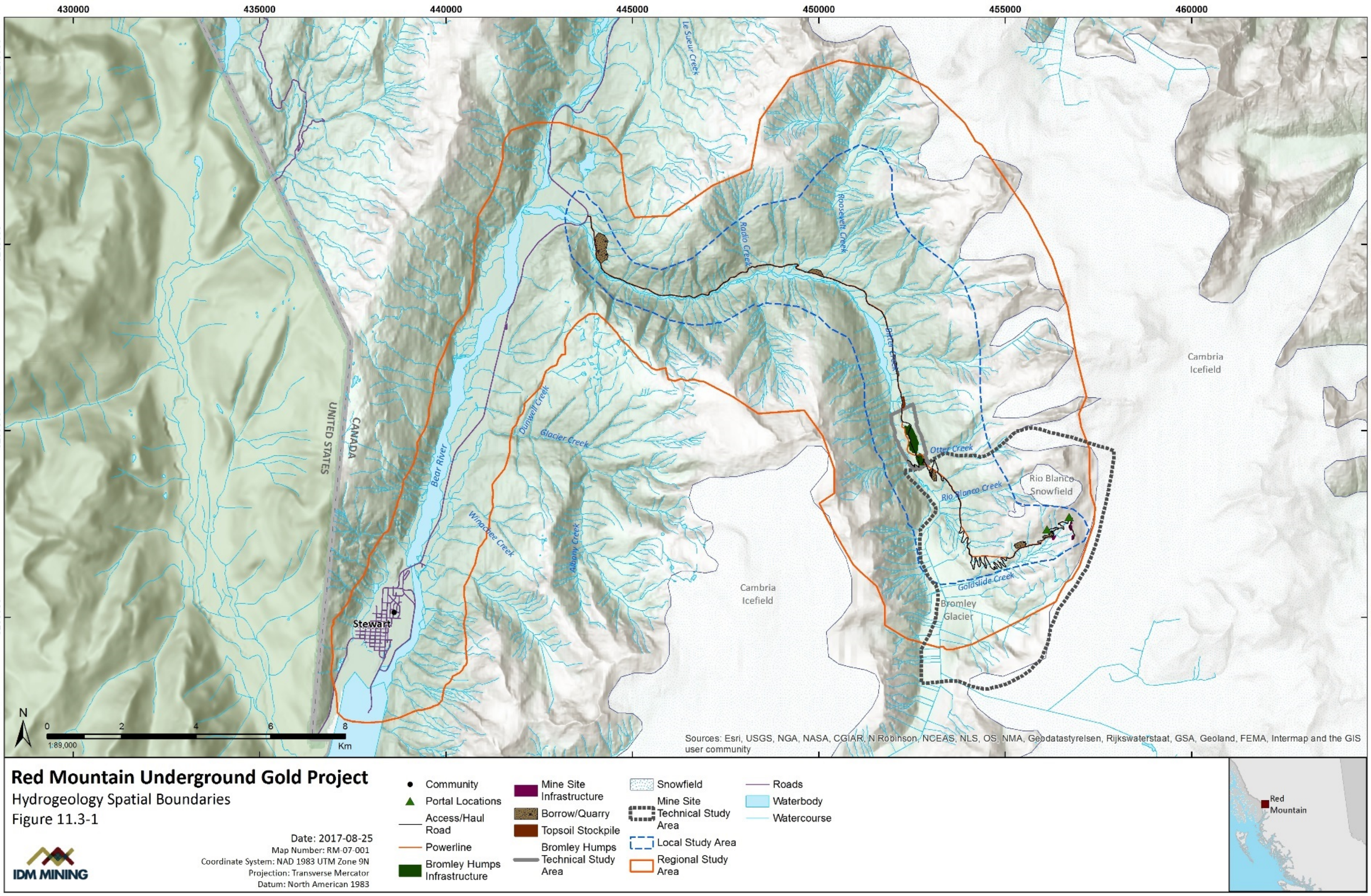
The RSA is a larger area that is used to provide context for the assessment of potential Project effects and represents the cumulative effects assessment study area.

The TSAs delineate the areas of the LSA where the Project components (i.e., within the Mine Site and Bromley Humps) are anticipated to affect the hydrogeological system. The TSAs encompass where technical and scientific information are available. A description of the spatial boundaries is provided in Table 11.3-3 the extent of the spatial boundaries is shown on Figure 11.3-1.

Table 11.3-3: Spatial Boundaries of the Groundwater Quality Assessment

Name	Spatial Boundary Description
LSA	Bitter Creek watershed up to the glacial extent, including Goldslide and Otter creeks.
RSA	Biter Creek and Bear River valleys, including Stewart and the northern end of the Portland Canal.
Mine Site TSA	Area bounded by the Cambria Ice Field to the east and south and the tongue of the Bromley Glacier to the north. This includes the proposed underground mine, the temporary WRSA footprint, and the areas where the water originates at or near the Project to where it drains or discharges. The TSA is drained by Bitter Creek and its three uppermost tributaries: Goldslide Creek, Rio Blanco Creek, and Otter Creek.
Bromley Humps TSA	Area comprising all the physical structures and mine activities of the Project at Bromley Humps and surface waters that could be affected by seepage of mine contact water. This includes the TMF, Process Plant, the Run of Mine (ROM) Stockpile, and Bitter and Otter creeks. The area is bounded to the north by an area of low relief located northwest of the TMF North Embankment where groundwater discharges may be expected and to the east by the 550 metre (m) contour elevation along the eastern slope of Bitter Creek valley, which reflects the approximate upper limit at which mine infrastructure along this slope exists.

Figure 11.3-1: Spatial Boundaries for Groundwater Quality



11.3.4.2 Temporal Boundaries

The temporal boundaries encompass the periods during which the Project is expected to have potential effects on Groundwater Quality. The relevant time-steps used for the Groundwater Quality effect assessment are provided in Table 11.3-4.

Table 11.3-4: Temporal Boundaries of the Groundwater Quality Assessment

Phase	Project Year	Length of Phase	Description of Activities
Construction	Year -1 to Year 1	18 months	Construction activities: Access Road, Haul Road, Powerline, declines, power supply to the underground, water management features, water treatment facilities, TMF, Process Plant, ancillary buildings and facilities, underground lateral development and underground dewatering, ore stockpile and ore processing start-up, and receiving environmental monitoring.
Operation	Year 1 to Year 6	6 years	Ramp up to commercial ore production and maintain a steady state of production, underground dewatering, tailings storage, water treatment, gold ore shipping, environmental monitoring, and progressive reclamation.
Closure and Reclamation, and Post-Closure	Year 7 to Year 21	15 years	Underground decommissioning and flooding, decommissioning of infrastructure at portals, Process Plant, TMF, ancillary buildings and facilities, reclamation, water treatment, removal of water treatment facilities, and receiving environment monitoring.

* Post-closure changes to groundwater will continue until water levels in the mine reach steady state in about 30 years, and monitoring of this component will continue until steady state conditions have been established.

11.3.4.3 Administrative and Technical Boundaries

No administrative boundaries are relevant to groundwater quality.

Technical boundaries for groundwater quality are reflected in the two TSAs described in Section 11.3.4.1 and Table 11.3-3.

11.4 Existing Conditions

Section 3.3 of the AIR requests the following information for existing conditions. Specific references are provided for each request in the following list.

- A description of the existing (or baseline) conditions within the study area in sufficient detail to enable potential Project-VC or -IC interactions to be identified, understood, and assessed: please see Sections 11.4.1, 11.4.3, and 11.4.4 in this chapter and the entirety of Appendix 14-A.

- A description of the quality and reliability of the existing (or baseline) data and its applicability for the purpose used, including any gaps, insufficiencies, and uncertainties, particularly for the purpose of monitoring activities: please see the "Limitations" discussion in Section 11.4.3.2 in this chapter and Section 3.3.3 in Appendix 14-A.
- Reference to natural and/or human-caused trends that may alter the environmental, economic, social, heritage, and health setting, irrespective of the changes that may occur as a result of the proposed Project or other project and/or activities in the area: please see Section 6.1 of Appendix 14-C on climate change.
- An explanation of if and how other past and present projects and activities in the study area have affected or are affecting each VC or IC: please see Section 11.4.2 of this chapter.
- Documentation of the methods and data sources used to compile information on existing (or baseline) conditions, including any standards or guidelines followed: please see Sections 11.4.1, 11.4.3, and 11.4.4 in this chapter and the entirety of Appendix 14-A.
- Where additional Project and VC- or IC-specific field studies are conducted, the scope and methods to be used will follow published documents pertaining to data collection and analysis methods, where these are available. Where methods used for the assessment deviate from applicable published guidance, the rationale for the variance will be provided in the Application: please see Sections 11.4.1, 11.4.3, and 11.4.4 in this chapter and the entirety of Appendix 14-A.
- Description of what Traditional Ecological Knowledge (TEK), including Aboriginal Traditional Knowledge, was used in the VC or IC assessment: please see Section 11.3.1 in this chapter.

11.4.1 Overview of Existing Conditions

Baseline Groundwater Quality in the Mine Site TSA has been characterized from three artesian drillholes (RMS5, RMS6, and RMS7), which were established as monitoring locations in the summer of 2014, and ponded water in the underground decline (RMS4). Groundwater in this area has circumneutral pH, moderate levels of alkalinity (approximately 60 milligrams (mg) $CaCO_3$ equivalent per litre (eq/L)) and is a calcium sulphate-dominated water influenced by mineralization. Metal concentrations do not exceed BC Contaminated Site Regulation (CSR) guidelines for groundwater. Historical Groundwater Quality results from the cirque also indicate that groundwater is dominated by calcium, magnesium, and sulphate and has very low sodium and potassium concentrations, which is typical of oxidized sulphide deposits. Seeps and springs throughout the area tend to be elevated in aluminum, manganese, copper, and zinc (Appendix 14-A).

Baseline Groundwater Quality in the Bromley Humps TSA has been characterized from three monitoring wells that were established as monitoring locations in the fall of 2016. Only three groundwater samples had been taken by the end of 2016. Preliminary monitoring results indicate that groundwater in this area is also a calcium sulphate dominated water with circumneutral pH and generally low metal concentration; i.e., it does not exceed BC CSR guidelines for groundwater (Appendix 14-A).

11.4.2 Past and Current Projects and Activities

Mineral exploration of the Project started in 1989 and has included exploration drilling, construction of an exploration decline, and a bulk sample program. These activities contributed to a better understanding of the baseline Groundwater Quality. However, the ponded water in the existing decline (monitored intermittently from 1996 to 2006 and regularly from 2014 to 2016) has been affected by these activities and does not fully represent pre-disturbance Groundwater Quality. Table 11.4-1 lists the past and current projects and activities related to Groundwater Quality.

Table 11.4-1: Past and Current Projects and Activities

Timeframe	Mine Site TSA, Bromley Humps TSA, and LSA	RSA
Past Projects and Activities (prior to 2014)	Groundwater samples collected from an artesian drillhole in the cirque from 1990 to 1992. This drillhole was also sampled in 1993, 1994, and 1996. A seeps and spring survey was conducted in 1993 from July through November, which included two underground boreholes, two surface piezometers, two discharge locations within the existing decline, and 18 seeps and springs in the Goldslide Creek and Rio Blanco Creek watersheds. Another seep near Rio Blanco Creek was sampled in 1993 and 1994. Six springs were sampled in 1994. Four of these springs may have been the same as those monitored in 1993, but this could not be confirmed. These springs were also sampled in 1996. Samples from ponded water in the underground decline were collected in 1996, 1997, 2000, 2003, 2004, 2005, and 2006.	None
Current Projects and Activities (2014 to 2016)	Seven monitoring locations were established during summer 2014, one was established in October 2015, and three more were established in fall 2016. Of these 11 monitoring locations, four are not relevant to baseline Groundwater Quality because they characterize seepage from the existing waste rock dump or the field cribs and seven are relevant to baseline Groundwater Quality. Of the seven relevant groundwater monitoring locations, three are artesian drillholes in the cirque close to the Mine Site, three are monitoring wells at Bromley Humps, and one is ponded water in the existing underground workings. These locations are monitored quarterly when possible.	None

11.4.3 Project-Specific Baseline Studies

11.4.3.1 Data Sources

Historical Groundwater Quality studies were completed from 1990 to 1992 by Hallam Knight Piésold (HKP 1992) on behalf of Bond Gold and Lac Minerals Ltd.; in 1993 by Klohn-Crippen (Klohn Crippen 1994a, 1994b) on behalf of Lac Minerals; from 1993 to 1994 by Rescan

(Rescan 1994, 1995) on behalf of Lac Minerals; and from 1996 to 1997 by Royal Oak. Baseline work related to Groundwater Quality included sampling seeps, springs, artesian drillholes, surface piezometers, underground discharge locations within the workings, and ponded water in the decline. Additionally, SRK collected samples of ponded water in the decline of the underground portal in 2000 and from 2003 to 2006 in support of ongoing compliance monitoring for the site.

Baseline studies were re-initiated in June 2014 to address gaps in the existing historical dataset. Avison Management Services Ltd. (Avision) collected quarterly groundwater samples from three artesian drillholes (RMS5, RMS6, and RMS7), the ponded water in the underground decline (RMS4), and three seeps on the existing waste rock dump (RMS1, RMS2, and RMS3), all in the Mine Site TSA. The waste rock dump seeps are included in the geochemical characterization report for waste rock and ore stockpiles (Volume 7, Appendix 1-B) and, as they do not represent baseline Groundwater Quality, they are not included in the baseline characterization of Groundwater Quality. In the fall of 2016, three monitoring wells in the Bromley Humps TSA were installed (MW16-002, MW16-003, and MW16-004) and were sampled for the first time in September 2016.

The quality assurance and quality control (QA/QC) methods for the baseline Groundwater Quality data are described in Volume 8, Appendix 14-A, Section 3.5. The data management methods for the baseline Groundwater Quality data are described in Volume 8, Appendix 14-A, Section 3.6.

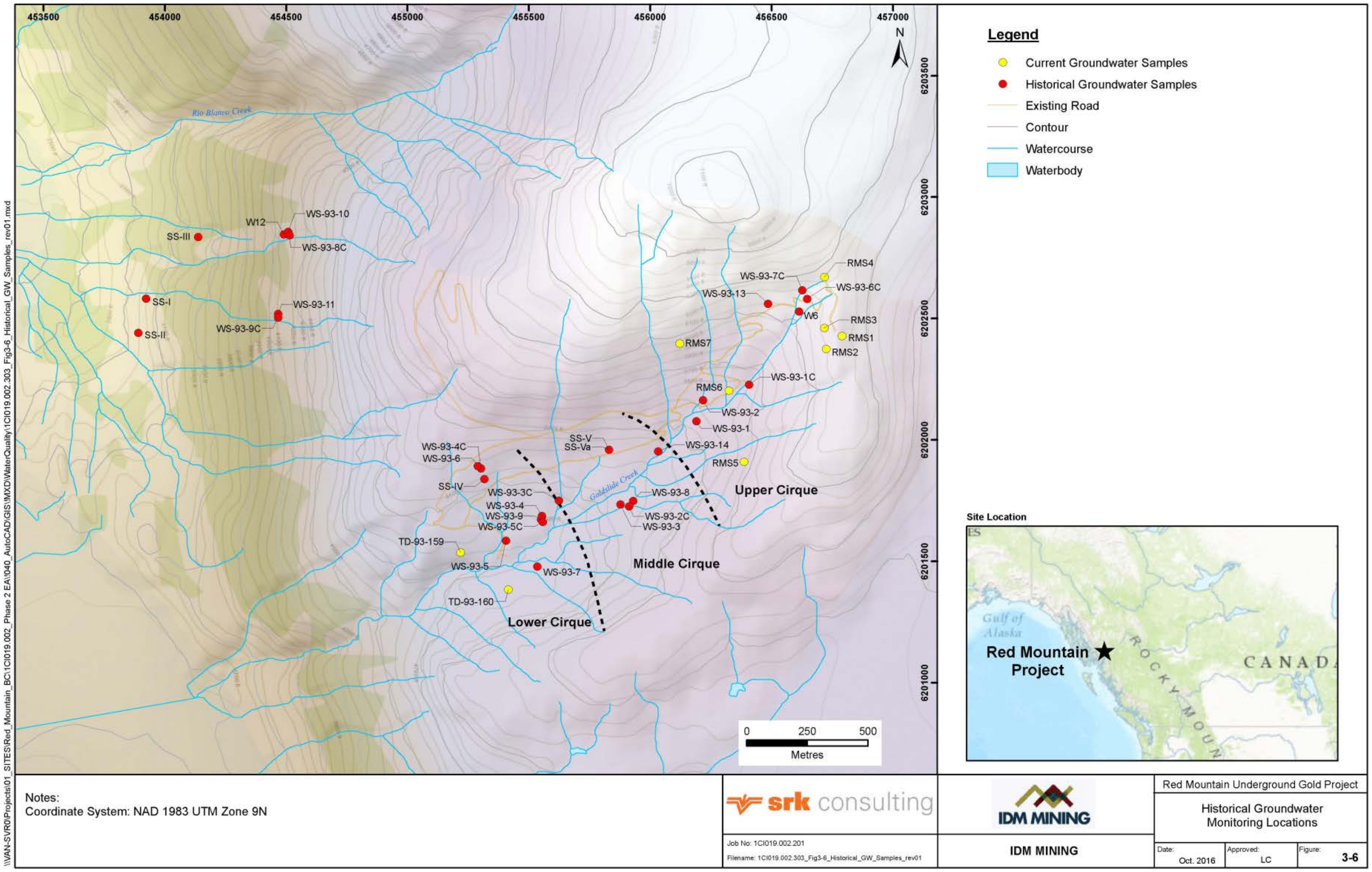
A summary of activities included in Project-specific Groundwater Quality baseline studies is provided in Table 11.4-2; details of these field programs are provided in Appendix 14-A. The historical and current groundwater monitoring locations are shown on Figure 11.4-1.

Table 11.4-2: Baseline Groundwater Quality Studies

Studies	Activities
HKP 1990 to 1992	• Collection of groundwater samples at location W6 (drillhole BZ89-02 in the upper cirque).
Klohn Crippen 1993	• Seeps and springs survey from July to November. • Samples collected from 24 monitoring locations, which included two underground boreholes (MC-92-124 and MC92-76), two surface piezometers (TD93-159 and TD93-160), two discharge locations from the existing decline, and 18 groundwater seeps and springs (the locations starting with “WS93“).
Rescan 1993 to 1994	• Collection of groundwater samples at location W6 (established in 1990 by HKP) and new monitoring location W12, a seep located near the middle reaches of Rio Blanco Creek. • Collection of samples from the ponded water in the decline of the underground portal and discharged water from the underground during dewatering efforts in 1994. • Collection of groundwater samples from six springs in 1994 (SS-1, SS-II, and SS-III near Rio Blanco Creek and SS-IV, SS-V, and SS-Va in the cirque); four of these springs may have been the same as those monitored in 1993, but this could not be confirmed.

Studies	Activities
Royal Oak 1996 to 1997	• Collection of groundwater samples at location W6 (established in 1990 by HKP) and from the six springs sampled in 1994 (SS-I through SS-Va).
SRK 2000, 2003 to 2006	• Collection of groundwater samples from the ponded water in the decline of the underground portal, following standard environmental sampling procedures (MWLAP 2013).
Avison, SRK, and Knight Piésold 2014 to 2016	• Collection of samples from seeps in the existing waste rock dump (RMS1, RMS2, and RMS3) and from the field cribs (NCribs), which are excluded from this evaluation. • Collection of samples from the ponded water in the decline of the underground portal (RMS4) beginning in June 2014. • Collection of samples from three artesian drillholes in the cirque (RMS5, RMS6, and RMS7) beginning in the summer of 2014. These were upgraded and plugged with a pressurized top, mounted with a pressure gauge, and equipped with a pressure transducer to record the seasonal change in groundwater levels. • Collection of samples from three monitoring wells in the Bromley Humps area (MW16-002, MW16-003, and MW16-004) beginning in September 2016. • Samples collected following standard environmental sampling procedures (MWLAP 2013).

Figure 11.4-1: Groundwater Monitoring Locations



11.4.3.2 Primary Data Collection and Analysis Methods

The samples taken from RMS4, RMS5, RMS6, and RMS7 as well as all the historical groundwater samples were grab samples because they were taken from ponded water or flowing drillholes. The samples taken from MW16-002, MW16-003, and MW16-004 were taken using a bladder pump. Samples were collected by Avison following the water sampling guidance in the British Columbia (BC) Field Sampling Manual (MWLAP 2013) when practical.

Field parameters were measured *in situ* or from a separate sub-sample and included temperature, conductivity, specific conductivity, dissolved oxygen, oxidation-reduction potential (ORP), and pH using a YSI 556 or Pro Plus, and turbidity using an Oakton Turbidity Meter. Field notes were taken recording time of sample collection, weather conditions, any deviations from regular sampling protocols, and any other information relevant to quality of the sample or the sample results. Notes and parameters were recorded in a field log book on waterproof paper. All sampling was conducted by qualified personnel with a minimum of one crew member having significant water quality sampling experience. Nitrile gloves were worn throughout sampling and filtration.

All sample bottles were obtained from ALS Laboratory in Burnaby, BC, and were pre-cleaned, so the bottles were not rinsed in the field. Sample bottles were only open long enough to fill and preserve the samples. Sample bottles and lids were only handled on the outside surface, and nothing foreign could touch the inside. Preservatives were added immediately after bottles were filled and samplers were careful not to touch the preservative containers to the sample bottles.

Sample filtration was conducted in the field using a reusable vacuum filter and hand pump provided by ALS. The filter used individually packaged disposable filter papers with a pore size of 0.45 micrometres (µm). The filter unit was rinsed thoroughly with deionized water for each new sample set. Field blank samples were also filtered using this filter.

Samples were stored with ice packs in a clean cooler immediately after being collected. Samples were packed with enough ice to ensure they remained below 4°C throughout sample collection and subsequent shipping to ALS. Chains of custody were included with each shipment.

Samples were analyzed for the following parameters.

- Physical parameters: color, conductivity, hardness, pH, total suspended solids (TSS), total dissolved solids (TDS), and turbidity;

- Anions and nutrients: acidity, bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity, phenolphthalein alkalinity, total ammonia, bromide, chloride, fluoride, nitrate, nitrite, total Kjeldahl nitrogen, dissolved orthophosphate, total phosphorus, total dissolved phosphorus, and sulphate;

- Total and dissolved organic carbon; and

- Total and dissolved metals: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silicon, silver, sodium, strontium, thallium, tin, titanium, uranium, vanadium, and zinc.

11.4.3.2.1 Limitations

The dataset available for Groundwater Quality has the following limitations:

- There is no pre-disturbance groundwater data within the Mine Site TSA;
- The number of Groundwater Quality samples, though considered adequate for this assessment, could be increased; and
- The baseline groundwater monitoring locations are distributed at and around the key mining areas (i.e., Mine Site and Bromley Humps), adjacent and downgradient to the areas that could be affected by mining operations. However, there are no monitoring wells upgradient of the Upper Portal and upgradient of the TMF because of the topography; i.e., the portal is located under the summit of Red Mountain, and the TMF is below an area that cannot be accessed due to steep topography.

11.4.4 Baseline Characterization

The full baseline Groundwater Quality dataset is provided in Appendix 14-A. Selected summary statistics for the Mine Site TSA Groundwater Quality and the Bromley Humps Groundwater Quality are provided in Table 11.4-3. These statistics were calculated using results from RMS5, RMS6, and RMS7 from 2014 to 2016 for the Mine Site TSA, 1994 to 2016 results from RMS4, and 2016 results from MW16-002 and MW16-004 for Bromley Humps. A comparison of the groundwater results to BC Contaminated Sites (CSR) guidelines for groundwater quality is provided in Section 4.2 of Appendix 14-A. The comparison indicates there were one or two exceedances of the BC CSR guidelines for nitrate, arsenic (total and dissolved), chromium, and selenium in groundwater from the underground decline (RMS4) and no exceedances for the cirque area samples (RMS5, RMS6, and RMS7).

Table 11.4-3: Summary Statistics for Baseline Groundwater Quality

Parameter (mg/L unless otherwise noted)	RMS4		RMS5, RMS6, and RMS7		Bromley Humps TSA
	Median	P90	Median	P90	Mean
SO_4	160	198	180	202	79
Alkalinity (as $CaCO_3$)	57	83	66.1	71	152
Aluminum, dissolved	0.0073	0.035	0.00215	0.0050	0.0142
Antimony, dissolved	0.012	0.11	0.00293	0.0057	0.00062
Arsenic, dissolved	0.007	0.013	0.00411	0.0071	0.000696667

Parameter (mg/L unless otherwise noted)	RMS4		RMS5, RMS6, and RMS7		Bromley Humps TSA
	Median	P90	Median	P90	Mean
Cadmium, dissolved	0.000105	0.0005	0.000035	0.000384	0.00007
Calcium, dissolved	63	89.6	74.8	83	89
Chromium, dissolved	0.00099	0.0033	0.0001	0.001	0.001
Cobalt, dissolved	0.0003	0.000724	0.0001	0.0003	0.00054
Copper, dissolved	0.0004	0.00241	0.0002	0.001	0.0058
Iron, dissolved	0.01	0.0672	0.034	0.056	0.033
Lead, dissolved	0.00008	0.000482	0.00005	0.0005	0.0005
Magnesium, dissolved	8.1	15	9.99	11	5.6
Manganese, dissolved	0.077	0.26	0.0231	0.083	0.015
Mercury, dissolved	0.00005	0.00005	0.000005	0.00001	0.00001
Molybdenum, dissolved	0.0020	0.00412	0.0215	0.026	0.0038
Nickel, dissolved	0.002	0.00544	0.00075	0.0012	0.0049
Selenium, dissolved	0.001	0.004	0.00129	0.0015	0.0059
Silver, dissolved	0.00001	0.00005	0.00001	0.00002	0.00002
Zinc, dissolved	0.0082	0.0314	0.0045	0.037	0.005

11.5 Potential Effects

11.5.1 Methods

A scoping exercise was undertaken to identify the Project components and activities that could be expected to interact with groundwater and cause a potential effect to Groundwater Quality. The potential interactions were identified based on professional experience with other mining projects in BC and through multi-disciplinary consultation with consultants working on behalf of IDM.

The feedback received during IDM's consultation efforts (as outlined in Table 11.3-1) informed the scoping and identification of potential interaction and effects on Groundwater Quality.

11.5.2 Project Interactions

The physical works and activities to be implemented during the Project have the potential to interact with and lead to effects on Groundwater Quality. Evaluation of the interaction matrix led to identification of key interactions. Key interactions are those that warrant further assessment as key interactions have greater potential to result in significant adverse residual effects or to be of greater concern to Nisga'a Nation, government, or the public. The remaining interactions were not carried forward in the assessment for one or several of the following reasons:

- They are known to have no or negligible adverse effects;
- They are already well regulated or managed under another regulatory process; and
- There are proven effective mitigation measures or Best Management Practices (BMPs), which IDM commits to implement, that would eliminate or reduce to a negligible level any residual adverse effects from those interactions.

Table 11.5-1 presents the Project components and activities and the expected degree of interaction with Groundwater Quality. Key interactions have been bolded.

Table 11.5-1: Potential Project Interactions, Groundwater Quality

Project Component or Activity	Potential Effect / Pathway of Interaction with Groundwater Quality
Construction Phase	
Excavate and secure Lower Portal entrance and access tunnel	**Changes to Groundwater Quality resulting from erosion and sedimentation, dust deposition, metal leaching/acid rock drainage (ML/ARD), and/or blasting**
Construct Mine Site water management infrastructure, including talus quarry and portal collection ponds, dewatering systems, and water diversion, collection and discharge ditches and swales.	Changes to Groundwater Quality caused by infiltration through water management features
Install and fill Fuel Tanks at Mine Site	Changes to Groundwater Quality from the storage, handling, and use of chemicals and fuels at the Mine Site, Access Road, and Haul Road
Initiate underground lateral development and cave gallery excavation	**Changes to Groundwater Quality resulting from ML/ARD, blasting, and groundwater interaction**
Temporarily stockpile ore at the Mine Site	Changes to groundwater flow paths and Groundwater Quality caused by infiltration and mounding of water table underneath ore stockpiles
Transport and deposit waste rock to Waste Rock Storage Area(s)	Changes to Groundwater Quality caused by infiltration and mounding of water table underneath waste rock stockpiles
Excavate rock and till from the TMF basin and local borrows / quarries for construction activities (e.g., dam construction for the TMF)	Changes to Groundwater Quality from erosion and sedimentation, ML/ARD, and dust deposition
Establish water management facilities, including diversion ditches for the TMF and Process Plant	Changes to Groundwater Quality caused by infiltration through water management features

Project Component or Activity	Potential Effect / Pathway of Interaction with Groundwater Quality
Construct the TMF	**Changes to Groundwater Quality caused by infiltration through water management features and construction activities**
Construct the Process Plant and Run of Mine Stockpile	Changes to Groundwater Quality caused by infiltration and mounding of water table underneath ore stockpile
Operation Phase	
Continue underground lateral development, including dewatering	**Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering**
Haul waste rock from the declines to the Waste Rock Storage Area(s) for disposal (waste rock transport and storage)	Changes to Groundwater Quality caused by infiltration and mounding of water table underneath waste rock stockpiles
Extract ore from the underground load-haul-dump transport to Bromley Humps to Run of Mine Stockpile (ore transport and storage)	Changes to Groundwater Quality caused by infiltration through and mounding of water table underneath ore stockpile
Temporarily store hazardous substances including fuel, explosives, and mine supplies	Changes to Groundwater Quality from the use of chemicals and fuel and the potential for spills
Progressively reclaim disturbed areas no longer required for the Project	Changes to Groundwater Quality through changes to local scale flow or drainage pathways
Closure and Reclamation Phase	
Decommission underground infrastructure	Changes to Groundwater Quality as a result of erosion and sedimentation
Flood underground	**Changes to Groundwater Quality as a result of flooding**
Decommission and reclaim all remaining mine infrastructure (Mine Site and Bromley Humps, except TMF) in accordance with Closure Plan	Changes to Groundwater Quality as a result of changes to infiltration rates
Conduct maintenance of mine drainage, seepage, and discharge	Changes in Groundwater Quality caused by infiltration through water management features

Groundwater is not expected to be used for direct industrial or domestic use in Project activities, such as water supply or drinking water.

11.5.3 Discussion of Potential Effects

Potential activities that are likely to influence Groundwater Quality include the development, dewatering, backfilling, and reflooding of the underground mine. The specific activities that fall within this group are

- Excavate and secure Lower Portal entrance and access tunnel;

- Initiate underground lateral development and cave gallery excavation, including dewatering, and discharge of water from underground;
- Continue underground lateral development, including dewatering; and
- Flood underground.

In the Bromley Humps area, potential activities that are likely to have an effect on Groundwater Quality include the construction of the TMF and the seepage of infiltration and process water. Although the magnitude of seepage flow from the TMF is small, it influences downgradient water quality.

Based on professional judgment, and with appropriate application of BMPs, all other activities listed in Table 11.5-1 are anticipated to have limited, localized effects to Groundwater Quality and no adverse effects. Therefore, further assessment is not warranted.

11.5.3.1 Changes to Groundwater Quality because of ML/ARD, Blasting, and Dewatering (Mine Site TSA)

During mining operations, the groundwater system will be affected by underground water management, drilling, blasting, excavation, and backfilling activities. Waste rock in the temporary stockpiles will be backfilled to the underground mine. There is a deficit of backfill, and additional backfill will be obtained from a quarry located in a talus deposit near the lower portal. The interaction of groundwater with backfill is the dominant effect on Groundwater Quality during operations.

The source term for the backfilled mine during operations is described in Appendix 14-C. This source term is a prediction of water chemistry for groundwater that interacts with and is discharged from the backfilled mine. During operations, predicted concentrations in the mine water are relatively low due to the relatively large amount of groundwater flow interacting with the mine workings. The groundwater is alkaline and provides sufficient alkalinity to maintain neutral pH in the mine drainage throughout operations. Backfilled waste rock is expected to remain neutral throughout operations due to the use of cemented rock fill (CRF) for legacy waste rock used as backfill, lag-times in the onset of acidic conditions in new waste rock used as backfill, and the addition of lime to talus used as backfill.

11.5.3.2 Changes to Groundwater Quality as a result of Flooding (Mine Site TSA)

At closure, a hydraulic bulkhead will be constructed in the lower access ramp, and pumps/drains will be shut off to allow reflooding of the mine. During flooding, soluble oxidation products generated during operations and flooding will be released into the reflooded mine pool. These will mix with water infiltrating through unflooded portions of the mine and groundwater. Over time, there may also be reductive dissolution of iron, manganese oxyhydroxides, and other trace metals that are associated with these mineral phases. Once the mine has reached its final flood level, ongoing loadings from the seasonally flooded portion of the mine and possibly from reductive dissolution is expected. Equilibrium modelling indicates that concentrations in the reflooded mine would remain neutral due to alkalinity present in the groundwater. However, inputs from the seasonally flooded part of the mine are expected to be an ongoing source of loading and will result in elevated concentrations in the flooded mine in comparison to baseline groundwater concentrations.

11.5.3.3 Changes to Groundwater Quality caused by Infiltration through Water Management Features (Bromley Humps TSA)

During mining operations, the groundwater system will be affected by the seepage of tailings process water from the TMF. Tailings process water is discharged to the TMF where it is fully contained. Water and load balance calculations (Appendix 14-C) indicate that precipitation and other fresh water inputs to the TMF will result in modest dilution of the process water. However, water in the pond may exceed federal Metal Mining Effluent Regulations (MMER) limits and/or thresholds for acute toxicity for a few key parameters, notably ammonia and copper. A limited amount of seepage from the TMF is expected to occur due to potential imperfections in the liner system. The seepage chemistry will be similar to that of the process water and has significantly elevated concentrations compared to baseline groundwater concentrations.

During closure, the tailings will be covered by a geomembrane liner and a soil cover to limit infiltration after a brief period of consolidation. The cover is also expected to limit ingress of oxygen. However, it is possible that acidic conditions will develop in areas where there are imperfections in the liner, which would result in increased concentrations of sulphate and metals in the very limited amount of infiltration that interacts with the tailings.

11.6 Mitigation Measures

11.6.1 Key Mitigation Approaches

Results from the review of best management practices, guidance documents, and mitigation measures conducted for similar projects, as well as professional judgment for the Project-specific effects and most suitable management measures, were considered in determining the mitigation measures. The approach to the identification of mitigation measures subscribed to the mitigation hierarchy, as described in the Environmental Mitigation Policy for British Columbia (http://www.env.gov.bc.ca/emop/).

Potential Project-related changes to Groundwater Quality will be reduced through mitigation measures, management plans, and adaptive management. If mitigation measures were considered entirely effective, potential Project-related effects to the Groundwater Quality IC were not identified as residual effects.

Specific mitigation measures were identified and compiled for each category of potential effect on Groundwater Quality and presented in this section. For the purposes of this assessment, mitigation measures included any action or project design feature that will reduce or eliminate effects to the Groundwater Quality IC. Key approaches include:

- Design Mitigation; and

- Best Management Practices (BMPs).

Technical and economic feasibility constraints dictated the highest level on the hierarchy that could be achieved for each potential effect and the identification of mitigation measures for managing these effects.

As the mine is being backfilled during operations, some waste rock will be cemented as CRF, and the talus will be mixed with lime to reduce metals and acidity loading from the backfill during operations and closure. At closure, a bulkhead will be installed to facilitate flooding of the underground mine. Additional reductions in metal leaching rates will be achieved by ensuring all of the backfill in the upper, unflooded/seasonally flooded part of the mine workings is comprised of CRF and/or talus backfill. These mitigations are intended to minimize potential changes to Groundwater Quality as a result of ML/ARD during blasting and dewatering (Section 11.5.3.1) and also during flooding (Section 11.5.3.2).

To limit seepage, the TMF will be fully lined prior to the Operation Phase. The upper bound seepage losses through the TMF geomembrane liner during operations were calculated to be minimal, less than 0.2 litres per second (L/s) (Volume 7, Appendix 1-H). Because there is very little flow from the TMF, loads from the TMF are expected to be insignificant. This small amount of seepage will eventually report to Bitter Creek. During closure, the geomembrane liner and soil cover will limit infiltration and ingress of oxygen, thereby limiting acidic conditions and the release of sulphate and metals. These mitigations are intended to address changes to Groundwater Quality from infiltration through the TMF (Section 11.5.3.3).

11.6.2 Environmental Management and Monitoring Plans

The management of water on site, including groundwater, will be guided by several Environmental Management Plans (EMPs), which will define the standard operating procedures, the BMPs, the adherence to existing environmental regulations, and the use of appropriate design criteria. The list below compiles the EMPs with a potential linkage to Groundwater Quality:

- Aquatic Effects Management and Response Plan (including the Aquatic Effects Monitoring Program (AEMP), the Surveillance Network Program, the Effluent Monitoring Program, and the Groundwater Monitoring Program), (Chapter 29.5);
- Site Water Management Plan (Chapter 29.18);
- Materials Handling and ML/ARD Management Plan (Chapter 29.15); and
- Mine Closure and Reclamation (Volume 2, Chapter 5).

11.6.3 Effectiveness of Mitigation Measures

The anticipated effectiveness of mitigation measures to minimize the potential for significant adverse effects is evaluated and classified as follows within this section:

- Low effectiveness: Proposed measure is experimental, or has not been applied in similar circumstances.

- Moderate effectiveness: Proposed measure has been successfully implemented, but perhaps not in a directly comparable situation.

- High effectiveness: Proposed measure has been successfully applied in similar situations.

- Unknown effectiveness: Proposed measure has unknown effectiveness because it has not been implemented elsewhere in a comparable project or environment.

The key measures proposed for minimizing potential changes to the Groundwater Quality IC as a result of ML/ARD during blasting, dewatering, and flooding, and from infiltration through the TMF, along with mitigation effectiveness and uncertainty, are outlined in Table 11.6-1. This table also identifies the residual effects that will be carried forward for residual effects characterization and significance determination.

The use of CRF and lime is intended to minimize potential changes to Groundwater Quality as a result of ML/ARD during blasting and dewatering (Section 11.5.3.1) and also during flooding (Section 11.5.3.2). Both measures are expected to have an immediate effect on rates of ML/ARD during this period.

CRF is expected to reduce the surface area of rock that is exposed to oxygen and the amount of rock that is contacted by groundwater. It is expected to reduce the rate of metal loading from the backfill by a factor of 10 in comparison to uncemented rock fill as described in Appendix D of Appendix 14-C. Considering the potential magnitude of residual loading from CRF, this is considered to have a moderate level of effectiveness. The reduction in loading is based on professional judgement considering the physical changes to the cemented rock. However, IDM and its consultants are not aware of any case studies where the rates of ML/ARD from cemented waste rock backfill have been compared to those from uncemented backfill. Therefore, there is a moderately high degree of uncertainty associated the level of effectiveness.

Lime addition to the talus is expected to reduce metal mobility from the waste rock by reducing the acidity already present in the talus. The effects of maintaining neutral pH in the mine were evaluated through geochemical equilibrium modelling described in Appendix D of Appendix 14-C and varies by parameter. Overall, the benefits are considered to have a moderate effect on concentrations and therefore loading rates. The equilibrium modelling provides a high degree of certainty in quantifying the changes for most parameters. However, it does not account for further reductions in concentration that may be achieved as a result of sorption and therefore provide conservative estimates for some parameters.

Flooding of the mine workings is expected to greatly reduce the rate of oxidation of sulphides in the backfilled mine and essentially eliminate ongoing sulphate and metal release in the flooded portion of the mine. Rates of flooding were quantified in the groundwater model, as described in Appendix 10-A (Volume 8). It will take approximately 13 years for the mine to fill to 90% of the final steady state water level and therefore for this mitigation to reach maximum effectiveness. The effectiveness of underwater disposal is supported by numerous studies by the Mine Effluent Neutral Drainage (MEND) program. Therefore, flooding is considered to be highly effective in controlling ML/ARD from the backfilled rock. However, flooding will also result in a short-term release of stored oxidation products during the flooding period and will not be possible in the uppermost part of the workings. Therefore, the overall effectiveness is considered to be moderate and resulting in potential for residual effects.

Lining of the TMF is expected to have a high degree of effectiveness in limiting groundwater seepage. Because liners are an engineering control, the effectiveness rating is considered to have a high degree of certainty.

Table 11.6-1: Proposed Mitigation Measures and Their Effectiveness

VC/IC	Potential Effects	Mitigation Measures	Rationale	Applicable Phase(s)	Effectiveness[1]	Uncertainty[2]	Residual Effect
Groundwater Quality	Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering (Mine Site TSA)	As the mine is being backfilled during operations, some waste rock will be cemented as CRF and the talus will be mixed with lime to reduce metals and acidity loading from the backfill.	Reduces metals and acidity loading from the backfill	Construction Operation	Moderate	Moderate	Yes
Groundwater Quality	Changes to Groundwater Quality as a result of flooding (Mine Site TSA)	The CRF and the lime in the backfill will reduce metals and acidity loading from the backfill during the reflooding period. Flooding will prevent ML/ARD in most of the backfill over the long-term, and alkalinity naturally present in the groundwater will help to maintain neutral pH conditions in the mine pool.	Reduces metal leaching rates	Closure and Reclamation Post-Closure	Moderate	Low	Yes
Groundwater Quality	Changes to Groundwater Quality caused by infiltration through water management features (Bromley Humps TSA)	The TMF will be fully lined before operations to limit seepage. During closure, the TMF will be covered with a geomembrane liner and soil cover to limit infiltration and the ingress of oxygen.	Limit acidic conditions and the release of sulphate and metals to groundwater	Operation Closure and Reclamation Post-Closure	High	Low	No

[1] Effectiveness: Low = measure unlikely to result in effect reduction; Moderate = measure has a proven track record of partially reducing effects; High = measure has documented success (e.g., industry standard; use in similar projects) in substantial effect reduction
[2] Uncertainty: Low = proposed measure has been successfully applied in similar; Moderate = proposed measure has been successfully implemented, but perhaps not in a directly comparable situation; High = situations proposed measure is experimental, or has not been applied in similar circumstances

11.7 Residual Effects Characterization

This section summarizes the analyses and results used to quantify the residual effects identified in Table 11.6-1. This chapter focuses on the groundwater flow system as a pathway to surface water. The residual effects on Surface Water Quality resulting from changes in Groundwater Quality are presented in Volume 3, Chapter 13.

Water quality predictions were not generated for Construction.

11.7.1 Summary of Residual Effects

The assessment identified the changes to Groundwater Quality caused by the development and reflooding of the mine as the two potential residual effects of the Project (identified in Table 11.6-1).

11.7.2 Methods

11.7.2.1 Residual Effects Criteria

The residual environmental effects are characterized using the criteria and general definitions presented in Volume 3, Chapter 6. Further details specific to Groundwater Quality effects are summarized in Table 11.7-1.

Table 11.7-1: Characterization of Residual Effects on Groundwater Quality

Criteria	Characterization for Groundwater Quality
Magnitude	Magnitude of potential effects were defined per the criteria presented in Volume 3, Chapter 13, as follows. Source terms were compared to baseline groundwater quality to assess magnitude. **Negligible:** no quantifiable change from baseline conditions. **Low:** lower than applicable water quality guideline or lower than the 90th percentile (if naturally greater than guideline or if no guideline exists). **Moderate:** exceeds applicable water quality guideline by less than 10x times or exceeds 90th percentile by less than 10x (if naturally greater than guideline or if no guideline exists). **High:** exceeds applicable water quality guideline by more than 10x or exceeds 90th percentile by more than 10x (if naturally greater than guideline or if no guideline exists). Changes in Groundwater Quality are evaluated for the mine-contact groundwater in the Mine Site. The applicable water quality guidelines for groundwater are the BC Contaminated Sites Regulation (BC CSR) Generic Numerical Water Standards for freshwater aquatic life (BC CSR 2016).

Criteria	Characterization for Groundwater Quality
Geographical Extent	Geographic extent of potential effects were defined relative to the study boundaries presented in Section 11.3.4.1, as follows: **Discrete:** effect is limited to the Mine Site. **Local:** effect is limited to the LSA. **Regional:** effect occurs throughout the RSA. **Beyond regional:** effect extends beyond the RSA.
Duration	**Short term (ST):** effect lasts less than 18 months (i.e., the Construction Phase of the Project). **Long term (LT):** effect lasts greater than 18 months and less than 22 years (encompassing the Project's Operation, Reclamation and Closure, and Post-Closure Phases). **Permanent (P):** effect lasts more than 22 years.
Frequency	**One time:** effect is confined to one discrete event. **Sporadic:** effect occurs rarely and at sporadic intervals. **Regular:** effect occurs on a regular basis. **Seasonal / Continuous:** effect occurs seasonally or constantly (i.e., year-round).
Reversibility	**Reversible:** effect can be reversed. **Partially reversible:** effect can be partially reversed. **Irreversible:** effect cannot be reversed, is of permanent duration.
Direction	**Positive:** the residual effect has a beneficial effect (not assessed for significance) **Neutral:** the residual effect has a neutral effect (not assessed for significance) **Negative:** the residual effect has a negative effect (assessed for significance)
Context	**High:** the receiving environment has a high natural resilience to imposed stresses and can respond and adapt to the effect. **Neutral:** the receiving environment has a neutral resilience to imposed stresses and may be able to respond and adapt to the effect. **Low:** the receiving environment has a low resilience to imposed stresses, and will not easily adapt to the effect.

11.7.2.2 Assessment of Likelihood

Likelihood refers to the probability of the predicted residual effect occurring and is determined per the attributes listed in Table 11.7-2. The probabilities are based on qualitative judgment and common understanding of the hydrogeological system within the profession.

Table 11.7-2: Attributes of Likelihood

Likelihood Rating	Quantitative Threshold[1]
High	More than 50% chance of effect occurring
Moderate	Equal chances of occurring or not occurring
Low	Less than 50% chance of effect occurring

11.7.2.3 Confidence and Risk

Confidence, which can also be understood as the level of uncertainty associated with the residual effects assessment (including significance determination), is a measure of how well residual effects are understood and the quality of the input data. The reliability of data inputs and analytical methods used to predict Project effects, confidence regarding the effectiveness of mitigation measures, and certainty of the predicted outcome are all considered. Confidence definitions are provided in the Assessment Methodology Section of the Application (Volume 3, Chapter 6, Table 6.10-1).

11.7.2.4 Analytical Assessment Techniques for Groundwater Quality

The analysis of the Project's residual effects in the Mine Site were performed by calculating source terms for the underground mine for 1) operations and 2) for closure and post-closure. The development of these source terms is described in Appendix 14-C. The source terms were compared to baseline Groundwater Quality (Table 11.4-3) specifically, the median values for RMS5, RMS6, and RMS7, which represent unaffected groundwater in the Mine Site TSA.

11.7.3 Potential Residual Effects Assessment

11.7.3.1 Changes to Groundwater Quality because of ML/ARD, Blasting, and Dewatering (Mine Site TSA)

11.7.3.1.1 Residual Effect Analysis

The residual effect of changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering was evaluated by comparing the source term for backfill during operations (Appendix 14-C) with baseline Groundwater Quality for groundwater from the middle cirque, as measured at monitoring locations RMS5, RMS6, and RMS7 (Table 11.4-2, Appendix 14-A).

The percent change from baseline Groundwater Quality and comparison to BC CSR water quality guidelines and the 90th percentile of baseline Groundwater Quality is shown in Table 11.7-3 (Operation).

11.7.3.1.2 Characterization of Residual Effect

The magnitude of the residual effect was rated low for all parameters except aluminum, cadmium, chromium, iron, and manganese, which exceed the CSR guideline or P90 water quality by less than 10x and are consequently rated as moderate (Table 11.7-3). Overall, the magnitude of the residual effect is rated moderate.

The geographic extent is discrete because the extent is limited to the Mine Site TSA; the mine contact groundwater mixes with non-contact groundwater as it flows away from the backfilled mine. The duration is long-term because the interaction between groundwater and the operating mine is limited to the Operation Phase (6 years), but the frequency is continuous. The residual effect is irreversible, as the backfill will permanently stay in place. The effects of this residual effect are evaluated by their effects on Surface Water Quality (Volume 3, Chapter 13). The direction is negative and the context is neutral.

11.7.3.1.3 Likelihood

The likelihood of this residual effect is high.

11.7.3.2 Changes to Groundwater Quality as a result of Flooding (Mine Site TSA)

11.7.3.2.1 Residual Effect Analysis

The residual effect of changes to Groundwater Quality as a result of flooding and ongoing loading from backfill above the flood level was evaluated by comparing the source term for backfill during closure (Appendix 14-C) with baseline Groundwater Quality for groundwater from the middle cirque, as measured at monitoring locations RMS5, RMS6, and RMS7 (Table 11.4-2, Appendix 14-A).

The percent change from baseline Groundwater Quality and comparison to BC CSR water quality guidelines and the 90th percentile of baseline Groundwater Quality is shown in Table 11.7-4 (Closure and Reclamation) and Table 11.7-5 (Post-Closure).

11.7.3.2.2 Characterization of Residual Effect

The magnitude of the residual effect for Closure and Reclamation (Table 11.7-4) was rated high for cadmium, chromium, and manganese and moderate for alkalinity, aluminum, calcium, cobalt, magnesium, mercury, and selenium. All other parameters were rated low. Overall, the magnitude of the residual effect is rated high for Closure and Reclamation.

The magnitude of the residual effect for Post-Closure (Table 11.7-5) was rated high for manganese and moderate for aluminum, cadmium, calcium, chromium, and magnesium. Overall, the magnitude of the residual effect is rated high for Post-Closure.

For both Closure and Reclamation and Post-Closure, the geographic extent is local because the spatial extent of groundwater that has been in contact with the mine workings is limited to the LSA. More specifically, mine contact groundwater is found within and downgradient of mine, extending to Bitter Creek upstream of BC08 where it discharges into surface water. The potential effects of groundwater discharges on Surface Water Quality are assessed in

Volume 3, Chapter 13. The duration is permanent, because the effect lasts more than 22 years, and the frequency is continuous. The residual effect is irreversible, because although the quality of the mine contact will improve after the mine floods (about 25 years into post-closure), concentrations of many parameters are still elevated. The direction is negative and the context is neutral.

11.7.3.2.3 Likelihood

The likelihood of this residual effect is high.

Table 11.7-3: Percent Change from Baseline Groundwater Quality and Comparison to Water Quality Guidelines - Operations

Parameter	GW Baseline (Base)	Predicted GW Quality (Operations)	Percent Change from Baseline (Operations)	BC CSR Water Quality Guideline (mg/L)	Baseline P90 Water Quality (mg/L)	Evaluation	Magnitude Rating
SO_4	180	190	6%	1000		Does not exceed CSR guideline	Low
Alkalinity	66.1	69	4%		71.1	Does not exceed P90 WQ	Low
Al	0.00215	0.02	830%		0.005	Exceeds P90 WQ by <10x	Moderate
Sb	0.00293	0.017	480%	0.2		Does not exceed CSR guideline	Low
As	0.00411	0.007	70%	0.05		Does not exceed CSR guideline	Low
Cd	0.000035	0.0008	>1000%	0.0006*		Exceeds CSR guideline by <10x	Moderate
Ca	74.8	75	0%		82.6	Does not exceed P90 WQ	Low
Cr	0.0001	0.002	>1000%		0.001	Exceeds P90 WQ by <10x	Moderate
Co	0.0001	0.0016	>1000%	0.04		Does not exceed CSR guideline	Low
Cu	0.0002	0.0042	>1000%	0.09*		Does not exceed CSR guideline	Low
Fe	0.034	0.06	76%		0.056	Exceeds P90 WQ by <10x	Moderate
Pb	0.00005	0.0008	>1000%	0.11*		Does not exceed CSR guideline	Low
Mg	9.99	9.4	<0%		11	Does not exceed P90 WQ	Low
Mn	0.0231	0.11	376%		0.0829	Exceeds P90 WQ by <10x	Moderate
Hg	0.000005	0.00005	900%	0.001		Does not exceed CSR guideline	Low
Mo	0.0215	0.0049	<0%	10		Does not exceed CSR guideline	Low
Ni	0.00075	0.005	567%	1.5*		Does not exceed CSR guideline	Low
Se	0.00129	0.0049	280%	0.01		Does not exceed CSR guideline	Low
Ag	0.00001	0.00004	300%	0.015*		Does not exceed CSR guideline	Low
Zn	0.0045	0.038	744%	1.65*		Does not exceed CSR guideline	Low

* CSR guideline based on median hardness during Construction and Operations (226 mg/L)

Table 11.7-4: Percent Change from Baseline Groundwater Quality and Comparison to Water Quality Guidelines - Closure & Reclamation

Parameter	GW Baseline	Predicted GW Quality (Closure – Reflood Period)	Percent Change from Baseline (Closure – Reflood Period)	CSR Water Quality Guideline (mg/L)	Baseline P90 Water Quality (mg/L)	Evaluation	Magnitude Rating
SO_4	180	600	233%	1000		Does not exceed CSR guideline	Low
Alkalinity	66.1	110	66%		71.1	Exceeds P90 WQ by <10x	Moderate
Al	0.00215	0.01	365%		0.005	Exceeds P90 WQ by <10x	Moderate
Sb	0.00293	0.08	>1000%	0.2		Does not exceed CSR guideline	Low
As	0.00411	0.017	314%	0.05		Does not exceed CSR guideline	Low
Cd	0.000035	0.01	>1000%	0.0006*		Exceeds CSR guideline by >10x	High
Ca	74.8	200	167%		82.6	Exceeds P90 WQ by <10x	Moderate
Cr	0.0001	0.068	>1000%		0.001	Exceeds P90 WQ by >10x	High
Co	0.0001	0.096	>1000%	0.04		Exceeds CSR guideline by <10x	Moderate
Cu	0.0002	0.025	>1000%	0.09*		Does not exceed CSR guideline	Low
Fe	0.034	0.03	<0%		0.056	Does not exceed P90 WQ	Low
Pb	0.00005	0.044	>1000%	0.16*		Does not exceed CSR guideline	Low
Mg	9.99	24	140%		11	Exceeds P90 WQ by <10x	Moderate
Mn	0.0231	2	>1000%		0.0829	Exceeds P90 WQ by >10x	High
Hg	0.000005	0.00005	900%	0.001		Exceeds CSR guideline by <10x	Moderate
Mo	0.0215	0.041	91%	10		Does not exceed CSR guideline	Low
Ni	0.00075	0.11	>1000%	1.5*		Does not exceed CSR guideline	Low
Se	0.00129	0.043	>1000%	0.01		Exceeds CSR guideline by <10x	Moderate
Ag	0.00001	0.0074	>1000%	0.015*		Does not exceed CSR guideline	Low
Zn	0.0045	0.56	>1000%	2.4*		Does not exceed CSR guideline	Low

* CSR guideline based on predicted hardness during Closure & Reclamation (819 mg/L)

Table 11.7-5: Percent Change from Baseline Groundwater Quality and Comparison to Water Quality Guidelines - Post-Closure

Parameter	GW Baseline	Predicted GW Quality (25 Years Post-Closure)	Percent Change from Baseline (25 Years Post-Closure)	CSR Water Quality Guideline (mg/L)	Baseline P90 Water Quality (mg/L)	Evaluation	Magnitude Rating
SO_4	180	420	133%	1000		Does not exceed CSR guideline	Low
Alkalinity	66.1	55	<0%		71.1	Does not exceed P90 WQ	Low
Al	0.00215	0.01	365%		0.005	Exceeds P90 WQ by <10x	Moderate
Sb	0.00293	0.013	344%	0.2		Does not exceed CSR guideline	Low
As	0.00411	0.0076	109%	0.05		Does not exceed CSR guideline	Low
Cd	0.000035	0.018	>1000%	0.0006*		Exceeds CSR guideline by <10x	Moderate
Ca	74.8	160	114%		82.6	Exceeds P90 WQ by <10x	Moderate
Cr	0.0001	0.0065	>1000%		0.001	Exceeds P90 WQ by <10x	Moderate
Co	0.0001	0.014	>1000%	0.04		Does not exceed CSR guideline	Low
Cu	0.0002	0.016	>1000%	0.09*		Does not exceed CSR guideline	Low
Fe	0.034	0.03	<0%		0.056	Does not exceed P90 WQ	Low
Pb	0.00005	0.042	>1000%	0.16*		Does not exceed CSR guideline	Low
Mg	9.99	12	20%		11	Exceeds P90 WQ by <10x	Moderate
Mn	0.0231	1.5	>1000%		0.0829	Exceeds P90 WQ by >10x	High
Hg	0.000005	0.0002	>1000%	0.001		Does not exceed CSR guideline	Low
Mo	0.0215	0.0059	<0%	10		Does not exceed CSR guideline	Low
Ni	0.00075	0.04	>1000%	1.5*		Does not exceed CSR guideline	Low
Se	0.00129	0.019	528%	0.01		Does not exceed CSR guideline	Low
Ag	0.00001	0.0012	>1000%	0.015*		Does not exceed CSR guideline	Low
Zn	0.0045	1.4	>1000%	2.4*		Does not exceed CSR guideline	Low

* CSR guideline based on predicted hardness during Post-Closure (449 mg/L)

11.7.4 Summary of Residual Effects Assessment

A summary of the residual effects assessment is provided in Table 11.7-6.

Table 11.7-6: Summary of the Residual Effects Assessment for Groundwater Quality

Residual Effect	Project Phase(s)	Mitigation Measures	Summary of Residual Effects Characterization Criteria	Likelihood *(High, Moderate, Low)*
Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering (Mine Site TSA)	Construction Operation	As the mine is being backfilled during operations, some waste rock will be cemented as CRF and the talus will be mixed with lime to reduce metals and acidity loading from the backfill.	**Magnitude:** Moderate **Geographic Extent:** Discrete **Duration:** Long-term **Frequency:** Continuous **Reversibility:** Irreversible **Direction:** Negative **Context:** Neutral	High
Changes to Groundwater Quality as a result of flooding (Mine Site TSA)	Closure and Reclamation Post-Closure	The CRF and the lime in the backfill will reduce metals and acidity loading from the backfill during the reflooding period.	**Magnitude:** High **Geographic Extent:** Local **Duration:** Permanent **Frequency:** Continuous **Reversibility:** Irreversible **Direction:** Negative **Context:** Neutral	High

The level of confidence associated with the predicted residual effects on Groundwater Quality in the mine area during construction and operations is relatively high in comparison to pre-mining predictions for other sites due to the availability and quality of both groundwater quantity data and water quality data from the existing exploration decline and waste rock stockpile.

However, for the Closure and Reclamation and Post-Closure Phases, the level of confidence is moderate due to inherent uncertainties associated with water quality modelling and the associated input assumptions. Where there were uncertainties in the model input assumptions, reasonably conservative assumptions were made to address those uncertainties and thereby reduce risk. For example, in the derivation of source terms, potential loadings from reductive dissolution of oxyhydroxides are considered, but potential decreases in loading from precipitation of sulphides increased sorption due to changes in speciation (e.g., selenite to selenite) are not considered.

11.8 Cumulative Effects

11.8.1 Cumulative Effects Assessment Boundaries

The cumulative effects assessment boundaries are identical to the spatial and temporal boundaries defined in Section 11.3.4 of this chapter.

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

Other projects within the spatial boundaries of the cumulative effects assessment are limited to the Bitter Creek Hydro Project, as shown in Figure 11.8-1. The proposed Bitter Creek Hydro Project involves the construction of an intake and diversion structure in the Bitter Creek valley, near the Bromley Humps TSA. A detailed description of the proposed Bitter Creek Hydro Project, including anticipated duration, is provided in the Past and Current Projects section of the Effects Assessment Methodology Chapter (Volume 3, Chapter 6).

11.8.3 Cumulative Effects Assessment

11.8.3.1 Review of Residual Effects

The two residual effects of the Project on Groundwater Quality are summarized in Table 11.7-6 and include:

- Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering (Mine Site TSA): effect of backfill on Groundwater Quality during Construction and Operation; and
- Changes to Groundwater Quality as a result of flooding (Mine Site TSA): effect of backfill on Groundwater Quality during Closure and Reclamation and Post-Closure.

11.8.3.2 Identification of Potential Cumulative Effects

Of the two residual effects of the Project on Groundwater Quality, one has the potential for cumulative effects and the other does not. Changes to Groundwater Quality during Construction and Operation does not have the potential for cumulative effects, as the effect on Groundwater Quality is limited to the Mine Site TSA. Changes to Groundwater Quality during Closure and Reclamation and Post-Closure does have the potential for cumulative effects, as the effect on Groundwater Quality extends to the LSA.

11.8.3.3 Identification of Additional Mitigation Measures

Optimizing the backfilling of the underground mine to reduce effects to Post-Closure Groundwater Quality would reduce the potential for cumulative effects.

11.8.3.4 Cumulative Effects Interaction Matrix

The cumulative effects interaction matrix is presented as Table 11.8-1.

Table 11.8-1: Interaction with Effects of other Past, Present, or Reasonably Foreseeable Future Projects and Activities

Residual Effects of the Project	Future Projects and Activities
	Bitter Creek Hydro Project
Changes to Groundwater Quality as a result of ML/ARD, blasting, and dewatering (Mine Site TSA)	N
Changes to Groundwater Quality as a result of flooding (Extends to LSA)	Y

Notes:
Y = Yes, interaction exists between the residual effect of the Project and the other past, current, or future project/activity
N = No, interaction does not exist between the residual effect of the Project and the other past, current, or future project/activity

11.8.3.5 Residual Cumulative Effects Assessment

The Bitter Creek Hydro Project is not expected to affect Groundwater Quality. Consequently, the assessment of residual effects remains the same as those considered for the Project alone and match the residual effects assessment (Table 11.7-6).

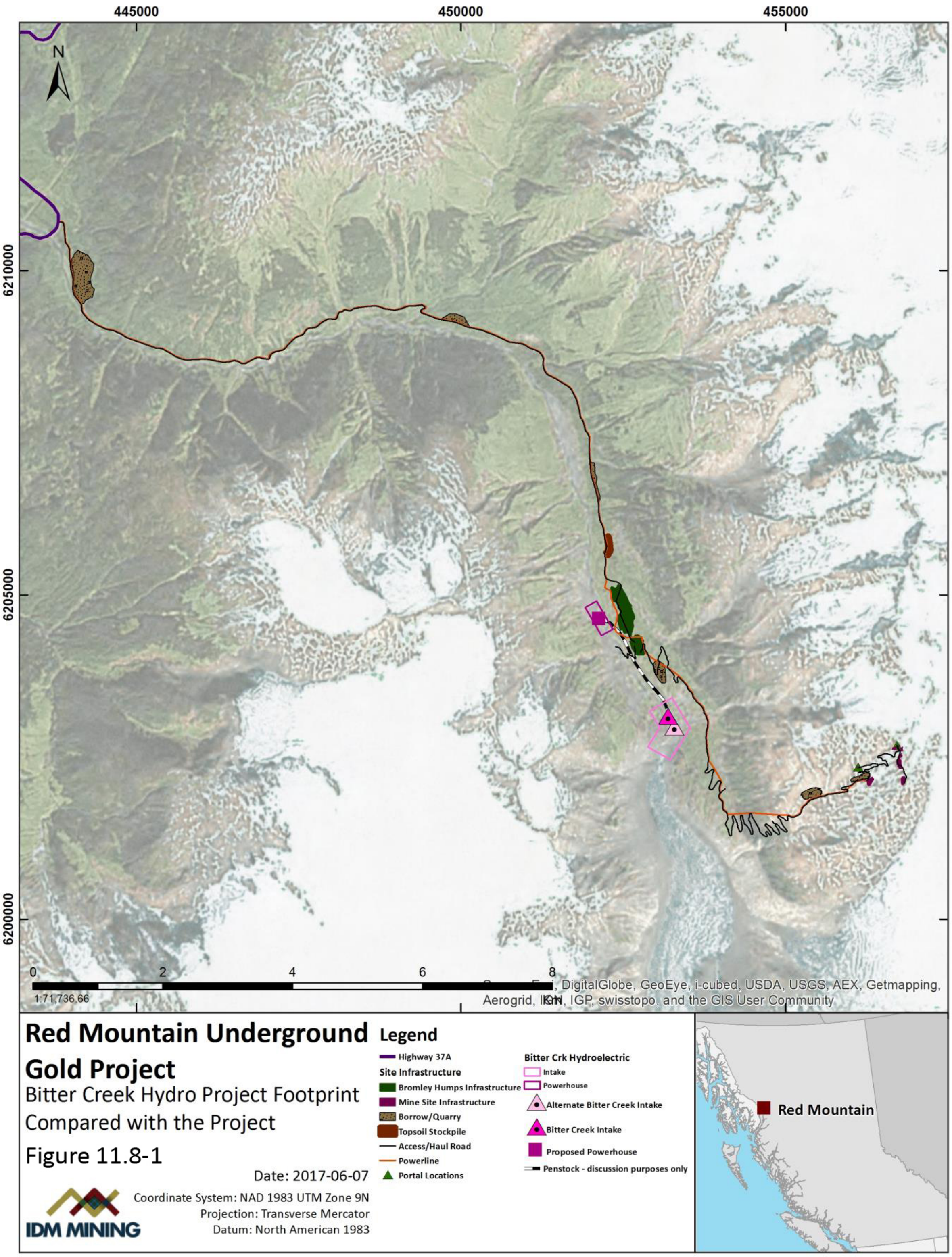
Table 11.8-2: Summary of Residual Cumulative Effects Assessment

Project Phase	Residual Cumulative Effect	Characterization Criteria	Likelihood
Closure and Reclamation Post-Closure	Changes to Groundwater Quality as a result of flooding	**Magnitude:** High **Geographic Extent:** Local **Duration:** Permanent **Frequency:** Continuous **Reversibility:** Irreversible **Direction:** Negative **Context:** Neutral **Confidence**: High	High

11.8.3.6 Summary of Cumulative Effects Assessment

The Bitter Creek Hydro Project, which is reasonably foreseeable, is not expected to have any effect on Groundwater Quality and thus the residual cumulative effects assessment is the same as the residual effects assessment conducted for the Red Mountain Project alone.

Figure 11.8-1: Bitter Creek Hydro Project Footprint Compared with the Project



11.9 Follow-up Program

IDM has identified a follow-up strategy to evaluate the accuracy of effects predictions and the effectiveness of proposed mitigation measures in regards to Groundwater Quality. The strategy focuses on implementation of the Site Water Monitoring Program contained within the Site Water Management Plan (Volume 5, Chapter 29.18). The purpose of this program is to minimize the effects of the Project's activities on surface and groundwater, monitor the results of mitigation to ensure effectiveness, and adaptively manage for any unanticipated effects resulting from the Project.

The program involves the implementation of widely recognized BMPs and the development of procedural mitigation measures during Project planning to minimize anticipated effects. The monitoring program is intended to detect unanticipated effects where adaptive management protocols will be triggered. Many mitigation measures have already been implemented during the planning stages of the Project. These include Project design such as site selection, selection of best available technologies to-date for Project infrastructure and mining equipment, and a commitment to progressive reclamation.

If original predictions of effects and mitigation effectiveness are not as expected, adaptive management principles and strategies will be implemented. Adaptive management will require consideration of monitoring results, management reviews, incident investigations, shared traditional, cultural, or local knowledge, new or improved scientific methods, regulatory changes, or other Project-related changes. Mitigation and monitoring strategies for groundwater will be updated to maintain consistency with action plans, management plans, and BMPs that may become available during the life of the Project. Key stakeholders, Aboriginal Groups, and government agencies will be involved, as necessary, in developing effective strategies and additional mitigation.

The follow-up strategy will also incorporate means to evaluate the effectiveness of implemented mitigation. Adaptive management principles rely on this evaluation to assess whether further mitigation is required to achieve desired outcomes. IDM will report on Project mitigation and monitoring activities related to the Site Water Monitoring Program as part of reporting requirements stipulated in operational permits.

IDM will review the results of the monitoring program on a frequency to be stipulated by future permit conditions and develop a detailed report on trends in monitoring indicators. Statistical analyses of the monitoring results will be performed, where appropriate.

11.10 Conclusions

11.10.1 Mine Site

Interaction between groundwater and the mine backfill will increase concentrations of most parameters in the mine contact groundwater. This effect will begin during operations and will last indefinitely into post-closure. The effect has been mitigated by encapsulating most of the waste rock in CRF, mixing the talus with lime during backfilling, and allowing the mine to flood. The effect of these changes to Groundwater Quality are evaluated by their effect on Surface Water Quality (Volume 3, Chapter 13).

Cumulative effects to Groundwater Quality are not expected to occur in the RSA from the Mine Site.

11.10.2 Bromley Humps

Process water from the TMF will seep into Bitter Creek. However, the flow of seepage is limited to no more than approximately 0.2 L/s because of the liner, and the effect of the TMF on Groundwater Quality is expected to be negligible during operations through post-closure.

Cumulative effects to Groundwater Quality are not expected to occur in the RSA from Bromley Humps.

The results of the Groundwater Quality Effects Assessment show that there will be no effects to Groundwater Quality outside of Canada.

11.11 References

[BC CSR] *British Columbia Contaminated Sites Regulation 2016.* BC Reg. 375/96 Generic Numerical Water Standards. Summary Table. Accessed June 2017.

[HKP] Hallam Knight Piésold Ltd. 1992. *Environmental Baseline Data Report*. Prepared for Lac Minerals Ltd. August 1992.

IDM Mining Ltd. 2017. *Application Information Requirements*. Red Mountain Underground Gold Project. Prepared for the Environmental Assessment Office. March 30, 2017.

[KC] Klohn-Crippen. 1994a. *Preliminary Assessment, Tailings Disposal and Hydrogeology. Draft*. Prepared for Lac North America Ltd. March 18, 1994.

[KC] Klohn-Crippen. 1994b. *Hydrogeology Assessment. Draft*. Prepared for Lac North America Ltd. June 24, 1994.

[MOE] British Columbia Ministry of Environment. 2016a. *Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators*. Version 2. Accessed August 2016. June 2016.

[Rescan] Rescan Consultants Inc. 1994. Red Mountain Project 1994: *Synopsis of Environmental Programs Undertaken, with Springs/Seeps Sample Locations & Environmental Files Location and Description*. Prepared for Lac Minerals.

[Rescan] Rescan Consultants Inc. 1995. *Draft Application for Mine Development Certificate*. Prepared for Lac North America Ltd. February 1995.